Appendix 1: Trial design document

Appendix 8.2 - Goat growth rate trial design

Goat growth rate trial design

NSW Department of Primary Industries

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Contents

Background

Although, the majority of goats sold from the rangelands are still opportunistically harvested rather than 'farmed', it is increasingly common for landholders to fence a portion of their property into a 'goat paddock'. This may be used to hold small goats until they reach a marketable liveweight or harvested goats so that larger, more uniform groups can be selected for sale. This represents an intermediate stage in the development of a 'rangeland goat' enterprise. The final stage of enterprise development usually involves retention of selected rangeland does which are subject to 'commercial' standards of management, to increase productivity.

This document outlines four experimental trial designs based on a contract signed between the New South Wales Department of Primary Industries (NSW DPI) and Meat and Livestock Australia (MLA).

The terms of reference include:

- Study the growth rate expected from 'growing out' of underweight (undersize goats).

- Comparison in growth rate between goats and meat sheep under similar conditions.

- Establishing breeding or herd improvement plan.

The project team was required to undertake consultations with the Goat Industry Council of Australia (GICA) and MLA to clarify the trial objectives and ensure the trials were industry relevant and practical. The project team had two consultations with GICA (one face-to-face and one via teleconference) and several important modifications were made to the original contract. These were:

- GICA did not see the need to compare growth rate of meat sheep or other goat breeds with rangeland goats.

- GICA wanted a full enterprise comparison between a goat growing and self-replacing Dorper enterprises in terms of profitability and impact on range condition.

Four experiments were designed based on the signed project agreement and consultation outcomes. The four experiments were:

Experiment 1 – Measuring the growth rate of underweight goats.

Experiment 2 – Measuring the growth rate of underweight goats- accounting for age.

Experiment 3 – The impact of weaning weight/age on the growth rate of rangeland goats.

Experiment 4 – Enterprise comparison; comparing goat growing and self-replacing Dorper enterprises.

Successful implementation of these trials will answer the following questions:

- What growth rate 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?

- Does weaning weight have an impact on the mature goat weight?

- How does a goat enterprise compare with Dorper enterprise under rangeland conditions?

- How does a goat production system influence rangeland condition?

Design principles

Agricultural experimental designs should be based on the objectives of the study. A well-designed experiment avoids bias and is sufficiently powerful to be able to detect effects of biological importance. Before attempting to undertake any experiment it is necessary to follow some basic principles. The four experiments have been designed by adhering to the following principles:

- Setting objectives-
  Before designing an experiment it is important that the objectives for the experiment are clear, well-defined, realistic and relevant. Successful planning of an experiment can lead to a revised set of objectives if it becomes clear that the original objectives are unrealistic.

- Sample size-
  Deciding how large an experiment needs to be is of critical importance. A sufficient number of animals are required to account for variation in animal, vegetation, seasonal conditions, instrument variability, observer variability and random effects. The number of animals to use is based on previous knowledge of the likely variation in growth rate. An experiment using too few animals may miss biologically important effects, whereas an experiment that is too large would waste resources without corresponding benefit. These requirements of sampling size and data collection need to balance against project funds (cost efficiencies).

- Randomization-
  Treatments should be assigned so that each experimental unit has a known, often equal, probability of receiving a given treatment. Randomisation enables the creation of experimental units that, at the time of assignment, are probabilistically similar on the average. Random assignment helps to distribute the individual differences over the treatment levels so that they do not selectively bias the outcome of the experiment. Also, random assignment permits the computation of an unbiased estimate of effects not attributable to specific treatment and it helps to ensure that the error effects are statistically independent.

- Replication-
  The precision of an experiment is increased by increasing the number of times each treatment is replicated. Replication enables a more precise estimate of treatment and error effects. In this context replication refers to the multiple applications of treatments at the paddock level. Paddock replication has two important roles in experiments. It allows the estimation of experimental error, and this estimate becomes the basic unit of variation for determining if treatment means are different. Secondly, increasing the number of replicates increases the precision of the estimates of treatment effects.

- Statistical analysis-
  The outcomes of most experiments should be investigated by an appropriate statistical analysis method. The analysis should reflect the objectives of the study. The general aim is to extract all of the useful information present in the data in a way that facilitates interpretation, taking account of biological variability and measurement error. Expressing the treatment effects in terms of their statistical significance is widely used to prevent unjustified claims about the effect of a treatment. However, caution is required as it is possible for an effect to be statistically significant but of little or no biological importance.

- Animal ethics-
  The use of animals in scientific experiments is likely to cause some distress and generates important ethical issues. Animal experiments may only be performed when the scientific merit justifies the use of animals and should be used only if the scientific objectives are valid. Under the NSW Animal Research Act, the necessary permit must be obtained by justifying that there is no other alternative, and the cost to the

animals is not excessive. Detailed animal welfare and biosecurity issues are addressed in Appendix 1.

- Industry and stakeholder consultation and industry application/adoption: Successful applied research needs input from stakeholders such as industry groups and experts in the field. A complete account of the consultation process is outline in Appendix 2.

Glossary

Treatment:	In experiments, a treatment is something that researchers administer to experimental units.
Treatment Variable:	A treatment variable is the variable that the experimenter has control over, what he/she can choose and manipulate. In some cases, one may not be able to manipulate the independent variable, for example sex of an animal in an experiment.
Dependant variable:	A dependent variable is what is measured and affected during an experiment. The dependent variable responds to the independent variable (response variable is dependent on treatment).
Concomitant variable:	A variable that is observed in experiments, but is not specifically measured in the analysis of the data although it is sometimes necessary to correct for concomitant variables in order to prevent distortion of the results.
Null Hypothesis:	Null hypothesis refers to a general statement or default position that there is no relationship between two measured phenomena.

Experiment 1 - Measuring the growth rate of underweight goats

Background

Producers in western NSW commonly capture unmanaged goats from a wild state either by mustering or 'trapping'. The proportion of goat captured that are over 24-kg liveweight (the threshold below which harvested goats are considered of 'no commercial value') ranges from 50 to 80%. The underweight animals may be released or sold (usually to a depot) for whatever price can be obtained. Pastoral businesses will commonly fence a portion of their land (typically 5 to 10%) to hold goats. These paddocks hold harvested goats that do not meet weight specification after harvesting. This experiment is designed to quantify the growth rate expected from these underweight goats and the impact of supplementary feeding.

Objectives

- Quantify the growth rate of underweight goats over time.

- Evaluate the effect of supplementary feeding on the growth rate of underweight rangeland goats.

Study sites

Experiment 1 will be implemented in three agricultural production zones.
- Rangelands –at sites in NSW, Qld and potentially WA

- Higher rainfall zone- located in north east NSW or south east Queensland

- Marginal-mixed farming zone– located in NSW

The methodology will be consistent across production zones, however the operational plan accounts for regional production system and environmental differences. In each region, the experiments will have at least two replicates of each treatment (supplemented and un-supplemented). This will require four paddocks. Replication can occur on the same property or on a separate property in the region with similar land systems or pasture types.

Animals

In each region, the growth rate of 300 underweight goats ranging in weight from 10 to 24-kg, will be measured over a 12 month period. The number of goats required is determined using published growth rate data of rangeland goats (see Appendix 3 for determining animal numbers). Numbers for subsequent trials (experiments 2 and 3 below) could be adjusted using results from this experiment.

Goats will be assigned to paddocks, allowing an even number of each sex, and a similar initial weight profile in each treatment and replicate. Only healthy animals should be included in the trial. Each treatment will be stocked at the same stocking rate. Growth rate will be monitored for one year. Animals will be individually identified.

Experimental design

The experimental design will be completely randomised block design. Minimum of two replicates for each treatment are required to account for paddock differences. However, more replicates (3 or 4) would be preferable if resources allow. Repeating the trial over time would also account for differences arising from seasonal variations. The trial could start in autumn after paddocks have been spelled during summer. However, the management group (Appendix 6) can determine an appropriate start time depending on local conditions.

The proposed experimental design includes replication both at the animal level and at the paddock level. At the animal level the experimental units are the animals and these data will be used to estimate growth curves and to examine the effect of treatments on individual growth.

At the paddock level the experimental units are the paddocks themselves. In the mixed models this level of analysis can be achieved by specifying paddock with site as a random effect, which is similar to averaging over all animals in the paddock. At the paddock level the appropriate comparisons are between feed supplement vs control which, if significant, needs to take into account the natural variation between paddocks, for example due to feed availability, species composition, nutritional value and other factors.

Treatment variables	2 feeding levels (plus or minus supplementation)
Dependant variable	Weight gain (weighing animals every four weeks)
Concomitant variable	Initial body weight, sex, site

Treatments

The experiment will involve two treatments:
- Treatment A: Goat grazing without supplementation
- Treatment B: Goat grazing with supplementation

The type and amount of supplement will depend on the available pasture in each region. However, as a guide 100 to 200-g of lupins per day could be considered. Lupins are a good source of energy (~ 13 ME (MJ/kg DM) and protein (~32 %). Lupins also have a relatively low starch content (<10%) and are relatively safe to feed (i.e. have a low risk of causing acidosis compared to cereal grains). If forage has sufficient protein and energy is limiting, cereal grain is an alternative supplement. Mineral supplementation should be considered if there is a definite mineral deficiency associated with the region or the forage the goats are grazing (e.g. deficiency detected by a veterinarian). It is important to ensure each individual animal has equal access to supplement so that every animal gets its fair share. A supplementary feeding plan for each site would be developed by the management group to minimise goat health risks, disruption to grazing behaviour and labour requirements.

Replication

In each region, the experiment will have two replicates. The allocation of treatments to paddocks is shown in Figure 1.

Replicate 1 (150 goats)

Treatment A   **Treatment B**

Paddock A		Paddock B
37 female goats		37 female goats
38 male goats		38 male goats
(No supplement)		(Supplemented)

Replicate 2 (150 goats)

Treatment A   **Treatment B**

Paddock C		Paddock D
37 female goats		37 female goats
38 male goats		38 male goats
(Supplemented)		(No Supplement)
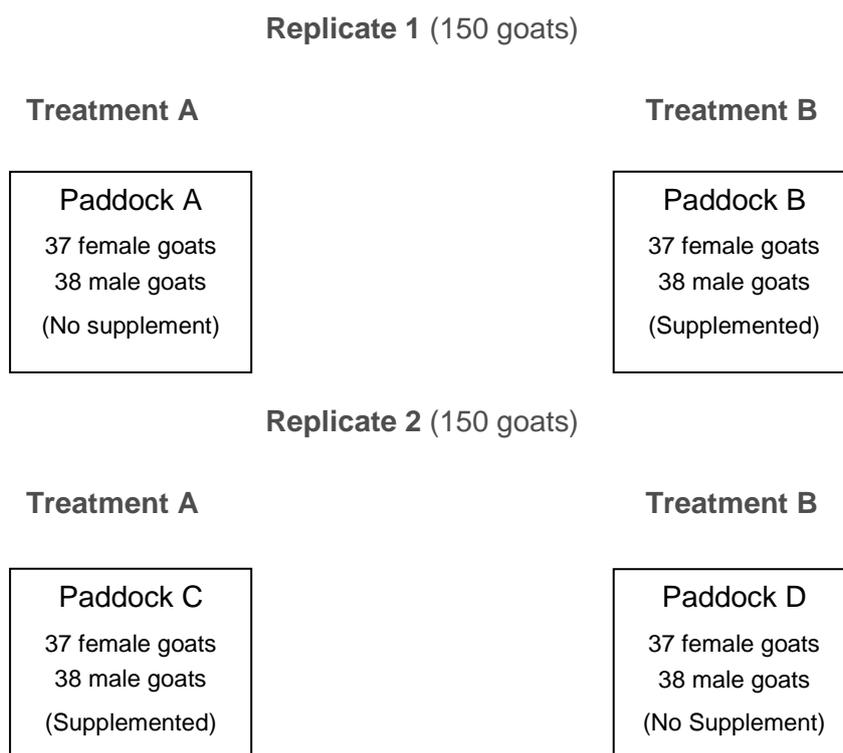
Figure 1 Experimental design – allocation of treatments, replicates and experimental units to paddocks.

Measurements and records

The following data will be collected:
- Date of commencement
- Initial goat liveweight
- Sex
- Average daily gain, from goat weight measured monthly.
- Faecal egg count
- Supplement: quality, quantity fed, quantity consumed
- Vegetation characteristics – Condition and feed quality and quantity
- Goat behaviour at feeding site (if practical)
- Water quality
- Rainfall

A sample data sheet has been included as Table 1.

Statistical analysis

Statistical analysis method
- Mixed model

Treatment variables	Nutrition
Dependent variables	Weight gain

Null Hypotheses:

There is no difference in average daily gain (ADG) of goats between the two levels of nutrition, sex and initial weight.

Concomitant variable	Initial weight, Sex
Random effect	Replication within site
Nonlinear term	Spline of weight

Initial weight represents a source of variation that has not been controlled in the experiment and one that is believed to influence weight gain. Through the linear mixed model analysis, weight gain will be adjusted to take into account the effect of initial weight.

Operational plan

Site and paddock selection

Trial paddock selection criteria

- Commercially relevant paddock size
- Securely fenced with goat fencing
- Located close to yards and weighing facilities
- Relatively easy to muster – the paddocks should be able to be mustered within half a day or less without excessive labour or resource requirements, with reasonable confidence of a complete muster.
- Serviced by a highly secure water source.
- Paddocks that meet the recommended minimum guidelines relating to pasture condition and botanical composition. For the rangeland zone, these are:
  - Average ground cover > 50%
  - Average Total Standing Dry Matter (TSDM) greater than 600-kg/ha
  - A good mix of perennial grasses, annual forbs and grasses and edible tree and shrubs
  - Edible trees and shrubs should be available to small goats. The structure or browse 'line' should be typical of the region and not favour large goats over small.
- For the higher rainfall zone (north east NSW, south east Qld) and marginal mixed farming zone, these are;
  - pasture/forage crop, similar to that upon which a typical sheep enterprise is run in that environment, in which the green component is greater than 6-cm high and has digestibility above 60%.
  - adequate feed quality and quantity for at least 12 months, outlined in a grazing plan (see Appendix 4).

Paddocks will be selected according to the criteria set out above; however, although these criteria are considered ideal, they can be modified at the discretion of the management group. The rangeland paddocks are more likely to be on the small end of commercial paddock size because of the small number of animals involved. Pair the paddocks in each replicate so they are as similar as possible and randomly allocate treatments. Trials should not be started under adverse seasonal conditions.

In the higher rainfall zone (north east NSW, south east Qld) and marginal mix farming zone (NSW) one pasture type or forage crop may not be able to supply adequate nutrition to young goats for twelve months (see Appendix 4). In such situations it is necessary to devise a grazing management plan that use a combination of pasture types and forage crop to meet the nutritional requirements of growing goats for 12 months. If and when moving animals between forage types is required, all treatments and replicates should be moved at the same time to avoid bias.

Animal identification

Individually identify goats using electronic and/or visual tags, depending on availability of facilities. Additionally, it will be an advantage to:

- Double tag goats (i.e. place an id tag in both ears), to increase chances of identifying goats with lost tags.

- Tag different treatments and replicates with different colour tags.

- Identify trial goats differently compared to commercial goats on the property.

Allocating goats to treatments and replicates

Assign animals to treatments and replicates so that the goats in each paddock have:

- A similar weight distribution profile.

- An adequate number of goats in each 2-kg weight increment (i.e. 10-12-kg, 12-14-kg,……., 22-24-kg)

- A similar number of males and females in each treatment.

- A similar number of males and females in each 2-kg weight increment block.

The lower weight limits of 10-kg is proposed because kids weighing less than 10 kg will most probably be running with their dams and scientific evidence and industry consultation suggests kids could be weaned without negative impact on growth rate once they attain 10 kg weight. The 24-kg higher limit will account for any goat that is unmarketable. A procedure for allocating goats to paddocks has been included as Appendix 5.

Stocking rate

Stock trial paddocks at the same stocking rate. Use a stocking rate that is representative of commercial practice for the region. Trial paddocks can be 'topped up' with non- trial animals to lift stocking rates to a commercial rate, if the number of trial animals isn't sufficient.

The following process can be used to determine an appropriate stocking rate and the number of goats (trial and commercial) required to stock each paddock.

- Use the expert opinion of the management group (Appendix 6) to set a commercially acceptable stocking rate DSE/ha.

- Using herbage mass estimate (kg/ha), predicted pasture growth rate and a calculation of estimated forage intake based on the stocking rate, check that the stocking rate will not result in over utilisation of herbage mass (for rangeland areas 20 to 30% is an acceptable level) or a herbage mass below a desired level.

- Accurately measure areas of each paddock.

- Calculating the number of DSE each paddock can carry at the desired stocking rate.

- Converting DSE to goat numbers using 1 goat = 0.7 DSE.

Non-trial animals (if used) are maintained and managed under trial conditions; however data isn't recorded for these animals.

Supplementation

Rangeland goats are unlikely to have been introduced to supplementary feed prior to the trial. Some of the measures that could be taken to introduce goats to the supplements could include:

- Using locally applicable attractants (e.g. salt, molasses or good quality hay) to encourage interest in the feed.

- Trailing feed and mustering goats onto the feed. If infrastructure is available, confine them to a supplementary feeding area for a short period upon introduction to the trial.

- It is important to ensure each individual animal has equal access to supplement so that every animal gets its fair share. Monitoring animal behaviour at feeding site using remote video or producer observation could identify disruptive behaviour and proportion of shy feeders.

Trial measurements

Goat liveweight

Frequency

Weigh individual goats at the start of the trial and monthly thereafter. The quality of the data could be enhanced by weighing animals in each replicate during alternate fortnights. This means growth rate would be calculated fortnightly but individual goats would only be weighed monthly.
The management group may choose to monitor the teeth of goats to examine the impact of cutting two teeth on weight gain and to have rough indication of age. This will require extra labour and time during weighing the benefit should be evaluated.

Weighing protocol

See Appendix 7

Vegetation characteristics

Higher rainfall zone and marginal mixed farming

- Stratify the paddock into nine sectors (of approximately the same size), using the GIS software (just in even areas, not according to land units, pasture types etc.).

- Overlay the paddock map with a grid pattern of 150 points.

- Determine sampling sites by randomly selecting 3 to 6 grid points in each sector.

- At each site, using a 50 cm x 50 cm quadrant estimate:
  - Height: Average pasture height of both the green and dead component of the pasture.
  - Ground cover
  - Quantity (Dry matter DM):
    - Average herbage mass kg/ha

- Average green DM yield
- Average dead DM yield
- % legume content (dry matter basis)

Feed quality assessment can be done using visual assessment, dry weight rank technique or pasture cuts, determined by management group, resources etc.

Rangeland

- In a desktop operation, divide each paddock into a 500-m by 500-m grid.
- Randomly identify five sampling points and record their GPS coordinates (identified sampling points should fall in the major productive land system(s).
- At each selected sampling point, establish 100-m transect, the direction of which is randomly determined.
- The transect should be:
  - Greater than 1km away from water
  - 100-m away from a fence, major track or water way
- At each transect record:
  - Ground cover, using step point method (100 points).
  - Botanical composition (pasture), noting presence of green leaf and phonological phase.
  - Herbage mass kg/ha, visually estimated.
  - Perennial grass utilisation percentage (20 plants).
  - Estimate mid-story shrub utilisation levels within a 5-m radius of the transects by giving utilisation scores ranging from 1 (nil utilisation) to 5 (maximum utilisation), and record species.

Supplement quality, quantity fed and intake

Test the quality of the supplement using a feed test analysis service. Test each time the feed, source of the feed or batch changes. At each feed record the date; weight or estimate of proportion of feed remaining from last feed; estimated wastage; and the quantity of feed fed.

Worm test

Conduct faecal egg counts on each herd of goats at times or situations recommended for each region by WormBoss (www.wormboss.com.au)

Water testing

Test water quality including pH, chloride content, alkalinity, turbidity, hardness, saturation index, sodium absorption ratio and electrical conductivity. On farm monitoring of pH and salinity could also be done more frequently.

Rainfall

Collect rainfall data using rain gauge installed at each site.

Operational plan summary

Number of Paddocks	At least 4
Number of goats	300
Animal description	Underweight rangeland goats, ranging in weigh from 10 to 24-kg.
Origin of trial animals	Harvested locally or commercially sourced from a harvest operation (i.e. from a depot).
Animal Identification	Individual tagging (visual or electronic)
Management	• Supplementary feeding in two paddocks • Maintaining an equivalent stocking rate in all paddocks. • Monthly weighing
Trial Duration	One year
Suggested start time	Autumn

Operational plan summary

Table 1 Sample data set rangeland goat supplementation and growth rate trial (Experiment 1)

Date :

Location:

Paddock:

Record	Tag No.	Sex	Treatment	Replicate	Wt (initial)	Wt (M1)	Wt (M2)	Wt (M3)	Wt (M4)	Wt (M5)	Wt (M6)	Wt (M7)	Wt (M8)	Wt (M9)	Wt (M10)	Wt (M11)	Wt (M12)	ADG
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
n																		

n=300   Sex = M/F   Wt (M1) = weight at month one   GW = Weight gain

Treatment 1/2 ; 1 = no supplement; 2 = supplement

Sex = M/F

Notes on animal health and condition:

Experiment 2 - Measuring the growth rate of underweight goats- accounting for age

Background

Experiment one above was designed to measure the growth rates of goats that do not meet the weight requirement (less than 24-kg) for marketing at the time of harvest. Results from experiment one while informing the time and nutrition supplement required to get the goats to marketable weight, does not account for differences in age and initial weight. Experiment two has been designed to determine the potential pre and post-weaning growth rate and variation in weight within the rangeland goat herd accounting for age. Understanding the potential growth rate of goats will therefore add further value to the ongoing development of the goat industry.

Objectives

- Quantify the potential growth rate of rangeland goats, accounting for both age and initial weight.

- Determine the seasonal growth rate of young rangeland goats.

- Determine the variation in weight within rangeland goat herds.

Study sites

Experiment two will be implemented in three agricultural production zones.
- Rangelands –at sites in NSW, Qld and potentially WA

- Higher rainfall zone- located in north east NSW or south east Queensland

- Marginal-mixed farming zone– located in NSW

The methodology will be consistent across production zones, however the operational plan accounts for regional production system and environmental differences. In each region, the experiments will have at least two replicates of each treatment (supplemented and un-supplemented). This will require four paddocks. Replication can occur on the same property or on a separate property in the region with similar land systems or pasture types.

Animals

In each region, 300 kids of known age will be run in four paddocks (two treatments, replicated; 75 goats per paddock). The number of goats required is determined using published growth rate data of rangeland goats (see Appendix 3 for determining animal numbers). This numbers could be adjusted using results from experiment 1.

Assign animals to treatments and replicate to allow an even number of each sex a similar initial weight profile. Only healthy animals should be included in the trial. Each treatment will be stocked at the same stocking rate. The trial could start in autumn after the paddocks have been spelled during summer. However, the management group can determine an appropriate start time depending on local conditions. Animals will need to be individually identified and their growth rate monitored for one year.

Experimental design

A minimum of two replicates for each treatment are required to account for paddock differences. However, more replicates (3 or 4) would be preferable if resources allow. Repeating the trial over time would also account for differences arising from seasonal

variations. The trial could start in autumn after paddocks have been spelled during summer. However, start time could vary depending on local conditions.

The proposed experimental design includes replication both at the animal level and at the paddock level. At the animal level the experimental units are the animals and these data will be used to estimate the pre and post-weaning growth curves and to examine the effect of treatments on individual growth.

At the paddock level the experimental units are the paddocks themselves. In the mixed models this level of analysis can be achieved by specifying paddock with site as a random effect, which is similar to averaging over all animals in the paddock. At the paddock level the appropriate comparisons are between feed supplement vs control which, if significant, needs to take into account the natural variation between paddocks, for example due to feed availability, species composition, nutritional value and other factors.

Experiment design and analysis is similar to experiment one. The main difference is that this trial needs to be stocked with goats of a similar (birth dates within three weeks of each other) and known age.

The experimental design is completely randomised design

Treatment variables	2 feeding levels (plus or minus supplementation)
Dependant variable	Weight gain (weighing animals every four weeks)
Concomitant variable	Initial body weight, sex, site

Treatment

The experiment will involve two treatments:

- Treatment A: Goat grazing without supplementation
- Treatment B: Goat grazing with supplementation

The type and amount of supplement will depend on the available pasture in each region. However, as a guide 100 to 200-g of lupins per day could be considered. Lupins are a good source of energy (~ 13 ME (MJ/kg DM) and protein (~32 %). Lupins also have a relatively low starch content (<10%) and are relatively safe to feed (i.e. have a low risk of causing acidosis compared to cereal grains). If forage has sufficient protein and energy is limiting, cereal grain is an alternative supplement. Mineral supplementation should be considered if there is a definite mineral deficiency associated with the region or the forage the goats are grazing. It is important to ensure each individual animal has equal access to supplement so that every animal gets its fair share. A supplementary feeding plan for each site would be developed by the management group to minimise goat health risk, disruption to grazing behaviour and labour requirements.

The age of the goats will be similar in each treatment and each treatment will have an equal number of male and female goats with a comparable weight structure.

Replication

In each region, the experiment will have two replicates. The allocation of treatments and replicates in each paddock is shown in Figure 2. A procedure for allocating goats to paddocks is given in Appendix 5.

Approach One

Joined for 21 days

300 goats of known age

Approach Two

Birth dates of kids collected for 21 days

300 goats of know age

Weaning

Replicate 1 (150 goats)

Treatment A

Paddock A

37 female goats

38 male goats

(No supplement)

Treatment B

Paddock B

37 female goats

38 male goats

(Supplemented)

Replicate 2 (150 goats)

Treatment A

Paddock C

37 female goats

38 male goats

(Supplemented)

Treatment B

Paddock D

37 female goats

38 male goats

(No Supplement)

Pre-trial

Trial
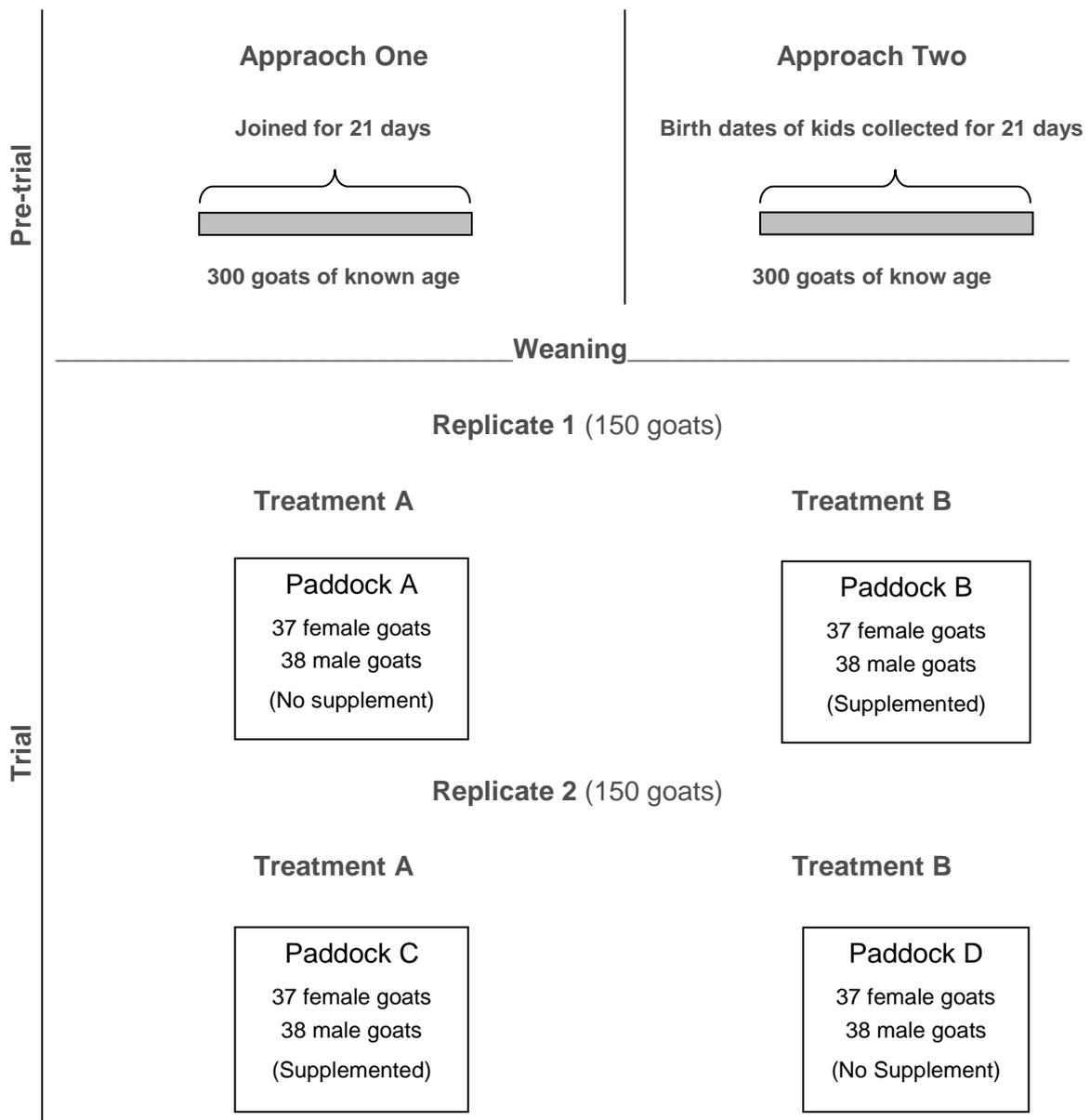
Figure 2 Experimental design – allocation of treatments, replicates and experimental units to paddocks

Measurements and records

The following measurements will be undertaken:

- Date of commencement

- Initial weight (birth weight)

- Age

- Monthly liveweight

- Sex

- Season

- Vegetation characteristics – condition and feed quality and quantity

- Supplement (quality and quantity)

An example data set is provided in Table 2.

Statistical analysis

- Mixed model

Treatment variables	Nutrition
Dependent variables	Weight gain

Null Hypotheses:

There is no difference in ADG of goats between the two levels of nutrition, sex and initial weight.

Concomitant variable	Initial weight, Sex
Random effect	Replication within site
Nonlinear term	Spline of weight

Initial weight represents a source of variation that has not been controlled in the experiment and one that is believed to influence weight gain. Through the linear mixed model analysis, weight gain will be adjusted to take into account the effect of initial weight.

Operational plan

An operational plan is provided to source these goats. The operational plan for the implementation of the growth rate trial is the same as experiment one.

Animals- Pre trial

About 400 rangeland does will be managed to produce 300 kids within 3 weeks of age. Acquiring enough numbers of kids of similar age could be difficult to achieve under rangeland conditions, due to uncontrolled mating even under relatively intensive management. We suggest trial goats be sourced from a natural mating of unselected rangeland females to randomly selected rangeland bucks (representative of the type of goats sourced from a feral harvest). Two alternative approaches have been offered to the management groups, as examples of the operational plans required for sourcing the goats. Graphic representations of the suggested approaches are shown in Figure 2. Each approach will have positive and negative aspect. Approach 1 could reliably produce the required number of kids. On the negative side it involves multiple properties and transportation. Moreover pregnancy testing using real-time ultrasound could incur substantial cost.

In approach 2, a managed joining is not required. The management group just needs to identify a suitable herd of kidding does. However, the risk of mis-mothering needs to be carefully managed. There is also the risk of not getting the required number of kids within the given time frame as well as high labour requirement.

Approach two allows analysis to include the date each individual was born, while approach one only allows for a median date to be used. This means that approach two slightly improves the analysis, although due to this small advantage the practicality of each approach needs to be considered by the management group.

Approach 1- Out of region or confined mating

- Select a large mob of mature does from a rangeland herd. Efforts should be made to keep these does from mating for 40 days.

- Randomly select 20 mature, healthy rangeland bucks. Truck bucks to non-rangeland goat region at least 60 days prior to planned joining to allow acclimatisation and avoid stress affecting sperm production prior to mating.

- Real-time ultrasound the herd to pregnancy test, identify 400 non-pregnant does (This number should be refined according to how successful excluding bucks has been for the 40 days prior to scanning and the expected kidding rate of the does at joining).

- Truck non-pregnant does to a region without rangeland bucks or confine in a rangeland buck free area.

- Re-scan does, after 40 days, to identify early foetuses (<40 days old) missed at first scanning.

- Join at least 300 does for 21 days, to rangeland bucks at a buck to doe ratio of 1:20.

- Remove bucks and ensure isolation from does.

- Keep does at the same locations for 6 weeks, to ensure pregnancies establish.

- If there is uncertainty about joining efficiency does can be scanned at 40 days, post joining.

- Truck does back to rangeland trial property.

- Run does together in one management group during pregnancy and lactation.

Approach 2- Kidding rounds

- Select a large mob of unselected/unimproved mature rangeland does (ideally not maidens) contain in a goat proof paddock.

- At the peak of kidding, do daily rounds of the kidding paddock for three weeks. Identify does that have just kidded. Catch day old kids using low stress techniques.

- While kids are captured, work quickly to;
    o Tag kids with a uniquely numbered management tag
    o Record birth type (single, twin, triplet)
    o Record weight

- Leave kids and does to restore mothering.

- At an adequate distance observe if doe re-established mothering and bonding behaviour.

Animal identification

Individually identify goat using electronic and/or visual tags, depending on availability of facilities. Additionally, it will be an advantage to:

- Double tag goats (i.e. place an id tag in both ears), to increase chances of identifying goats with lost tags.

- Tag different treatments and replicates with different colour tags.

- Identified trial goats differently compared to commercial goats on the property.

Allocating goats to treatments and replicates

Assign animals to treatments and replicates so that the goats in each paddock have:

- A similar weight distribution profile.

- A similar number of males and females in each treatment.

Procedures for allocating goats to paddocks have been included as Appendix 5.

Site and paddock selection

Trial paddock selection criteria

- Commercially relevant paddock size

- Securely fenced with goat fencing

- Located close to yards and weighing facilities

- Relatively easy to muster – the paddocks should be able to be mustered within half a day or less without excessive labour or resource requirements, with reasonable confidence of a complete muster.

- Serviced by a highly secure water source.

- Paddocks that meet the recommended minimum guidelines relating to pasture condition and botanical composition. For the rangeland zone, these are:
  - Average ground cover greater than 50%
  - Average Total Standing Dry Matter (TSDM) greater than 600-kg/ha
  - A good mix of perennial grasses, annual forbs and grasses and edible tree and shrubs.
  - Edible trees and shrubs should be available to small goats. The structure or browse 'line' should be typical of the region and not favour large goats over small.

- For the higher rainfall zone (north east NSW, south east Qld) and marginal mixed farming zone, these are:
  - pasture/forage crop, similar to that upon which a typical sheep enterprise is run in that environment, in which the green component is greater than 6 cm high and has digestibility of 65% or greater.
  - adequate feed quality and quantity for at least 12 months, outlined in a grazing plan (see Appendix 4).

Paddocks will be selected according to the criteria set out above; however, although these criteria are considered ideal, can be modified at the discretion of the management group. The rangeland paddocks are more likely to be on the small end of commercial paddock size because of the small number of animals involved. Pair the paddocks in each replicate so they are as similar as possible and randomly allocate treatments. Trials should not be started under adverse seasonal conditions.

In the higher rainfall zone (north east NSW, south east Qld) and marginal mix farming zone (NSW) one pasture type or forage crop may not be able to supply adequate nutrition to young goats for twelve months (see Appendix 4). In such situations it is necessary to devise a grazing management plan that uses a combination of pasture types and forage crop to meet the nutritional requirements of growing goats for 12 months. If and when moving animals between forage types is required, all treatments and replicates should be moved at the same time to avoid bias.

Stocking rate

Stock trial paddocks at the same stocking rate. Use a stocking rate that is representative of commercial practice for the region. Trial paddocks can be 'topped up' with non- trial animals to lift stocking rates to a commercial rate, if the number of trial animals isn't sufficient.

The following process can be used to determine an appropriate stocking rate and the number of goats (trial and commercial) required to stock each paddock.

- Use the expert opinion of the management group (Appendix 6) to set a commercially acceptable stocking rate DSE/ha.

- Using herbage mass estimate (kg/ha), predicted pasture growth rate and a calculation of estimated forage intake based on the stocking rate, check that the stocking rate will not result in over utilisation of herbage mass (for rangeland areas 20-30% is an acceptable level) or a herbage mass below a desired level.

- Accurately measure the areas of each paddock.

- Calculating the number of DSE each paddock can carry at the desired stocking rate.

- Converting DSE to goat numbers using 1 goat = 0.7 DSE.

Non-trial animals (if used) are maintained and managed under trial conditions; however data isn't recorded for these animals.

Supplementation

Rangeland goats are unlikely to have been introduced to supplementary feed prior to the trial. Some of the measures that could be taken to introduce goats to the supplements could include;

- Using locally applicable attractants (e.g. salt, molasses or good quality hay) to encourage interest in the feed.

- Trailing feed and mustering goats onto the feed.

It is important to ensure each individual animal has equal access to supplement so that every animal gets its fair share. Monitoring animal behaviour at feeding site using remote video or producer observation could identify disruptive behaviour and proportion of shy feeders.

Trial measurements

Goat weighing guideline

Frequency

Weigh individual goats at the start of the trial and monthly thereafter. The quality of the data could be enhanced by weighing animals in each replicate during alternate fortnights. This means growth rate would be calculated fortnightly but individual goats would only be weighed monthly.

Weighing protocol

See Appendix 7

Vegetation characteristics

Higher rainfall zone and marginal mixed farming

- Stratify the paddock into nine sectors (of approximately the same size), using the GIS software (just in even areas, not according to land units, pasture types etc.).

- Overlay the paddock map with a grid pattern of 150 points.

- Determine sampling sites by randomly selecting 3 to 6 grid points in each sector.

- At each site, using a 50-cm x 50-cm quadrant estimate:

- o Height: Average pasture height of both the green and dead component of the pasture.
  - o Ground cover
  - o Quantity (Dry matter DM):
    - Average herbage mass kg/ha
    - Average green DM yield
    - Average dead DM yield
    - % legume content (dry matter basis)

Feed quality assessment can be done using visual assessment, dry weight rank technique or pasture cuts, determined by management group, resources etc.

Rangeland

- In a desktop operation, divide each paddock into a 500-m by 500-m grid.

- Randomly identify five sampling points and record their GPS coordinates (identified sampling points should fall in the major productive land system(s).

- At each selected sampling point, establish 100m transect, the direction of which is randomly determined.

- The transect should be:
  - o Greater than 1km away from water.
  - o 100m away from a fence, major track or water way.

- At each transect record:
  - o Ground cover, using step point method (100pts).
  - o Botanical composition (pasture), noting presence of green leaf and phonological phase. Estimates of digestibility from published literature.
  - o Herbage mass kg/ha, visually estimated.
  - o Perennial grass utilisation percentage (20 plants)
  - o Estimate mid-story shrub utilisation levels within a 5-m radius of the transects by giving utilisation scores ranging from 1 (nil utilisation) to 5 (maximum utilisation), and record species.

Supplement quality, quantity fed and intake

Test the quality of the supplement using a feed test analysis service. Test each time the feed, source of the feed or batch changes. At each fed record the date; weight or estimate of proportion of feed remaining from last feed; estimated wastage; and the quantity of feed fed.

Worm test

Conduct faecal egg counts on each herd of goats at times or situations recommended for each region by WormBoss (www.wormboss.com.au)

Water testing

Test water quality including pH, chloride content, alkalinity, turbidity, hardness, saturation index, sodium absorption ratio and electrical conductivity. On farm monitoring of pH and salinity could also be done more frequently.

Rainfall

Collect rainfall data using rain gauge installed at each site.

Operational plan summary

Number of paddocks	At least 4
Number of goats	300
Animal description	Rangeland goats, of known age greater than 10-kg.
Pre-trial management	- Joining or kids tagged at birth, due to requirement to know age. - Monthly weighing of kids to weaning (10-kg)
Animal identification	Individual tagging (visual or electronic)
Management	- Supplementary feeding in two paddocks - Maintaining an equivalent stocking rate in all paddocks. - Monthly weighing
Trial duration	One year
Suggested start time	Autumn

Table 2 Sample data set rangeland goat supplementation and growth rate trial (experiment 1)

Record	Tag No.	sex	Treatment	Replicate	Birth wt	Wt (M1)	Wt (M2)	Wt (M3)	Wt (M4)	Wt (M5)	Wt (M6)	Wt (M7)	Wt (M8)	Wt (M9)	Wt (M10)	Wt (M11)	Wt (M12)	WG
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
N																		

n=300   Sex = M/F   Wt (M1) = weight at month one   GW = Weight gain

Treatment 1/2 ; 1 = no supplement; 2 = supplement

Sex = M/F

Experiment 3 - The impact of weaning weight/age on the growth rate of rangeland goats

Background

Among all superior traits for meat production, heavier body weight and faster growth rate are the most notable. Improving growth performance is an important way of increasing meat output in a goat production system as is in all meat livestock production systems. The main factors affecting growth rate in meat animals are: breed, sex and nutrition. Other factors such as age of dam, birth type and season of birth also affect growth rate.

Young animals usually grow faster than older animals and following weaning, goats will grow slowly until mature size. Several studies have shown weaning substantially slows the rate of growth in kids especially doe kids. However, the impact of weaning age and/or weaning weight on kid growth rate and body weight at marketable age is not studied. The sustainability of the Australian rangeland goat industry depends on achieving timely marketable weight.

Objectives

- Determine the impact of weaning age/weight on the average daily gain (ADG) and weight (kg) of rangeland goats.
- Determine an optimum weaning age/weight for rangeland goats.

Study sites

The experiment was designed specifically for rangeland goats under rangeland production system. This trial design could be implemented in other agricultural zones with minor modifications if required. The operational plan would be considerably less complicated in systems where controlled mating is assured.

Animals

In each region, the growth rate of 150 kids with differing age of up to 12 weeks will be measured until they attain 24-kg liveweight in two paddocks (two replicates; 75 goats per paddock). The number of goats required is determined using published growth rate data of rangeland goats (see Appendix 3 for determining animal numbers). Numbers could be adjusted using results from experiment 1. Kids will be assigned to paddocks, allowing an even number of each sex and similar age and initial weight profile. Only healthy animals should be included in the trial. Alternative approaches of sourcing kids are out-lined below. Depending on the availability of resources, approach 1 is recommended because in case recording each kidding becomes difficult there will at the minimum be two groups of kids with at least six weeks and up to three months of age difference.

Approach two allows analysis to include the date each individual was born, while approach one only allows for a median date to be used. This means that approach two slightly improves the analysis, although due to this small advantage the practicality of each approach needs to be considered by the management group.

Approach 1   Out of region or confined mating

- Select a large mob of mature does from a rangeland herd. Efforts should be made to keep these does from mating for 40 days.

- Randomly select 20 mature, healthy rangeland bucks. Truck bucks to non-rangeland goat region at least 60 days prior to planned joining to allow acclimatisation and avoid stress affecting sperm production prior to mating.

- Real-time ultrasound the herd to pregnancy test, identify 400 non-pregnant does (This number should be refined according to how successful excluding bucks has been for the 40 days prior to scanning and expected kidding rate of the does at joining).

- Truck non-pregnant does to a region without rangeland bucks or confine in a rangeland buck free area.

- Re-scan does, after 40 days, to identify early foetuses (<40 days old) missed at first scanning.

- Join at least 300 does for 21 days, to rangeland bucks at a buck to does ratio of 1:20.

- Remove bucks and ensure isolation from does.

- Keep does at the same locations for 6 weeks, to ensure pregnancies establish.

- If there is uncertainty about joining efficiency does can be scanned at 40 days, post joining.

- Truck does back to rangeland trial property.

- Repeat the procedure twice so that you have two drops of kids, born over two 3 week periods. Plan to have the second kidding commence 6 weeks after the start of the first kidding.

- Run does together in one management group during pregnancy and lactation (unless the management group decides they will not be able to visually identify early and late born kids. If this is the case doe herds will need to be separated before kidding and run under similar conditions as possible).

Approach 2   Kidding rounds

- Select a large mob of unselected/unimproved mature rangeland does (ideally not maidens) contain in a goat proof paddock.

- At the peak of kidding, do daily rounds of the kidding paddock for six to eight weeks. Identify does that have just kidded. Catch day old kids using low stress techniques.

- While kids are capture, work quickly to:
  - Record birth type (single, twin, triplet)
  - Record weight

- Leave kids and does to restore mothering.

- At an adequate distance observe if doe re-established mothering and bonding behaviour.

Experimental design

The experimental design will be completely randomised block design. A minimum of two replicates are required to account for paddock differences. Repeating the trial over time would also account for differences arising from seasonal variations. However, trial could also be run using one paddock per region as there are no treatments involved. The trial could start in autumn after paddocks have been spelled during summer. However, start time could vary depending on local conditions.

If the more than one paddock option is used, the design includes replication both at the animal level and at the paddock level. If on the other hand the one paddock option is used, the animal are experimental units and these data will be used to estimate growth curves and to examine the effect of weaning age on individual growth.

At the paddock level the experimental units are the paddocks themselves. In the mixed models this level of analysis can be achieved by specifying paddock with site as a random effect, which is similar to averaging over all animals in the paddock.

Rangeland does will be managed to produce kids with a range of known ages and weights. These kids will be weaned as a group and managed in two paddocks (treated as replicates). Paddocks will be representative of regional commercial sizes and stocked at the same stocking rate. Goats will be weaned at ages between three and six months and their growth rate monitored.

The experimental design will be a replicated design with multiple animals per replicate.

Treatment variables	Weaning weight, Weaning age
Dependant variable	Weight gain (weighing animals every four weeks)
Concomitant variable	Dam condition score

Replication

The experiment will have two paddocks, treated as replicates. Replication can occur on the same property or on a separate property in the region with similar land systems or pasture types. Paddocks should be selected to be as similar as possible. The allocation of replications to paddocks is shown in Figure 3.

Measurements and records

The following data will be collected
- Date of commencement
- Initial goat liveweight
- Sex
- Average daily gain, from goat weight measured monthly.
- Faecal egg count
- Pasture characteristics - Feed quality and quantity
- Rainfall

Statistical analysis

- Mixed model

Treatment variables	Weaning weight, weaning age, sex,
Dependent variables	Weight gain

Null Hypotheses:

There is no difference in post-weaning average daily gain (ADG) of goats weaned at different ages and weights.

Concomitant variable	Initial weight
Random effect	Replication within site
Nonlinear term	Spline of weight

Initial weight represents a source of variation that has not been controlled in the experiment and one that is believed to influence weight gain. Through the linear mixed model analysis, weight gain will be adjusted to take into account the effect of initial weight.

Operational Plan

Site and paddock selection

- Commercially relevant paddock size

- Securely fenced with goat fencing

- Located close to yards and weighing facilities

- Relatively easy to muster – the paddocks should be able to be mustered within half a day or less without excessive labour or resource requirements, with reasonable confidence of a complete muster.

- Serviced by a highly secure water source.

Paddocks will be selected according to the criteria set out above; however, although these criteria are considered ideal, they can be modified at the discretion of the management group. Trials should not be started under adverse seasonal conditions and paddocks in each replicate should be as similar as possible.

Doe paddocks

Management plans should be set to meet the maintenance requirements of does, until the last 8 weeks before pregnancy. The minimum nutritional requirements of the does provided by McGregor (2005) should be used as a guide. If the pasture conditions are not sufficient to meet doe requirements in late pregnancy and lactation, introduce a supplementary feeding program. Aim to minimise nutritional differences in the does' diets in different joining groups and between early and late born kids.

Weaner paddocks

Paddocks that meet the following recommended minimum guidelines relating to pasture condition and botanical composition:
- Average ground cover greater than 50%.

- Average Total Standing Dry Matter (TSDM) greater than 600 kg/ha.

- A good mix of perennial grasses, annual forbs and grasses and edible tree and shrubs.

- Edible trees and shrubs should be available to small goats. The structure or browse 'line' should be typical of the region and not favour large goats over small.
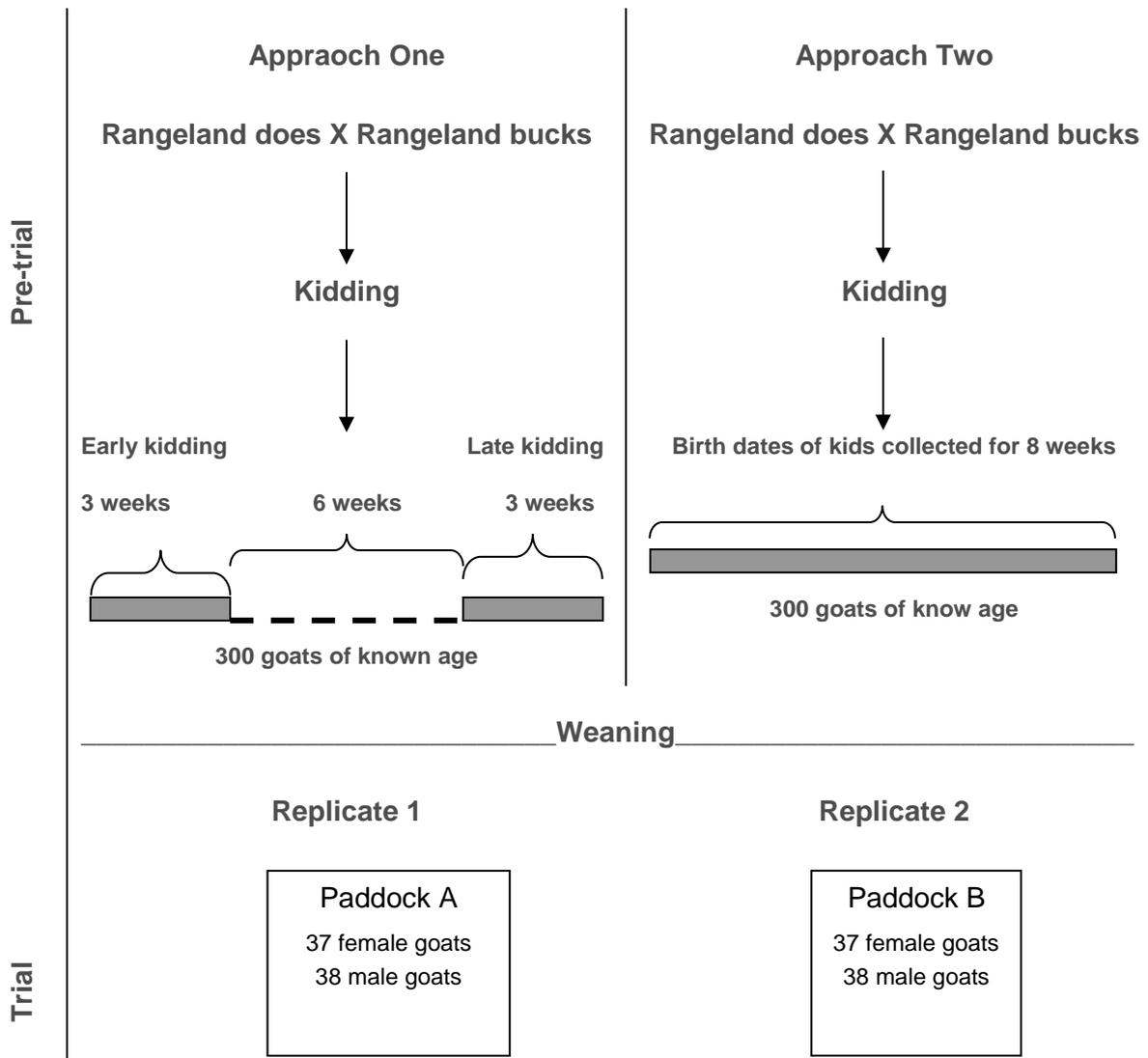
Figure 3 Experimental paddock layout

Animal identification

Individually identify goats using electronic and/or visual tags, depending on availability of facilities. Additionally, it will be an advantage to double tag goats (i.e. place an ID tag in both ears), to increase chances of identifying goats with lost tags. Identifying goats in different birth groups and replicates using different coloured tags is also recommended. If using approach one, tag does individually to allow allocation into replicates based on weight. Tag the early and late kidding does with different coloured tags. If approach two is used, there is no need to tag does.

Allocating goats to replicates

Does

For approach one, allocate does into first mating and second mating groups so that both groups have a similar weight distribution.

Weaners

Assign weaner goats to replicates so that each paddock contains:

- An even number of early and late born kids.

- Goats with a similar weight distribution profile.

- A similar number of males and females.

This can be achieved by separating kids into early and late born kids and with each of these groups follow a similar for allocation goats to paddocks as outline in Appendix 5.

Stocking rate

Does

For the does, use a stocking rate that is representative of commercial practice for the region. If doe mating groups are separated the same stocking rate should be used for each group.

Weaners

Stock trial paddocks at the same stocking rate. Use a stocking rate that is representative of commercial practice for the region. Trial paddocks can be 'topped up' with non- trial animals to lift stocking rates to a commercial rate, if the number of trial animals isn't sufficient.

The following process can be used to determine an appropriate stocking rate and the number of goats (trial and commercial) required to stock each paddock.

- Use the expert opinion of the management group to set a commercially acceptable stocking rate DSE/ha.

- Using herbage mass estimate (kg/ha), predicted pasture growth rate and a calculation of estimated forage intake based on the stocking rate, check that the stocking rate will not result in over utilisation of herbage mass (for rangeland areas 20 to 30% is an acceptable level) or a herbage mass below a desired level.

- Accurately measure the areas of each paddock.

- Calculating the number of DSE each paddock can carry at the desired stocking rate.

- Converting DSE to goat numbers using 1 goat = 0.7 DSE.

Trial measurements

Goat liveweight

Frequency

Weigh individual goats at the start of the trial and monthly thereafter. The quality of the data could be enhanced by weighing animals in each replicate during alternate fortnights. This means growth rate would be calculated fortnightly but individual goats would only be weighed monthly.

Weighing protocol

See Appendix 7.

Vegetation characteristics

- In a desktop operation, divide each paddock into a 500-m by 500-m grid.

- Randomly identify five sampling points and record their GPS coordinates (identified sampling points should fall in the major productive land system(s).

- At each selected sampling point, establish 100m transect, the direction of which is randomly determined.

- The transect should be:

- o Greater than 1km away from water.
  - o 100m away from a fence, major track or water way.
- At each transect record:
  - o Ground cover, using step point method (100pts).
  - o Botanical composition (pasture), noting presence of green leaf and phonological phase. Estimates of digestibility from published literature.
  - o Herbage mass kg/ha, visually estimated.
  - o Perennial grass utilisation percentage (20 plants).
  - o Estimate mid-story shrub utilisation levels within a 5-m radius of the transects by giving utilisation scores ranging from 1 (nil utilisation) to 5 (maximum utilisation), and record species.

Worm test

Conduct faecal egg counts on each herd of goats at times or situations recommended for each region by WormBoss (www.wormboss.com.au)

Water testing

Testing water quality includes pH, chloride content, alkalinity, turbidity, hardness, saturation index, sodium absorption ratio and electrical conductivity. On farm monitoring of pH and salinity could also be done more frequently.

Rainfall

Collect rainfall data using rain gauge installed at each site.

Operational plan summary

Number of paddocks	1 or 2
Number of goats	150 weaner goats of known age and liveweight
Animal description	Rangeland goats, of known age.
Pre-trial management	Joining or kids tagged at birth, due to requirement to know age.
Animal identification	Individual tagging (visual or electronic)
Management	Monthly weighing
Trial duration	One year
Suggested start time	Autumn

Experiment 4: Enterprise comparison; comparing goat growing and self-replacing Dorper enterprises

Background

The economic and environmental sustainability of 'growing out' goat enterprises has not been studied. Moreover, goat enterprises in the semi-arid rangelands need to compete with Dorper sheep enterprises that have become common and wide spread mainly due to their productivity, hardiness, and reputation as adaptable animals that can produce marketable lambs under less than ideal pasture conditions.

This document lays out the experimental design to compare growing out goat enterprises with that of self-replacing Dorper enterprise. In designing this experiment a two-phase approach is used.

- Phase one will compare the Gross Margin (GM) per area ($/ha), per animal ($/ewe or $/goat) and per DSE ($/DSE). Desk top analysis will be used to model a comparison of both enterprises. The parameters used in calculating the GM for each enterprise will be developed using industry data, pasture growth modelling and expert opinion. If the results of the GM calculations undertaken using the best industry knowledge showed that there are clear and wide differences, then producers could make decisions based on the GM outcomes. If on the other hand the GM calculations for the two enterprises are close, then a second study (phase 2) would be undertaken.

- Phase two will involve running self-replacing Dorper enterprise side by side with growing out goat enterprise.

Objectives

- Compare a growing goat enterprise with a self-replacing Dorper enterprise with regard to profitability and rangeland condition.

Phase one

Experimental design

Desk top analysis is used to model a comparison of both enterprises. Modelling gross margin analysis using existing data or data collected from industry benchmarking/ consultation and basic rangeland pasture modelling tools.

Modelled outputs

- Gross Margin per DSE

- Gross Margin per ha

- Average annual Total Standing Dry Matter (TSDM)

- Percentage of days less than 300-kg/ha

- Percentage of days greater than 50% ground cover

Operational Plan

Three gross margin templates for comparing goat enterprises with a self-replacing Dorper enterprise have been provided to MLA in an excel spread sheet format. The third template models a goat harvesting and growing out enterprise as an alternative although this was not specifically requested during consultation with GICA.

Data to populate these gross margins and to generate sensitivity parameters could be sourced from:

- Experiments one and two

- Expert opinion

- Industry benchmarking

- Recent work (e.g. Khairo *etal.* 2013)

- MLA's market data and National Livestock Reporting Service.

Pasture modelling methodology

- Select regions with an existing GRASP pasture models.

- Couple pasture models with local daily historical weather records sourced from SILO.

- Compile annual DSE/stocking rate profiles/dynamics for the enterprises for a twelve month production cycle.

- Manipulate models to simulate stocking rate and strategic spelling.

- Generate daily estimate of total standing dry matter (TSDM) for the modelling period.

- Convert TSDM estimate to ground cover estimate (experimental).

Phase two

Experimental design

The experimental design will be completely randomised block design.

Treatment variables	Two enterprises
Dependant variable	GM/ha, GM/DSE, GM/animal
Concomitant variable	Current price

The research will be conducted in the semi-arid rangelands of NSW and/or Queensland. A goat enterprise based on 'growing out underweight goats' will be run alongside a self-replacing Dorper enterprise. The two enterprises will be run in comparable sized paddocks with similar land systems and water distribution. The trial paddocks will be representative of regional commercial paddock sizes. Enterprises will be managed to maintain a comparable number of DSE days per ha per year. Experimental animals will be put in the paddocks at an appropriate time for both enterprises determined by the management group and the experiment will run for at least three years.

Goat enterprise description

Stock the goat enterprise with underweight goats ranging in weight from 10 to 24-kg, sourced from a local depot or property, following capture from a wild harvest. The trial paddock will be summer spelled. The stocking rate will be set to achieve an equivalent stocking rate on an annual basis as the Dorper enterprise. Goats can be marketed from the paddock according to management group decisions, as long as this is managed to allow for equivalent annual stocking rates.

This experimental design can also be used to compare alternative goat enterprises e.g. incorporating harvesting and growing out goats (a gross margin has been included), as long as the design is followed to allow comparable DSE days per ha (as described below). The enterprise described above was prescribed in industry consultation.

Self-replacing Dorper enterprise description

The Dorper enterprise will be stocked with three year old Dorper ewes. The flock will have lambed previously, although not undergone any selection based on their reproductive performance (e.g. dry ewes have not been removed from the mob or ewes that reared lambs selected). The ewes will be joined once per year. Progeny will run with ewes until they reach a marketable weight. Maiden ewes are joined at one year of age, provided they have reach liveweight thresholds).

The stocking rate will be set to achieve an equivalent stocking rate on an annual basis as the goat enterprise.

Replication

In each region, the experiment/enterprises will have two replicates. The allocation of treatments to paddocks is shown in Figure 4.

Layout of the experimental design

Replicate 1

Goat growing enterprise

Self-replacing Dorper enterprise

Paddock A
Underweight goats

Paddock B
3yo Dorper ewes plus followers

Replicate 2

Goat growing enterprise

Self-replacing Dorper enterprise

Paddock C
Underweight goats

Paddock D
3yo Dorper ewes plus followers
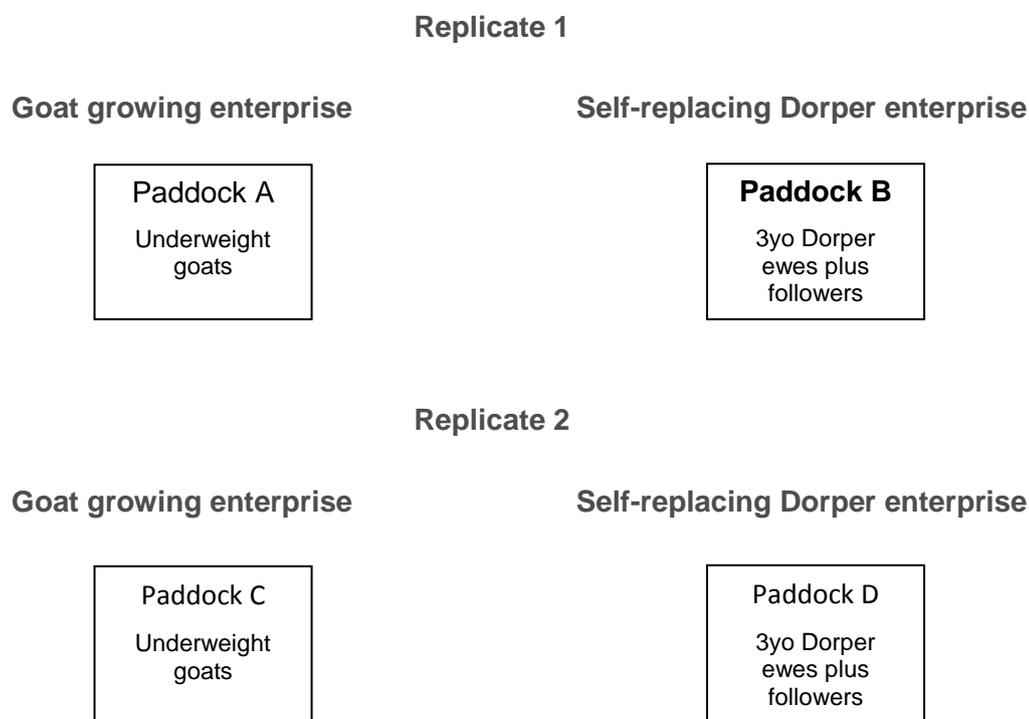
Figure 4 Experimental design – allocation of replicates and experimental units to paddocks

Measurements and records

The following data will be collected:

Goats

- Weight and commercial value of individual goats going into paddock
- Weight and commercial value of individual goats going out of paddocks
- Time spent in paddock
- Mortality rates (from roll call of ear tag numbers)
- Range condition
- Animal (harvesting) cost ($/Goat)
- Mustering costs
- Transport ($/goat)
- NLIS cost
- Selling costs (e.g. levies)
- Other costs ($/goat)

Sheep

- Fertility (ewe lambing / ewe joined)

- Fecundity (lambs born/ ewe lambing)

- Lambing Percentage (number of lambs at marking / ewe joined)

- Survival (Lambs weaned / lambs born)

- Net Reproduction Rate (number of lambs weaned / ewe joined)

- Ewe mortality rate

- Commercial value of lambs ($/lamb)

- Mustering cost

- Transport cost ($/animal)

- NLIS cost ($/?)

- MLA levy ($/?)

- Animal health cost ($/animal)

Impact on range condition

To assess the impact on range conditions an exclosure will be established in each of the paddocks. Two permanent transects (50m in length) will be established in each of these exclosures and paired with transects outside the exclosures. Species presence and absence will be recorded in quadrats located at 1m intervals along these transects (50 quadrats per transect). Ground cover, herbage mass and perennial grass and shrub utilisation will also be estimated.

Statistical analysis

Statistical analysis method
- Mixed model

Treatment variables	Enterprise type
Dependent variables	GM

Null Hypotheses:

There is no difference in gross margins of a goat growing enterprise and a self-replacing Dorper enterprise.

There is no difference in range condition associated with a goat growing enterprise and a self-replacing Dorper enterprise, when run at the same DSE Days per ha annually.

Concomitant variable	Site, ADG, Animal price
Random effect	Replication within site

Operational Plan

Paddock selection guidelines

Select trial paddocks that are:

- A commercially relevant size (>1500 ha).

- Securely fenced with goat/Dorper fencing.

- Similar to the other trial paddocks in regard to their water distribution.

Paddocks that meet the following recommended minimum guidelines relating to pasture condition and botanical composition:

- Average ground cover greater than 50%.

- Average Total Standing Dry Matter (TSDM) greater than 600-kg/ha.

- A good mix of perennial grasses, annual forbs and grasses and edible tree and shrubs.

- Edible trees and shrubs should be available to small goats. The structure or browse 'line' should be typical of the region and not favour goats over sheep.

Trials should not be started under adverse seasonal conditions.

Animals

Goats

Select 300 goats for each study, which are a mix of males and females and typical of underweight harvested goats. Initial liveweights should range from 10 to 24-kg.

Sheep

Select a ewe flock that:

- Are not pregnant.

- Have had their progeny weaned for at least two months.

- The majority are fat score of three, avoid flocks with a large proportion of ewes under 2.5 score or over 4.5 score.

- Have not been previously selected on reproductive performance.

- Are at least 4th cross Dorpers.

Select Dorper rams with approximately average ASBV for growth, rangeland acclimatised and physically sound.

Management

Both goat and Dorper enterprises will be run and managed according the recommended practices for the region. Animal handling and health, pasture/rangeland assessment, grazing management should all be of high standard.

Animal identification

Identifying and weighing (goats only) experimental animals could be useful to follow their development through the experimental period. However costs that are not associated with the normal running of commercial enterprises should be handled separately and not included in estimating GM. Individually identify goats and ewes using electronic and/or visual tags. Identify Dorper lambs with management tags, there is no requirement to individually identify these. Individually identify replacement ewes when they are selected. The host properties' facilities will determine if electronic or visual tags are used. Additionally, it will be an advantage to double tag trial animals (i.e. place an id tag in both ears).

Allocating animals to treatments and replicates

Goat enterprise

Assign animals to treatments and replicates so that the goats in each paddock have:

- A similar weight distribution profile.

- A similar number of males and females in each treatment.

Dorper ewe enterprise

Assign animals to replicates so that Dorpers in each paddock have:

- Similar fat score

- Similar age and weight profile

Stocking rate

Two approaches are outlined for calculating stocking rate to maintain a comparable number of DSE days per ha per year.

Approach 1

- The management group determines a regionally appropriate stocking rate DSE/ha.

- Assess TSDM and check that the proposed stocking rate will not exceed 30% utilisation of TSDM. (This is a process for checking that the proposed stocking rate is conservative and will not result in excessive utilisation of TSDM).

- Profile the DSE rating of the Dorper enterprise, on a monthly basis, for their twelve month management calendar.

- Calculate the DSE days per ha per annum for the Dorper enterprise.

- Calculate the number of goats to be carried from March to December to match the DSE days per ha.

- Goats can be removed and replaced (e.g. larger goats marketed and replaced with smaller goats), based on management group decision. However, the DSE days per ha must be annually equal to the Dorper enterprise.

Approach 2

- Estimate the average TSDM (kg/ha) visually, at ten locations, in each paddock.

- Calculate the amount of available feed (pasture only), assuming no further growth (unless seasonal conditions are such further growth is assured), by allowing 20-30% utilisation of TSDM.

- Calculate the annual forage intake for each animal unit (Dorper ewes and young goats) per annum.

- Set the stocking rate of each enterprise to allow 20 to 30% utilisation of TSDM (determined by the management group).

- Goats can be removed and replaced (e.g. larger goats marketed and replaced with smaller goats), based on management group decision. However, the stocking rate must remain comparable to the Dorper enterprise on a DSE days per ha basis.

Trial Measurements

Frequency

Weigh individual goats as they enter and leave the trial paddock. Weight lambs as they are marketed and replacement ewes when they are selected.

Weighing Protocol

See Appendix 7.

Worm test

Conduct faecal egg counts on each herd of goats at times or situations recommended for each region by WormBoss (www.wormboss.com.au).

Water testing

Test water quality including pH, chloride content, alkalinity, turbidity, hardness, saturation index, sodium absorption ratio and electrical conductivity. On farm monitoring of pH and salinity could also be done more frequently.

Rainfall

Collect rainfall data using a rain gauge installed at each site.

Operational plan summary

Number of paddocks	At least 4
Number of animals	• To be determined
Animal description	• Underweight rangeland goats, ranging in weight from 10 to 24-kg. • 3 year old Dorper ewes and followers.
Origin of trial animals	Commercial animals
Animal identification	Individual tagging (visual or electronic)
Management	• Maintaining equivalent stocking rates in both enterprises. • Summer pasture spelling- goat enterprise • Recording weight of goats going into paddock • Recording weight of goats going out of paddock • Recording weight of lambs • Normal ewe joining and lambing management, including scanning. • Maintaining production and Cost of production records
Trial duration	3 years

Appendix 1 - Biosecurity, animal welfare and workplace health and safety- Requirements and recommendations

Biosecurity

To conduct the four experiments, animals will be sourced from rangeland properties and/or depots and will inevitably move from property to property, within and between regions, and potentially between states. Each movement will require a biosecurity risk assessment and a plan to overcome identified risks. The risk assessment and plans should consider:

- Johne's disease

- Worms; especially those resistant to anthelminthics.

- Footrot

- Caprine arthritis encephalitis (also known as caprine retrovirus)

- Lice

- Weeds

- Hendra virus exposure

- Arbovirus exposure

- Other locally relevant biosecurity issues.

Tools used to minimise risk will include:

- National Vendor Declarations (NVDs)

- National Goat Health statements

- Regional biosecurity plans

- Worm testing, quarantine drenching and WormBoss (principles are relevant for goats, however the anthelmintic recommendations will require veterinary consultation).

- Vaccination

There will be National Livestock Identification System (NLIS) requirements associated with moving goats from property to property, or from depot to property. The current requirements (Feb 2014) are listed below:

- Prior to being moved, goats must be identified with an NLIS approved tag printed with the property of origin or depot Property Identification Code (PIC).

- Goat must be accompanied by an accurately completed NVD or other approved movement document.

- The property receiving the goats must upload the movement of the goats onto their PIC to the NLIS within seven days of the goat arriving on the property (In NSW and WA step 3 is required; in Queensland it is voluntary but recommended).

Animal Welfare

All four experiments will require Animal Care and Ethics Committee approval before the research is commenced. The proposal will require:

- The justification for the use of animals.

- The justification for the number and species of animals used.

- The procedures to be used.

- The expected impact on the welfare of the animals and the methods which will be used to avoid and alleviate these.

Some potential issues and opportunities for demonstrating best practice have been identified while designing the experiments, these include:

- Trucking procedures for small goats; including adhering to the *National Animal Welfare Standards Guidelines- Land Transport of Livestock* and potentially increasing the minimum weight of transported trial goats or drafting according to weight before loading.

- Preparing goats for water and feed changes.

- Prevention of colostridal diseases and excessive internal parasite (including coccidia), particularly associated with changing regions and forage. Rangeland goats will be naive to internal parasite infection and will not have strong immunity, due to lack of exposure.

- Provision of shade when yarding and handling.

Work place health and safety

Handling goats may potentially place people at risk. Work place health and safety assessing and planning procedures can be used to avoid or minimise risk. Consideration should be given issues such as handling goats with horns and risks associated with Q fever and heat stress.

Appendix 2 - Industry consultation

Two industry consultation meetings were held with the Goat Industry Council of Australia (GICA). Consultation one was held in Sydney on November 11 2014 and consultation two was convened via teleconference on December 11 2014.

The purpose of consultation one was to:

- Agree on key research questions and additional requirements.

- Determine experimental design elements to meet priorities and outcomes.

- Determine the number of trials and production zones where the trials will be conducted.

The major outcomes that had implications on the trial design were:

- GICA would prefer an enterprise comparison study between growing young goats and a self-replacing Dorper ewe flock, rather than comparing the growth rates of weaner lambs, other goat breeds and rangeland goat.

- Industry is interested in assessing the benefits of summer spelling rangeland pastures in a conjunction with a growing goat enterprise. This could be incorporated as part of the enterprise study.

- Industry's preferred regional trial locations are included in Table 3.

Table 3 Proposed trial locations

SITE	1	2	3	4	5
State	NSW	QLD	WA (potentially)	NSW	NSW/QLD
Agri-zone	Rangeland	Rangeland	Rangeland	Marginal mixed farming	Higher rainfall zone
Area					North East NSW or South East Qld

The purpose of consultation two was to:

- Gain industry endorsement for the four experiments:

- Discuss trial limitations, alternative approaches and researcher recommendations.

- List and address issues associated the practical implementation of the experimental design.

The major outcomes that had implications on the experimental design included:

- Experiments endorsed:

    1. 'Growing out' rangeland goats (experiment 1) to be undertaken in Rangeland, Marginal mixed-farming and Higher Rainfall zones.

    2. Quantifying the potential growth rate of rangeland goats accounting for age (experiment 2) to be undertaken in Rangeland, Marginal mixed-farming and Higher Rainfall zones.

3. Assessing the impact of weaning weight on growth rate (experiment 3) to be undertaken in rangeland sites only.

4. Enterprise comparison (experiment 4); 'growing out' rangeland goat enterprise verses self-replacing Dorper enterprise. Rangeland sites only.

Furthermore:

- Researchers argued the need to account for age in determining growth rate in young goats and gained support from industry for experiment two.

- It was decided that experiment three should be designed in this suite of experiments for later use as industry develops.

- The need for replication of the experiments was supported on the recommendation of the project team.

- For experiment four, a recommendation that for a desk-top methodology be developed to model the comparison before implementing the experiment was supported by industry.

- Mustering and tagging herds of kidding does for determining the age kids, was not supported by industry due to the risk of mismothering.

- It was agreed trial paddocks should represent typical commercial sizes.

- Trial should include male and female goats.

The project team conducted further one-on-one consultations to inform the development of the experimental design and the operational plans with industry experts. Details of the consultation are presented below.

Contact	Organisation and Location	Input
Dr Greg Curran Senior Veterinary Officer	NSW DPI, Broken Hill	Biosecurity and welfare recommendations
Lester McCormick Leader- Tropical and Rangeland Pasture Systems	NSW DPI, Tamworth	Fitting goats into higher rainfall production system
Brent McLeod SLSO (Livestock)	Local Land Services, Glen Innes	Fitting goats into higher rainfall production system
Phil Graham Technical Specialist – Livestock Management	NSW DPI, Yass	Nutrition, pasture assessment and paddock recommendations
Dr Greg McCann Veterinary Officer	Macquarie Artificial Breeders, Dubbo	Artificial reproduction procedures to assist aging goats in a rangeland production system.
Geoff Casburn Development Officer	NSW DPI, Wagga	Balancing stocking rates for gross margin comparisons.
Saladhadin Khairo Senior Economist	NSW DPI, Orange	Gross margins for enterprise comparisons
Amy Gunn SLSO (Livestock)	Local Land Services, Cobar	Fitting goats into marginal mix farming production system
Nicole Sallur Extension Officer	Department of Agriculture Fisheries and Forestry, Charleville	Access to information from goats trials in 1990s.
Dr Stephen Love Research Officer	NSW DPI, Armidale	Recommendations for monitoring and managing internal parasites
Rob Newton Depot Operator	Depot Operator, Bourke	Souring rangeland goats of known age
Bob Crouch	GICA Representative and goat producer	Operational plan and trial design

Appendix 3 - Sample size requirements

Table 4 shows the statistical power of a number of sample sizes (numbers of goats per treatment) and several overall treatment differences. The number of replicates has not been specified and it is assumed that variation between replicates is minimal compared to the variation between animals.

Delta is the assumed treatment difference in kg. This is the average difference in weight per animal at the end of the time period as a result of the feeding regime. Power is the probability of detecting an actual difference of delta, at the given level of significance ($p < 0.05$), with the assumed number of animals. As a guide the power should be 80% or better.

Table 4 The statistical power of a number of sample sizes.

No. of goats per treatment	Delta	Power (%)
75	2.0	56.0
100	2.0	69.0
150	2.0	86.3
60	3.0	81.7
75	3.0	89.4
40	4.0	87.4
50	4.0	93.7

Appendix 4 – Growing goats in non-rangeland production system

A goat growing enterprise will most likely commercially fit into a mixed-farming production systems (such as the marginal mixed-farming or higher rainfall zones) where there is a seasonal excess of quality feed. For growth, feed quality needs to be high (aiming for 65% digestibility or greater) and quantity adequate to not limit intake.

Commercially, there are a number of possible forage crops or pasture systems capable of finishing goats in less than twelve months e.g. sown tropical grasses over summer. However, running the trials for twelve months is desirable to establish growth rate curves. The local management group can make an assessment about the best likely fit for goat in their production system, guided by recommendations made in the methodology.

Higher rainfall zone (Northern Tablelands and North West Slope NSW, South East Queensland)

There are a number of options for fitting goats into production systems in these regions. These include grazing sown tropical grass pastures in summer and shifting to forage oats in winter on the western slopes or cocksfoot/fescue/white clover pasture on the Tablelands. The various native and sown pastures and forage crops in this area vary considerably in quality, quantity and growth rate during the year. Generally, all pasture and sown forage types will supply adequate nutrition at times during the year to achieve liveweight gain. However, if goats are run for twelve months in these regions, to profile growth, it is likely a change of pasture/crop type will be required to maintain adequate conditions for liveweight gain and avoid goats rapidly losing weight. NSWDPI & MLA (2011), provides a guide to annual pasture and forage crops nutrition of achieving at least 75% of maximum liveweight gain (sheep and cattle, although applicable to goats) given best practice pasture management. Management groups could use this as a tool to establish grazing plan to meet goat nutritional requirements during the year.

Marginal mixed-farming

There are a number of options for fitting goats into production systems in these regions. These include grazing native grass and annual legume, wheat stubble, lucerne and annual pastures when wheat cropping areas go into a pasture rotation. These pasture and forage types are likely to be suitable for short-term commercial finishing of goats. However, for a 12 month trial it is likely changing forage types will be required to maintain adequate conditions for liveweight gain.

The Condobolin area may be a good potential location. Local advice indicates that there are a number of producers starting to grow goats and run does in this area. Some producers are seeing the benefits of grazing goats on lucerne for weed control. The main issue will be how well a growing goat enterprise compares on a gross margin basis with other livestock enterprises e.g. agistment cattle or lamb finishing.

Appendix 5 - Procedure for allocating animals to treatments

1. Select 150 male and 150 female goats. Ideally, these would be selected from a larger pool of goats and for both sexes there would be goats (at least 15) across each 2 kg weigh increment from 10-24 kg (i.e. 10- 12 , 12-14 kg…..22-24 kg).

2. Identify the 300 goats with a unique identifier and record their weight according to the weighing protocol).

3. Record data in an electronic spreadsheet (e.g. excel) that has a sort function.

4. Sort the data according to animal weight in ascending order.

5. On a map of the trial paddocks allocate each paddock a letter A, B, C or D.

6. Working down the list, for each group of four animals randomly allocate a letter A, B, C or D in the column next to them. This will determine which paddock (i.e. treatment and replicate) each goat goes into.

7. Individual goats are draft/sorted into their treatment groups.

Example spreadsheet for allocating 300 goats to replicates and treatments

Females

Goat ID	Initial Weight (kg)	Paddock
033	10.5	B
053	13.6	C
255	14.9	D
017	15.5	A
016	17.7	D
145	19.8	B
001	20.1	A
025	22.3	C

Males

Goat ID	Initial Weight (kg)	Paddock
045	10.5	B
026	13.6	C
199	14.9	D
299	15.5	A
002	17.7	D
023	19.8	B
034	20.1	A
166	22.3	C

Appendix 6 - Trial management group

It is recommended that each experiment in each region is implemented by a management group with a structure outlined in Table 5.

Table 5 Recommended management group structure

Role	Description	Responsibilities
Trial Coordinator	The person responsible for implementing the trial and coordinating the management team	• Developing local management, welfare and WHS plans • Ensuring all data is collect as outlines in the experimental design • Data collection and collation • Liaising and reporting with industry bodies (e.g. MLA and GICA) • Field day coordination • Communication and promotion
Collarborating landholder	The landholder willing to host the trial on their property. Selection based on: • A business interest in the commerical impact of the trials. • Facilities and access to paddocks and livestock that meet the guidelines.	• Assisting with data collection • Recording and reporting observation of goat performance and behaviour • Commercial management of the trial animals
Advisory group	Group of interested local landholders and advisory staff	• Contributing to trial management e.g. determining stocking rates • Ensuring trials are commercially relevant • Assisting with data collection • Setting timing, agendas etc. for field days.
Veterinary and biosecurity support	Local professionals willing to assist and advice the group.	• Contributing to the development of the local management, biosecurity, welfare and WHS plans – Identifying risks and procedures to address this risk. • Investigating any ill health or mortalities in trial animals

A management group will ensure the trials are well run, coordinated and minimise any risk to industry. The management group will also allow action learning, knowledge transfer and faster uptake of the trial information in industry, improving the return on industry investment beyond the collection of information on goat growth rates.

Appendix 7 - Weighing protocol

1. Muster all goats in the afternoon

2. Penned goats overnight with access to water but no feed.

3. Ideally, shut off water at least 2 hours before weighing

4. Weigh goats in the morning (starting at the same time at each weighing).

5. Ideally, weight a proportion of animals from each treatment alternatively, rather than weighing all treatment one animals first and then all treatment two animals second. If weighing fortnightly proves impractical, monthly weighing is essential to generate sufficient data.

6. Weigh goats to the nearest 100 g.

7. Calibrate/test the scales with a standard weight at the start of weighing and intermittently during weighing (e.g. after 20 goats have been weighed).

8. Visual tags are read by two operators; one operator reads aloud, recorder repeats ear tag number, after recoding the number.

9. Recorded the following additional information:

   - time goats were yarded

   - time goats were released

   - time off feed

   - time off water

   - minimum and maximum ambient temperature; and,

   - general comments about health and condition of goats.

10. The management group may choose to monitor the teeth of goats to examine the impact of cutting two teeth on weight gain and to have rough indication of age. This will require extra labour and time during weighing the benefit should be evaluated.

Appendix 2 : Feed analysis of pellet

Supplementary Goat Pellet
28/04/16

Rumevite

```
Name      : GOAT SUPPLEMENT PELLET
Batch [Kg]   1000.0
Created : 19/04/16
Updated : 28/04/16
User name: MCALLAGH
```

Notes

1: Custom pellet for supplementry feeding at depots

Nutrient		'as-fed' Analysis	Dry Matter Analysis	Nutrient			'as-fed' Analysis	Dry Matter Analysis
[VOLUME]	% :	100.0	112.225416	ASH	%	:	7.260875	8.148547
DRY MATTER	% :	89.106375	100.0	MG	%	:	0.270425	0.303486
MOISTURE	% :	10.893625	12.225416	S	%	:	0.223913	0.251287
PROTEIN	% :	15.526125	17.424258	VIT A	IU/g	:	7.0	7.855779
FAT	% :	3.6635	4.111378	VIT D3	IU/g	:	0.7	0.785578
ADF	% :	7.56975	8.495183	VIT E	mg/kg	:	74.665	83.793107
NDF	% :	28.74625	32.260599	FE	mg/kg	:	140.9375	158.167696
UDP	% :	7.375	8.276624	ZN	mg/kg	:	119.93125	134.593344
EQ PROTEIN	% :	1.09925	1.233638	MN	mg/kg	:	120.26375	134.966494
ME_RUM MJ	MJ/kg :	10.568875	11.860964	CU	mg/kg	:	31.9145	35.81618
CALCIUM	% :	1.017625	1.142034	MO	mg/kg	:	0.6975	0.782772
PHOSPHORUS	% :	0.512875	0.575576	SE	mg/kg	:	0.57875	0.649505
CAL:PHOS	NIL :	1.984158	1.984158	CO	mg/kg	:	0.363938	0.40843
NA	% :	0.33897	0.38041	I	mg/kg	:	0.608375	0.682751
K	% :	0.801088	0.899024	MONENSIN	mg/kg	:	25.0	28.056354
CL	% :	0.807588	0.906318	LASALOCID	mg/kg	:	0.0	0.0
SALT NACL	% :	0.6	0.673352	TYLOSIN	mg/kg	:	0.0	0.0

Raw materials

```
WHEAT FINE 12.5% CP AF            - starch
SORGHUM FINE 10%CP AF             - starch
CANOLA MEAL SOLVENT 37% CP AF     - protein source containing UDP
DRIED DISTILLERS GRAIN            - protein and energy source
MILLRUN - contributes starch but lower rate of fermentation to ensure safety
LEGUME HULLS - approx 10% included as fibre source - would still need to feed long fibre
MOLASSES                          - dust suppressant; aids pelleting
LIMESTONE FINE BULK               - added to balance Ca: P ratio
RAM DRIED FINE NO2 SALT           - sodium
AMMONIUM CHLORIDE                 - acidifying agent; urinary calculi
GRAN BENTONITE                    - aids pelleting; low inclusion rate
RAP PMX                           - trace mineral and vitamin premix
MYCO CURB LIQ                     - mould inhibitor
RUMENSIN 100                      - coccidiostat
```

Appendix 3: Feed analysis of lupins

CERTIFICATE OF ANALYSIS

CERTIFICATE NO.:	566560-A	**REVISION NO.:**	00
ISSUE DATE:	26/06/2017	This certificate supersedes any previous revisions	

CLIENT DETAILS: Steve Banney
Grazserv Pty Ltd
89 Peacons Pocket Road
Tuchekoi QLD 4570

ORDER NO:
DATE RECEIVED: 19/06/2017
TEST DATE: Sample tested between date received and reported.

CONDITIONS OF SAMPLE: Receipt Temperature: Room Temperature
Storage Temperature: Ambient

RESULTS OF ANALYSIS:

Sample Description Procedure Code Test	Method	Unit	566560-A-1 Milled Feed Lupins
Protein	CF003.1	% (w/w)	31.6
Fat	CF004.1	% (w/w)	4.7
Ash	CF007	% (w/w)	3.7
Crude Fibre	CF038.1	% (w/w)	16.0
Dry Matter#	CF006.1	% (w/w)	91.8
Nitrogen Free Extract DWB#	CF037.1	% (w/w)	39.1
Metabolisable Energy DWB# (Cattle)	CF037.4	MJ/kg	12.1
Moisture (air)	CF005.1	% (w/w)	8.1

DEFINITIONS: < = Less than, > = Greater than, - = Not Tested, DWB = Dry Weight Basis.
* Test not covered by NATA scope of accreditation
# = The result is derived from calculation.
The following equation was used in the estimation of Metabolizable energy:
ME (MJ/Kg DM) = 0.12xCP+0.31xEE+0.05xCF+0.14xNFE
and complies with FLIAC/NFAS Rules and standards - 2011/12.

Results were reported on an "as received" basis unless otherwise indicated.
Sampling was conducted by the customer and results reported pertain only to the samples submitted.
Responsibility for representative sampling rests with the customer.

Stefanie Kessel, Team Leader
Chemistry (Brisbane)

Appendix 4: R code

```
### ------------------
### data_merge.R
# load libraries
library(reshape)    # data table manipulation
library(XLConnect)  # import/exporting excel
library(lubridate)  # date manipulation

# set working directory
#setwd("C:\\Users\\rohan\\Dropbox\\Rohan\\data and analysis\\old data")


# system options
# options()

# load previous session
# load(".RData")


#######################
## old folder
setwd("C:\\Users\\rohan\\Dropbox\\Rohan\\data and analysis\\old data")

## Euolo Paddock
mod1 <- read.csv("Eulo_original_paddocks.csv", header=TRUE) #'mod1 is just the name I've given to this
dataset, to be used in further lines of code (see below)
ls()
str(mod1)
summary(mod1$X20.09.2016 )
# Min. 1st Qu.  Median   Mean 3rd Qu.   Max.   NA's
#  11.00  14.75  18.60  18.55  21.80  30.00      2

names(mod1)
# [1] "RFID"       "NLIS.Tag.."  "Group"        "Management.Tag" "Lice"        "Famacha"      "sex"
# [8] "CS.16.08.2016" "X16.08.2016" "X20.09.2016"  "Gain..Loss."  "ADG..g.day." "X21.10.2016"
"Gain..Loss..1"
# [15] "ADG..g.day..1" "X23.11.2016"  "Gain..Loss..2" "ADG..g.day..2" "X20.12.2016"  "Gain..Loss..3"
"ADG..g.day..3"
# [22] "kids"        "Group2"      "Location"     "Dead"         "Feed"         "Kid_weight"

EuloEarly<-melt(mod1, id=c("Group","Management.Tag", "Lice", "sex", "Group2", "Location", "CS.16.08.2016",
"Kid_weight","Dead", "kids", "Feed", "Famacha"))

# needless addition of -supp in blue paddock, as have Feed variable.
EuloEarly$Group<-ifelse(EuloEarly$Group=="Blue - supp","Blue",as.character(EuloEarly$Group))

# change name of variables to something more meaningful
names(EuloEarly)[which(names(EuloEarly)=="Group")]<-"Paddock"  # paddock may not be feasible ...
names(EuloEarly)[which(names(EuloEarly)=="Group2")]<-"Supplement"
```

```r
EuloEarly<-EuloEarly[EuloEarly$variable == "X16.08.2016" | EuloEarly$variable == "X20.09.2016" |
EuloEarly$variable == "X21.10.2016" |
                EuloEarly$variable == "X23.11.2016" | EuloEarly$variable =="X20.12.2016",]

# Change variable to date
names(EuloEarly)[which(names(EuloEarly)=="variable")]<-"Date"
EuloEarly$Date<-as.character(EuloEarly$Date)
EuloEarly$Date<-substr(EuloEarly$Date,2,nchar(EuloEarly$Date))
EuloEarly$Date<-as.Date(EuloEarly$Date,format="%d.%m.%Y")

#Drop some columns and re-order to assist appending
EuloEarlyShort<-within(EuloEarly, rm( Lice, 'CS.16.08.2016', kids, Famacha,Kid_weight))
EuloEarlyShort<-EuloEarlyShort[c(2,3,4,7,5,8,9)]


### KINGAROY
modk <- read.csv("Kingaroy Weights.csv", header=TRUE) #'mod1 is just the name I've given to this dataset, to
be used in further lines of code (see below)
names(modk)
# [1] "X"          "Management.Tag" "X31.08.2016"  "X3.10.2016"  "X.1"        "Gain..loss."  "ADG..g."
# [8] "X1.11.2016"  "X26.11.2016"  "Gain..loss..1" "ADG..g..1"   "Dead"        "Location"    "Feed"
# [15] "Group2"      "Kid_weight"   "sex"

# transform "Dead" to NA

#Convert wide-formatted data into long
KingaroyEarly<-melt(modk, id=c("X","Management.Tag", "X.1","sex", "Group2", "Location",
"Kid_weight","Dead", "Feed"))

KingaroyEarly<-KingaroyEarly[which(KingaroyEarly$variable == "X31.08.2016"| KingaroyEarly$variable ==
"X3.10.2016" |
                KingaroyEarly$variable == "X1.11.2016" | KingaroyEarly$variable == "X26.11.2016"),]

KingaroyEarly$value<-as.numeric(ifelse(KingaroyEarly$value=="Dead" |
KingaroyEarly$value=="",NA,KingaroyEarly$value))

# Change variable to date
names(KingaroyEarly)[which(names(KingaroyEarly)=="variable")]<-"Date"
KingaroyEarly$Date<-as.character(KingaroyEarly$Date)
KingaroyEarly$Date<-substr(KingaroyEarly$Date,2,nchar(KingaroyEarly$Date))
KingaroyEarly$Date<-as.Date(KingaroyEarly$Date,format="%d.%m.%Y")

# change name of variables to something more meaningful
names(KingaroyEarly)[which(names(KingaroyEarly)=="Group2")]<-"Supplement"  # paddock may not be
feasible ...

#Drop some columns and re-order to assist appending
KingaroyEarlyShort<- within(KingaroyEarly, rm(X, X.1))
KingaroyEarlyShort<-KingaroyEarlyShort[c(1,2,3, 7,4, 8,  9)]
str(KingaroyEarlyShort)


### Dirranbandi/Perkins
```

```
#Import Dirranbandi data
modd <- read.csv("Perkins_phase 1.csv", header=TRUE)

DirranbandiEarly<-melt(modd, id=c("Type", "NLIS.ID", "Management.Tag", "sex", "Group2", "Location",
"Kid_weight","Dead", "Feed"))

#instead of casting, just select the correct rows of data into variable b

DirranbandiEarly<-DirranbandiEarly[DirranbandiEarly$variable == "X14.10.2016" | DirranbandiEarly$variable
== "X9.12.2016" |
                        DirranbandiEarly$variable == "X21.01.2017"| DirranbandiEarly$variable ==
"X25.02.2017",]

# Change variable to date
names(DirranbandiEarly)[which(names(DirranbandiEarly)=="variable")]<-"Date"
DirranbandiEarly$Date<-as.character(DirranbandiEarly$Date)
DirranbandiEarly$Date<-substr(DirranbandiEarly$Date,2,nchar(DirranbandiEarly$Date))
DirranbandiEarly$Date<-as.Date(DirranbandiEarly$Date,format="%d.%m.%Y")

names(DirranbandiEarly)[which(names(DirranbandiEarly)=="Group2")]<-"Supplement"  # paddock may not be
feasible ...

#Drop some columns and re-order to assist appending
DirranbandiEarlyShort<- within(DirranbandiEarly, rm(Type,NLIS.ID))
DirranbandiEarlyShort<-DirranbandiEarlyShort[,c(1,2,3, 7,4, 8,  9)]
str(DirranbandiEarlyShort)


### Warwick/Maher
#Imprt Warwick data
modw <- read.csv("Copy of Maher 1.csv", header=TRUE)

WarwickEarly<-melt(modw, id=c("RFID", "NLIS.Tag..", "Group", "Lice", "Famacha", "Other", "Kids.1.11",
"CS.09.07.2016", "Management.Tag", "sex", "Group2", "Location", "Kid_weight","Dead", "Feed"))

WarwickEarly<-WarwickEarly[WarwickEarly$variable == "X9.07.2016" | WarwickEarly$variable ==
"X6.08.2016" |
                WarwickEarly$variable == "X9.09.2016"| WarwickEarly$variable == "X1.10.2016"|
                WarwickEarly$variable == "X1.11.2016"| WarwickEarly$variable == "X1.12.2016"|
                WarwickEarly$variable == "X29.12.2016",]

names(WarwickEarly)[which(names(WarwickEarly)=="variable")]<-"Date"
WarwickEarly$Date<-as.character(WarwickEarly$Date)
WarwickEarly$Date<-substr(WarwickEarly$Date,2,nchar(WarwickEarly$Date))
WarwickEarly$Date<-as.Date(WarwickEarly$Date,format="%d.%m.%Y")

names(WarwickEarly)[which(names(WarwickEarly)=="Group2")]<-"Supplement"  # paddock may not be
feasible ...


#Drop some columns and re-order to assist appending
WarwickEarlyShort<- within(WarwickEarly, rm(RFID, NLIS.Tag.., Group, Lice, Famacha, Other,Kids.1.11,
CS.09.07.2016))
```

```
WarwickEarlyShort<-WarwickEarlyShort[c(1,2,3, 7, 4, 8, 9)]
str(Warwick_2)

#Append all data together
allEarly<-rbind(KingaroyEarlyShort,EuloEarlyShort, DirranbandiEarlyShort, WarwickEarlyShort)


# treat tags as character variable not factor variable for ease of later coding
allEarly$Management.Tag<-as.character(allEarly$Management.Tag
                         )

# normalise Supplement values to either Pellet, Lupins or None
allEarly$Supplement<-as.character(allEarly$Supplement)
allEarly$Supplement<-ifelse(allEarly$Supplement=="supp","Pellet","None")

# rename value to Weight.kg to be more descriptive
names(allEarly)[names(allEarly)=="value"]<-"Weight.kg"

# normalise sex values to either M or F
names(allEarly)[names(allEarly)=="sex"]<-"Sex"
allEarly$Sex<-ifelse(allEarly$Sex=="f","F",
           ifelse(allEarly$Sex=="m","M",
               ifelse(allEarly$Sex=="",NA,allEarly$Sex)
                   ))
allEarly$Sex<-as.factor(allEarly$Sex)

# change zero weight to missing data.
allEarly$Weight.kg<-ifelse(allEarly$Weight.kg==0,NA,allEarly$Weight.kg)


# a few tests for logically inconsistent data; TRUE is a pass of the test
#  no supplement but feed > 0
length(which(allEarly$Supplement=="Pellet" & allEarly$Feed==0)) ==0
length(which(allEarly$Supplement=="None" & allEarly$Feed>0)) ==0

# test for dead; assumed that if no further records after first few
allEarly$Dead<-2
allEarlyMissing<-which(is.na(allEarly$Weight.kg))

missingTags<-as.character(allEarly$Management.Tag[allEarlyMissing])
missingTagsTable<-table(missingTags)
missingTagMultiple<-names(missingTagsTable)[missingTagsTable>1]

for(i in 1:length(missingTagMultiple)){
  deadWhich<-which(allEarly$Management.Tag==missingTagMultiple[i] & is.na(allEarly$Weight.kg))
  allEarly$Dead[deadWhich]<-1
}

# This is approximate estimate of death - considers if animal has more than one missing record then
#   it has died. Only one missing record is considered as a miss-capture.
#   This ignores the 'dead' information provided in each of the data sets - corrected below.
#   ideally set this up as consecutive missing data over time.
deathRate<-length(missingTagMultiple)/length(levels(allEarly$Management.Tag))*100
```

```
# check against dead tags in original datasets
kingaroyDead<-unique(KingaroyEarly$Management.Tag[KingaroyEarly$Dead==1])
euloDead<-unique(EuloEarly$Management.Tag[EuloEarly$Dead==1])
DirranbandiDead<-unique(DirranbandiEarly$Management.Tag[DirranbandiEarly$Dead==1])
warwickDead<-unique(WarwickEarly$Management.Tag[WarwickEarly$Dead==1])

allDead<-
c(as.character(kingaroyDead),as.character(euloDead),as.character(DirranbandiDead),as.character(warwickDea
d))

allDead%in%missingTagMultiple
#[1] FALSE FALSE  TRUE  TRUE  TRUE  TRUE
# missing "K1R05"  "K1R21"
for(i in 1:length(kingaroyDead)){
  deadWhich<-which(allEarly$Management.Tag==kingaroyDead[i] & is.na(allEarly$Weight.kg))
  allEarly$Dead[deadWhich]<-1
}


#######################
## new folder
setwd("C:\\Users\\rohan\\Dropbox\\Rohan\\data and analysis\\new data")

wb<-loadWorkbook("2nd MLA Goat Weighing Warwick.xlsx")
warwickSheet<-readWorksheet(wb,sheet=1)
lupinStart<-which(warwickSheet$NO.Lupins=="Lupins")
warwickNoLupins<-readWorksheet(wb,sheet=1,startRow=1,endRow=lupinStart-1)
warwickLate<-data.frame(Management.Tag=as.character(warwickNoLupins$Ear.Tag.No))
warwickLate$Sex<-ifelse(is.na(warwickNoLupins$Male),"F","M")
warwickLate$Sex<-ifelse(is.na(warwickNoLupins$Male) &
is.na(warwickNoLupins$Female),NA,warwickLate$Sex)
warwickLate$Supplement<-"None"
warwickLate$Feed<-0
warwickLate$Location<-"Warwick"

# fix up naff numbers in weight values
warwickDates<-warwickNoLupins[c(5,6,9,12,17,20,21,24)]
names(warwickDates)<-
c("X15.07.17","X12.08.17","X10.09.17","X08.10.17","X05.11.17","X28.11.17","X02.12.17","X20.01.18")

warwickDates$X15.07.17_Comment<-NA   # no character entries in weight record

warwickDates$X12.08.17_Comment<-ifelse(warwickDates$X12.08.17=="inf ear   15.8","Infected Ear",
                    ifelse(warwickDates$X12.08.17=="Brok leg 22.4","Broken Leg",
                        ifelse(warwickDates$X12.08.17=="Dead","Dead",NA)
                    ))
warwickDates$X12.08.17<-ifelse(warwickDates$X12.08.17=="inf ear   15.8",15.8,
                ifelse(warwickDates$X12.08.17=="Brok leg 22.4",22.4,
                    ifelse(warwickDates$X12.08.17=="Dead",NA,warwickDates$X12.08.17)
                    ))

warwickDates$X10.09.17_Comment<-ifelse(warwickDates$X10.09.17=="Dead","Dead",NA)
```

```
warwickDates$X10.09.17<- ifelse(warwickDates$X10.09.17=="Dead",NA,warwickDates$X10.09.17)


warwickDates$X08.10.17_Comment<-ifelse(warwickDates$X08.10.17=="Non Reader 15.6","Non Reader",NA)
warwickDates$X08.10.17<- ifelse(warwickDates$X08.10.17=="Non Reader
15.6",15.6,warwickDates$X08.10.17)

warwickDates$X05.11.17_Comment<-ifelse(warwickDates$X05.11.17=="dead  stuck in fence","Dead",
                  ifelse(warwickDates$X05.11.17=="?","Missing reading?",NA))
warwickDates$X05.11.17<- ifelse(warwickDates$X05.11.17=="dead  stuck in fence",NA,
                ifelse(warwickDates$X05.11.17=="?",NA,warwickDates$X05.11.17)
             )

warwickDates$X28.11.17_Comment<-NA
warwickDates$X02.12.17_Comment<-NA

warwickDates$X20.01.18_Comment<-ifelse(warwickDates$X20.01.18=="Non Reader 23.3","Non Reader",NA)
warwickDates$X20.01.18<- ifelse(warwickDates$X20.01.18=="Non Reader
23.3",23.3,warwickDates$X20.01.18)

warwickLate<-cbind(warwickLate,warwickDates)

# addin lupins
warwickLupins<-readWorksheet(wb,sheet=1,startRow=lupinStart+1,endRow=127)
warwickLupinsLate<-data.frame(Management.Tag=as.character(warwickLupins$Ear.Tag.No))
warwickLupinsLate$Sex<-ifelse(is.na(warwickLupins$Male),"F","M")
warwickLupinsLate$Sex<-ifelse(is.na(warwickLupins$Male) &
is.na(warwickLupins$Female),NA,warwickLupinsLate$Sex)
warwickLupinsLate$Supplement<-"Lupins"
warwickLupinsLate$Feed<-0
warwickLupinsLate$Location<-"Warwick"

# fix up naff numbers in weight values
warwickDates<-warwickLupins[c(5,6,9,12,17,20,21,24)]
names(warwickDates)<-
c("X15.07.17","X12.08.17","X10.09.17","X08.10.17","X05.11.17","X28.11.17","X02.12.17","X20.01.18")

warwickDates$X15.07.17_Comment<-NA   # no character entries in weight record
warwickDates$X12.08.17_Comment<-NA
warwickDates$X10.09.17_Comment<-NA

warwickDates$X08.10.17_Comment<- ifelse(warwickDates$X08.10.17=="No White tag    23.0","No White
tag",
                  ifelse(warwickDates$X08.10.17=="2x Puss Ears     9.8","2x Puss Ears",
                     ifelse(warwickDates$X08.10.17=="non  reader    26.0","non reader",
                        ifelse(warwickDates$X08.10.17=="Dead","Dead",NA)
                 )))
warwickDates$X08.10.17<-ifelse(warwickDates$X08.10.17=="No White tag    23.0",23.0,
                ifelse(warwickDates$X08.10.17=="2x Puss Ears     9.8",9.8,
                    ifelse(warwickDates$X08.10.17=="non  reader    26.0",26.0,
                       ifelse(warwickDates$X08.10.17=="Dead",NA,warwickDates$X08.10.17)
                )))
```

```r
warwickDates$X05.11.17_Comment<-ifelse(warwickDates$X05.11.17=="No White tag   27.6","No White tag",
                 ifelse(warwickDates$X05.11.17=="Dead","Dead",NA)
             )
warwickDates$X05.11.17<- ifelse(warwickDates$X05.11.17=="No White tag   27.6",27.6,
             ifelse(warwickDates$X05.11.17=="Dead",NA,warwickDates$X05.11.17)
             )


warwickDates$X28.11.17_Comment<-NA

warwickDates$X02.12.17_Comment<-ifelse(warwickDates$X02.12.17=="No White tag   32.4","No White
tag",NA)
warwickDates$X02.12.17<- ifelse(warwickDates$X02.12.17=="No White tag
32.4",32.4,warwickDates$X02.12.17)


warwickDates$X20.01.18_Comment<- ifelse(warwickDates$X20.01.18=="No White tag   37.2","No White
tag",
                  ifelse(warwickDates$X20.01.18=="Non Reader 41.4","Non Reader",
                    ifelse(warwickDates$X20.01.18=="Non  Reader   36.8","Non  Reader",
                      ifelse(warwickDates$X20.01.187=="Dead","Dead",NA)
                    )))
warwickDates$X20.01.18<-ifelse(warwickDates$X20.01.18=="No White tag   37.2",37.2,
             ifelse(warwickDates$X20.01.18=="Non Reader 41.4",41.4,
               ifelse(warwickDates$X20.01.18=="Non Reader 36.8",36.8,
                 ifelse(warwickDates$X20.01.18=="Dead",NA,warwickDates$X20.01.18)
               )))


warwickLupinsLate<-cbind(warwickLupinsLate,warwickDates)
warwickLupins<-rbind(warwickLate,warwickLupinsLate)


# add kid weights, sex and comments

WarwickDataLate<-melt(warwickLupins, id=c("Management.Tag","Sex","Supplement","Feed","Location"))
WarwickDataLate$Comment<-
WarwickDataLate$value[(nrow(WarwickDataLate)/2+1):nrow(WarwickDataLate)]
WarwickDataLate<-WarwickDataLate[1:(nrow(WarwickDataLate)/2),]

names(WarwickDataLate)[which(names(WarwickDataLate)=="variable")]<-"Date"
WarwickDataLate$Date<-as.character(WarwickDataLate$Date)
WarwickDataLate$Date<-substr(WarwickDataLate$Date,2,nchar(WarwickDataLate$Date))
WarwickDataLate$Date<-as.Date(WarwickDataLate$Date,format="%d.%m.%y")

names(WarwickDataLate)[which(names(WarwickDataLate)=="value")]<-"Weight.kg"


########
# Eulo Lupins

wb<-loadWorkbook("Pdks 3-6 Round 2 weights Eulo.xlsx")
```

```r
EuloBlue<-readWorksheet(wb,sheet=1,startRow=2,endRow=87,startCol=1,endCol=6)
EuloGreen<-readWorksheet(wb,sheet=1,startRow=2,endRow=83,startCol=8,endCol=13)
names(EuloGreen)<-c("Management.Tag","Sex","X2017.09.15","X2017.10.27","X2017.12.06","X2018.01.18")
names(EuloBlue)<-c("Management.Tag","Sex","X2017.09.15","X2017.10.27","X2017.12.06","X2018.01.18")
EuloGreen$Supplement<-"Lupins"
EuloBlue$Supplement<-"None"
EuloGreen$Feed<-494
EuloBlue$Feed<-0

EuloWide<-rbind(EuloGreen,EuloBlue)
EuloWide$X2017.10.27

EuloWide$Location<-"Eulo"

# add comments here
#EuloWide$X2017.10.27_Comment<-ifelse(EuloWide$X2017.10.27=="sick","sick",NA)

EuloWide$X2017.10.27<- ifelse(EuloWide$X2017.10.27=="sick",NA,EuloWide$X2017.10.27)

EuloLate<-melt(EuloWide, id=c("Management.Tag","Sex","Supplement","Feed","Location"))
#EuloLate$Comment<-WarwickDataLate$value[(nrow(WarwickDataLate)/2+1):nrow(WarwickDataLate)]
#WarwickDataLate<-WarwickDataLate[1:(nrow(WarwickDataLate)/2),]

names(EuloLate)[which(names(EuloLate)=="variable")]<-"Date"
EuloLate$Date<-as.character(EuloLate$Date)
EuloLate$Date<-substr(EuloLate$Date,2,nchar(EuloLate$Date))
EuloLate$Date<-as.Date(EuloLate$Date,format="%Y.%m.%d")

names(EuloLate)[which(names(EuloLate)=="value")]<-"Weight.kg"


### Dirranbandi  Lupins
wb<-loadWorkbook("Copy of weights second lot 2_Dirranbandi.xlsx")
DirranbandiRed<-readWorksheet(wb,sheet=1,startRow=1,endRow=81,startCol=3,endCol=7)
DirranbandiGreen<-readWorksheet(wb,sheet=1,startRow=86,endRow=167,startCol=3,endCol=7)
names(DirranbandiGreen)<-names(DirranbandiRed)<-
c("Management.Tag","X29.05.2017","X19.08.2017","X01.10.2017","Sex")
DirranbandiRed$Management.Tag<-paste0("DRL",DirranbandiRed$Management.Tag)    # DRL -
Dirranbandi:Red:Lupins
DirranbandiGreen$Management.Tag<-paste0("DGN",DirranbandiGreen$Management.Tag) # DGN -
Dirranbandi:Green:None
DirranbandiRed$Supplement<-"Lupins"
DirranbandiGreen$Supplement<-"None"
DirranbandiWide<-rbind(DirranbandiRed,DirranbandiGreen)

DirranbandiWide$Location<-"Dirranbandi"
DirranbandiWide$Feed<-0  # unknown for lupins the feed amount

DirranbandiLate<-melt(DirranbandiWide, id=c("Management.Tag","Sex","Supplement","Feed","Location"))
#EuloLate$Comment<-WarwickDataLate$value[(nrow(WarwickDataLate)/2+1):nrow(WarwickDataLate)]
#WarwickDataLate<-WarwickDataLate[1:(nrow(WarwickDataLate)/2),]

names(DirranbandiLate)[which(names(DirranbandiLate)=="variable")]<-"Date"
```

```r
DirranbandiLate$Date<-as.character(DirranbandiLate$Date)
DirranbandiLate$Date<-substr(DirranbandiLate$Date,2,nchar(DirranbandiLate$Date))
DirranbandiLate$Date<-as.Date(DirranbandiLate$Date,format="%d.%m.%Y")

names(DirranbandiLate)[which(names(DirranbandiLate)=="value")]<-"Weight.kg"


#### Compile data
allLate<-rbind(WarwickDataLate[,-ncol(WarwickDataLate)],EuloLate,DirranbandiLate)
allLate$Weight.kg<-as.numeric(allLate$Weight.kg)
allLate$Management.Tag<-as.character(allLate$Management.Tag)
## deal with dead ...
# only have heuristic of >1 consecutive NA data at end of data record to define death for Eulo, of which there
was only one case  - tag 60
# for Dirranbandi, possible deaths seem to correlate with "missing" on sex
# for Warwick, can work out with a bit of coding from record.

# key idea with death is to include delta.death = time of death - time of measurement
#   this would accomodate for drop in growth rate associated with sick animals that are dying.
#   but would be averaged over both slow and sudden deaths, along with some failed captures.
#     so conclude that inclusion of delta.death is of minor importance.

allLate$Sex<-ifelse(allLate$Sex=="m","M",
            ifelse(allLate$Sex=="f","F",
                ifelse(allLate$Sex=="missing" | allLate$Sex=="missing ",NA,allLate$Sex)))


# replicate indicator
allLate$Replicate<-"LupinLate"
allEarly$Replicate<-"PelletEarly"

allData<-rbind(allEarly[,-8,],allLate)

# correct outlying weights:
allData$Weight.kg[allData$Weight.kg==212]<-21.2

# complete kingaroy and warwick early sex data
setwd("C:\\Users\\rohan\\Dropbox\\Rohan\\data and analysis\\old data")
wbWarwick<-loadWorkbook("Copy of Maher 1_with sex.xlsx")
warwickSex<-readWorksheet(wbWarwick,sheet=1)
warwickTag<-paste0("W1",warwickSex$Management.Tag)
warwickMatch<-match(allData$Management.Tag,warwickTag)
warwickNA<-which(!is.na(warwickMatch))
allData$Sex[warwickNA]<-warwickSex$Sex[warwickMatch[warwickNA]]

wbKingaroy<-loadWorkbook("Kingaroy Weights_with sex.xlsx")
kingaroySex<-readWorksheet(wbKingaroy,sheet=1)
kingaroySex<-kingaroySex[!is.na(kingaroySex$SEX),]
kingaroyTag<-paste0("K1",kingaroySex[,2])

kingaroyMatch<-match(as.character(allData$Management.Tag),as.character(kingaroyTag))
kingaroyNA<-which(!is.na(kingaroyMatch))
allData$Sex[kingaroyNA]<-kingaroySex$SEX[kingaroyMatch[kingaroyNA]]
```

```
# all Dirranbandi animals for the Pellet study were male
# allData$Sex[allData$Location=="Dirranbandi" & allData$Replicate=="PelletEarly"]<-"M"
# this is not true as "Perkins_phase1.csv" for Dirranbandi early has m,f coded
# Warwick and Kingaroy early do not have sex coded
# sex coded for all three locations in late lupin trial

#  Calculate days as numeric for package sitar
replicateUnique<-unique(allData$Replicate)
locationUnique<-unique(allData$Location)
allData$Days<-NA     # needs to be numeric for sitar package to work, can't use dates directly.
allData$Day.of.Year <- yday(allData$Date)
# control for time in season when feeding trial started


for(j in 1:length(replicateUnique)) {
  for(k in 1:length(locationUnique)) {
    repLocWhich<-which(allData$Replicate==replicateUnique[j] & allData$Location==locationUnique[k])
    dateUnique<-sort(unique(allData$Date[repLocWhich]))
    if(length(dateUnique)==0)  next   # miss Kingaroy lupins trial as does not exist
    allData$Days[repLocWhich]<-allData$Date[repLocWhich]-min(dateUnique)
  }
}



# add in kid weights manually; treat as interaction between female and total kid weight
allData$KidWeight.kg<-NA

# Dirranbandi Late
allData$KidWeight.kg[allData$Location=="Dirranbandi" & allData$Replicate=="LupinLate" &
allData$Date=="2017-05-29"]<-0
allData$KidWeight.kg[allData$Location=="Dirranbandi" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-08-19" & allData$Supplement=="Lupins"]<- 8
allData$KidWeight.kg[allData$Location=="Dirranbandi" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-08-19" & allData$Supplement=="None"]<- 15
allData$KidWeight.kg[allData$Location=="Dirranbandi" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-10-01" & allData$Supplement=="Lupins"]<- 32
allData$KidWeight.kg[allData$Location=="Dirranbandi" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-10-01" & allData$Supplement=="None"]<- 90

# Dirranbandi Early
allData$KidWeight.kg[allData$Location=="Dirranbandi" & allData$Replicate=="PelletEarly"]<-0   # all males


# Warwick Late - kid weights calculated in "2nd MLA Goat Weighing
Warwick_pinklake_kidweightssummed.xlsx"
sort(unique(WarwickDataLate$Date))
#[1] "2017-07-15" "2017-08-12" "2017-09-10" "2017-10-08" "2017-11-05" "2017-11-28" "2017-12-02" "2018-
01-20"
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-07-15" & allData$Supplement=="Lupins"]<-0
```

```r
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-07-15" & allData$Supplement=="None"]<-0
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-08-12" & allData$Supplement=="Lupins"]<-0
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-08-12" & allData$Supplement=="None"]<-5.6
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-09-10" & allData$Supplement=="Lupins"]<-33.8
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-09-10" & allData$Supplement=="None"]<-12.2
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-10-08" & allData$Supplement=="Lupins"]<-63.4
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-10-08" & allData$Supplement=="None"]<-12.2
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-11-05" & allData$Supplement=="Lupins"]<-102.4
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-11-05" & allData$Supplement=="None"]<-21.6
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-11-28" & allData$Supplement=="Lupins"]<-139.4  # recycle kid weight for
field day kill
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-11-28" & allData$Supplement=="None"]<-30.8
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-12-02" & allData$Supplement=="Lupins"]<-139.4
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2017-12-02" & allData$Supplement=="None"]<-30.8
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2018-01-20" & allData$Supplement=="Lupins"]<-220.4
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2018-01-20" & allData$Supplement=="None"]<-53.6


# Warwick Early
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="PelletEarly" &
          allData$Date=="2016-10-01" & allData$Supplement=="Pellet"]<-54.2
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2016-10-01" & allData$Supplement=="None"]<-29.6
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="PelletEarly" &
          allData$Date=="2016-10-01" & allData$Supplement=="Pellet"]<-99.6
allData$KidWeight.kg[allData$Location=="Warwick" & allData$Replicate=="LupinLate" &
          allData$Date=="2016-10-01" & allData$Supplement=="None"]<-38.6



# Eulo Late
allData$KidWeight.kg[allData$Location=="Eulo" & allData$Replicate=="LupinLate" &
          allData$Date=="2018-01-18" & allData$Supplement=="Lupins"]<-83   # the rest are missing data


# Eulo Early
allData$KidWeight.kg[allData$Location=="Eulo" & allData$Replicate=="PelletEarly" &
                allData$Date=="2016-12-20" & allData$Supplement=="Pellet"]<-183   # the rest are
missing data
allData$KidWeight.kg[allData$Location=="Eulo" & allData$Replicate=="PelletEarly" &
          allData$Date=="2016-12-20" & allData$Supplement=="None"]<-122   # the rest are missing data
```

```
# Kingaroy Early
allData$KidWeight.kg[allData$Location=="Kingaroy" & allData$Replicate=="PelletEarly" &
            allData$Date=="2016-11-26" & allData$Supplement=="Pellet"]<-23.6
allData$KidWeight.kg[allData$Location=="Kingaroy" & allData$Replicate=="PelletEarly" &
            allData$Date=="2016-11-26" & allData$Supplement=="None"]<-9.2

# now as a per animal weight -
# really kid weight should impact most on the growth curve of the mother, particularly in early period, but this
information is mostly absent
allData$KidWeight.kg.head<-NA


# ignores dead animals ... calculated off starting number of animals
for(j in 1:length(replicateUnique)) {
 if(replicateUnique[j]=="PelletEarly") {
   supplementUnique<-c("Pellet","None")
 }else{
   supplementUnique<-c("Lupins","None")
 }
 for(k in 1:length(locationUnique)) {

  for(l in 1:length(supplementUnique)) {
    repLocSuppWhich<-which(allData$Replicate==replicateUnique[j] & allData$Location==locationUnique[k] &
                allData$Supplement==supplementUnique[l] )
    ncount<-length(repLocSuppWhich)
    if(ncount==0) next
    allData$KidWeight.kg.head[repLocSuppWhich]<-allData$KidWeight.kg[repLocSuppWhich]/ncount
  }
 }
}

#### Feed - Lupin trials
allData$Feed[allData$Location=="Warwick" & allData$Supplement=="Lupins"]<-307
allData$Feed[allData$Location=="Eulo" & allData$Supplement=="Lupins"]<-494
allData$Feed[allData$Location=="Dirranbandi" & allData$Supplement=="Lupins"]<-190

# correction to Supplement
allData$Supplement<-ifelse(allData$Supplement=="Lupins","Lupin",allData$Supplement)

# Hay information ignored at this point in time

### Weather
## append weather averages and soil moisture indices - to do
# iterate through unique dates at each location
# Dirranbandi: 28.5780° S, 148.2292° E
# Eulo: 28.1670° S, 145.0385° E
# Warwick: 28.2157° S, 152.0282° E
# Kingaroy: 26.5309° S, 151.8400° E

# monthly sum rainfall up to Date
allData$Rain<-NA
```

```r
# monthly average temperature up to Date
allData$Temperature.Max <- NA
# monthly average temperature up to Date
allData$Temperature.Min <- NA
# soil moisture index (source) - 100 mm soil depth   - modelling annuals
#allData$SMI_100<-NA
# soil moisture index (source) - 500 mm soil depth   - modelling perennials
#allData$SMI_500<-NA
# Keech-Bryam drought index - faster cycling soil moisture index related to flammabilty of surface litter fuels.
allData$KBDI<-NA
allData$Drought.Factor<-NA

### goto data_weather.R to complete values

### Pasture metrics
# dry matter yield estimate at start of trial
allData$Yield <- NA
# pasture greeness estimate at start of trial
allData$Green <- NA

# Lupin trial data from email from Brendan
# Pellet trial data from dd.csv


pastureDF<-data.frame(Location = rep(rep(c("Dirranbandi","Eulo","Warwick","Kingaroy"),length=7),each=2),
            Replicate = rep(c(rep("PelletEarly",4),rep("LupinLate",3)),each=2),
            Supplement = c(rep(c("None","Pellet"),4),rep(c("None","Lupin"),3)),
            Greeness = c( 29, 29, 14.3, 14.3,  44, 81, 61.75, 61.75,
                          2, 2, 14.3, 14.3, 60.5, 53),
            Yield = c(591, 591, 454, 454,  76, 134, 566, 566,
                          403.5, 403.5, 200, 200, 774, 958)
)

for(i in 1:nrow(pastureDF)) {
  suppWhich<-which(allData$Location==pastureDF$Location[i] & allData$Replicate==pastureDF$Replicate[i] &
            allData$Supplement==pastureDF$Supplement[i])
  allData$Green[suppWhich]<-pastureDF$Greeness[i]
  allData$Yield[suppWhich]<-pastureDF$Yield[i]
}

# Technically pasture metrics and weather metrics should define each location uniquely,
#   and allow removal of 'Location' variable from the analysis.


##########################
# Count missing data
allUnique<-unique(allData[c("Supplement","Location","Date","Replicate")])
allUnique$Count<-allUnique$SexMissing<-allUnique$WeightMissing<-allUnique$KidWeightMissing<-NA

for(i in 1:nrow(allUnique)) {
  rowWhich<-which(allData$Supplement==allUnique$Supplement[i] &
            allData$Location==allUnique$Location[i] &
            allData$Supplement==allUnique$Supplement[i] &
```

```r
          allData$Replicate==allUnique$Replicate[i])
  allUnique$Count[i]<-length(rowWhich)
  allUnique$SexMissing[i]<-length(which(is.na(allData$Sex[rowWhich])))
  allUnique$WeightMissing[i]<-length(which(is.na(allData$Weight.kg[rowWhich])))
  allUnique$KidWeightMissing[i]<-length(which(is.na(allData$KidWeight.kg[rowWhich])))
}

allUnique[c("KidWeightMissing","WeightMissing","SexMissing")]<-
allUnique[c("KidWeightMissing","WeightMissing","SexMissing")]/allUnique$Count*100

kidweightAgg<-aggregate(KidWeightMissing~Location+Replicate+Supplement,data=allUnique,FUN="mean")
sexAgg<-aggregate(SexMissing~Location+Replicate+Supplement,data=allUnique,FUN="mean")
weightAgg<-aggregate(WeightMissing~Location+Replicate+Supplement,data=allUnique,FUN="mean")
countAgg<-aggregate(Count~Location+Replicate+Supplement,data=allUnique,FUN="sum")

countAgg<-cbind(countAgg,sexMissing=sexAgg[,ncol(sexAgg)],
          weightMissing=weightAgg[,ncol(weightAgg)],
          kidWeightMissing=kidweightAgg[,ncol(kidweightAgg)])
countAgg[c("sexMissing","weightMissing","kidWeightMissing")]<-
round(countAgg[c("sexMissing","weightMissing","kidWeightMissing")],1)
countAgg$sampleSizeSexOnlyModel<-round((1-countAgg$sexMissing/100)*countAgg$Count*(1-
countAgg$weightMissing/100),0)
countAgg$sampleSizeKidOnlyModel<-round((1-countAgg$kidWeightMissing/100)*countAgg$Count*(1-
countAgg$weightMissing/100),0)
countAgg$sampleSizeSexXKidModel<-round((1-countAgg$sexMissing/100)*countAgg$Count*
                  (1-countAgg$weightMissing/100)*(1-countAgg$kidWeightMissing/100),0)




#####################
# write outputs to excel
# creation of spreadsheet commented out below
#wb2 <- loadWorkbook("all_goat_data_20180307.xlsx", create = TRUE)
wb2 <- loadWorkbook("all_goat_data_20180307.xlsx")

# write allData
#createSheet(wb2, name = "data")
writeWorksheet(wb2, allData, sheet = "data")

# # write data dictionary
# dfNames<-
data.frame(Attribute=names(allData),Values=rep("",ncol(allData)),Definition=rep("",ncol(allData)))
# createSheet(wb2, name = "data_dictionary")
# writeWorksheet(wb2, dfNames, sheet = "data_dictionary")

# # completed data dictionary
# wb2 <- loadWorkbook("all_goat_data_20180307.xlsx", create = TRUE)
# dataDictionary<-readWorksheet(wb2,sheet=2)
# write.csv(dataDictionary, "data_dictionary.csv")

# dataDictionary<-read.csv("data_dictionary.csv")
# dataDictionary<-dataDictionary[,-1]
# writeWorksheet(wb2, dataDictionary, sheet = "data_dictionary")
```

```
# write error report
#createSheet(wb2, name = "missing_data_report")
#writeWorksheet(wb2, countAgg, sheet = "missing_data_report")

# Save workbook - this actually writes the file to disk
saveWorkbook(wb2)



### ------------------

### data_weather.R

library(mgcv)
library(lubridate)
library(XLConnect)

setwd("C:\\Users\\rohan\\Dropbox\\Rohan\\data and analysis\\")

# source weather functions
source("..\\code\\weather_functions.R")

### Weather
## append weather averages and soil moisture indices - to do
# iterate through unique dates at each location
# 044117 Dirranbandi: 28.5780° S, 148.2292° E   # with temperature: 044010 Bolton
# 044153 Eulo: 28.1670° S, 145.0385° E     # with temperature: 044026 Cunnamulla
# 041534 Warwick: 28.2157° S, 152.0282° E  # with temperature: 041525 Warwick town
# 040922 Kingaroy: 26.5309° S, 151.8400° E

weatherStations<-data.frame(stationID=c("044010","044026","040922","041525"),
                station = c("Dirranbandi","Eulo",
                        "Kingaroy","Warwick"),
                rank=1:4, stringsAsFactors = FALSE)

# download rainfall
bdata<-bomdata(weatherStations$stationID,136,2000)

# download max temperature
bomdata(weatherStations[,1],122,2000)

# download min temperature
bomdata(weatherStations[,1],123,1950)

# unpack downloads
dir.create("data_weather")
dir.create("data_weather/temperature")
dir.create("data_weather/rainfall")

system("mv *123.zip data_weather/temperature")
system("mv *122.zip data_weather/temperature")
system("mv *136.zip data_weather/rainfall")
```

```r
for(i in 1:nrow(weatherStations)) {
  system(paste0("unzip data_weather/temperature/",weatherStations$stationID[i],"_122.zip -d
data_weather"))
  system(paste0("unzip data_weather/temperature/",weatherStations$stationID[i],"_123.zip -d
data_weather"))
  system(paste0("unzip data_weather/rainfall/",weatherStations$stationID[i],"_136.zip -d data_weather"))
}

tThreshold<-2010


# append the data for the four files; add columns for rainfall, tmin, tmax
for(i in 1:nrow(weatherStations)){
  wFile<-
read.csv(paste("data_weather/IDCJAC0009_",weatherStations$stationID[i],"_1800_Data.csv",sep=""),stringsAs
Factors =FALSE)
  tMaxFile<-
read.csv(paste("data_weather/IDCJAC0010_",weatherStations$stationID[i],"_1800_Data.csv",sep=""),stringsAs
Factors =FALSE)
  tMinFile<-
read.csv(paste("data_weather/IDCJAC0011_",weatherStations$stationID[i],"_1800_Data.csv",sep=""),stringsAs
Factors =FALSE)
  if(i ==1) {
    wDF<-wFile[wFile$Year>=tThreshold,2:8]
    wdfDate<-as.Date(paste(wDF$Year,wDF$Month,wDF$Day,sep="-"))
    tMaxDate<-as.Date(paste(tMaxFile$Year,tMaxFile$Month,tMaxFile$Day,sep="-"))
    tMaxMatch<-match(wdfDate,tMaxDate)  # NAs in match?
    wDF$tMax<-tMaxFile[tMaxMatch,6]
    tMinDate<-as.Date(paste(tMinFile$Year,tMinFile$Month,tMinFile$Day,sep="-"))
    tMinMatch<-match(wdfDate,tMinDate)  # NAs in match?
    wDF$tMin<-tMinFile[tMinMatch,6]

    # calculate mean yearly rainfall
    rainYear<-aggregate(wDF[,5]~wDF$Year,FUN="sum",na.rm=TRUE)
    meanRain<-mean(rainYear[,2])

    # calculate KBDI, drought factor, soil moisture index; write as wrapper function
    KBDI<-numeric(nrow(wDF))
    KBDI[1]<-200
    rain.effective<-P.eff(wDF[,5])

    for(j in 2:length(KBDI)) {
      KBDI.temp<-KBDI[j-1]
      rain.temp<-rain.effective[j]
      ET.temp<-calcET(KBDI=KBDI.temp,Tmax=wDF$tMax[j],R=meanRain,dT=1)
      KBDI.temp<-KBDI.temp-rain.temp+ET.temp
      KBDI[j]<-ifelse(is.na(KBDI.temp),KBDI[j-1],ifelse(KBDI.temp>200,200,ifelse(KBDI.temp<0,0,KBDI.temp)))
    }
    wDF$KBDI<-KBDI
    wDF$droughtFactor<-droughtFactor(KBDI=KBDI,rain=wDF[,5])


  }else{
```

```r
    wDate<-as.Date(paste(wFile$Year,wFile$Month,wFile$Day,sep="-"))
    wMatch<-match(wdfDate,wDate)
    wDFTemp<-wFile[wMatch,2:8]
    tMaxDate<-as.Date(paste(tMaxFile$Year,tMaxFile$Month,tMaxFile$Day,sep="-"))
    tMaxMatch<-match(wdfDate,tMaxDate)  # NAs in match?
    wDFTemp$tMax<-tMaxFile[tMaxMatch,6]
    tMinDate<-as.Date(paste(tMinFile$Year,tMinFile$Month,tMinFile$Day,sep="-"))
    tMinMatch<-match(wdfDate,tMinDate)  # NAs in match?
    wDFTemp$tMin<-tMinFile[tMinMatch,6]

    # calculate mean yearly rainfall
    rainYear<-aggregate(wDFTemp[,5]~wDFTemp$Year,FUN="sum",na.rm=TRUE)
    meanRain<-mean(rainYear[,2])

    # calculate KBDI, drought factor, soil moisture index; write as wrapper function
    KBDI<-numeric(nrow(wDFTemp))
    KBDI[1]<-200
    rain.effective<-P.eff(wDFTemp[,5])

    for(j in 2:length(KBDI)) {
      KBDI.temp<-KBDI[j-1]
      rain.temp<-rain.effective[j]
      ET.temp<-calcET(KBDI=KBDI.temp,Tmax=wDFTemp$tMax[j],R=meanRain,dT=1)
      KBDI.temp<-KBDI.temp-rain.temp+ET.temp
      KBDI[j]<-ifelse(is.na(KBDI.temp),KBDI[j-1],ifelse(KBDI.temp>200,200,ifelse(KBDI.temp<0,0,KBDI.temp)))
    }
    wDFTemp$KBDI<-KBDI
    wDFTemp$droughtFactor<-droughtFactor(KBDI=KBDI,rain=wDFTemp[,5])
    wDF<-rbind(wDF,wDFTemp)
  }
}

names(wDF)[c(1,5)]<-c("stationID","rainfall.mm")
wDF$Date<-wdfDate

wDF$Station<-weatherStations$station[match(wDF$stationID,
                        as.integer(weatherStations$stationID))]

# interpolate missing values; alternative strategy is to garner missing readings from
#   nearby stations, or access BOM silo interpolations.
#   2% missing data rate
length(which(is.na(wDF$rainfall.mm) & wDF$Date > "2016-01-01"))


# match dates to extract 30 day rainfall, temp, and KBDI & drought factor
# do by station
for(j in 1:nrow(weatherStations)) {

  # identify station specific observations
  wDFstationWhich<-which(wDF$Station==weatherStations$station[j])
  allDataStationWhich <- which(allData$Location==weatherStations$station[j])
  wDateMatch<-match(allData$Date[allDataStationWhich],wDF$Date[wDFstationWhich])
```

```
# extract KBDI & drought factor; only need latest measure as index is cumulative through time
allData$KBDI[allDataStationWhich]<-wDF$KBDI[wDFstationWhich[wDateMatch]]
allData$Drought.Factor[allDataStationWhich]<-wDF$droughtFactor[wDFstationWhich[wDateMatch]]

# interpolate missing temp & rainfall values (KBDI and drought factor already interpolated)
#    interpolate rainfall on log(1+x) scale
jDate<-wDF$Date[wDFstationWhich]
jTempMax<-wDF$tMax[wDFstationWhich]
naWhich<-which(is.na(jTempMax))
jTempApprox<-approx(jDate,y=jTempMax,xout=jDate[naWhich])$y
wDF$tMax[wDFstationWhich[naWhich]]<-jTempApprox

jTempMin<-wDF$tMin[wDFstationWhich]
naWhich<-which(is.na(jTempMin))
jTempApprox<-approx(jDate,y=jTempMin,xout=jDate[naWhich])$y
wDF$tMin[wDFstationWhich[naWhich]]<-jTempApprox

jRain<-wDF$rainfall.mm[wDFstationWhich]
naWhich<-which(is.na(jRain))
jRainApprox<-approx(jDate,y=log(jRain+1),xout=jDate[naWhich])$y
wDF$rainfall.mm[wDFstationWhich[naWhich]]<-exp(jRainApprox)-1


prev30day<-allData$Date[allDataStationWhich]-30
for(i in 1:length(allDataStationWhich)) {
  daySeq<-prev30day[i]:allData$Date[allDataStationWhich[i]]
  dayMatch<-match(daySeq,wDF$Date[wDFstationWhich])
  allData$Rain[allDataStationWhich[i]]<-sum(wDF$rainfall.mm[dayMatch])
  allData$Temperature.Max[allDataStationWhich[i]]<-mean(wDF$tMax[dayMatch])
  allData$Temperature.Min[allDataStationWhich[i]]<-mean(wDF$tMin[dayMatch])
}

}

# there is a more efficient way of doing this by considering unique dates in allData

## add soil moisture index - use ET calculation from KBDI - vary soil depth
#    source: CLIMEX -  https://www.hearne.software/getattachment/199e1f3e-460a-4ac8-8f7f-
1eeee84110c7/Climex-v4-User-Guide.aspx
## calculate means for last 30 days of rainfall, tempmax and tempmin

## summary weather data - by location
rainYear<-aggregate(rainfall.mm~Year+Station,FUN=sum,data=wDF)
tempYear<-aggregate(tMax~Year+Station,FUN=mean,data=wDF)
minTempYear<-aggregate(tMin~Year+Station,FUN=mean,data=wDF)
kbdiYear<-aggregate(KBDI~Year+Station,FUN=mean,data=wDF)
droughtYear<-aggregate(droughtFactor~Year+Station,FUN=mean,data=wDF)

yearTrends<-cbind(rainYear,tempYear[,3],minTempYear[,3],kbdiYear[,3],droughtYear[,3])
names(yearTrends)<-c("Year","Rainfall_sum_mm","Max_daily_temperature_mean_C",
            "Min_daily_temperature_C","KBDI_mean","Drought_factor_mean")
dir.create("data_weather/figures")
write.csv(yearTrends,"data_weather/figures/yearlyWeatherTrends.csv")
```

```r
rainMonth<-aggregate(rainfall.mm~Year + Month+ Station,FUN="sum",na.rm=TRUE,data=wDF)
rainMonthlyMean<-aggregate(rainfall.mm~Month+Station,FUN="mean",na.rm=TRUE,data=rainMonth)
tempMonth<-aggregate(tMax~Year + Month+ Station,FUN="mean",na.rm=TRUE,data=wDF)
tempMonthlyMean<-aggregate(tMax~Month+Station,FUN="mean",na.rm=TRUE,data=tempMonth)
minTempMonth<-aggregate(tMin~Year + Month+ Station,FUN="mean",na.rm=TRUE,data=wDF)
minTempMonthlyMean<-aggregate(tMin~Month+Station+
Station,FUN="mean",na.rm=TRUE,data=minTempMonth)
kbdiMonth<-aggregate(KBDI~Year + Month+ Station,FUN="mean",na.rm=TRUE,data=wDF)
kbdiMonthlyMean<-aggregate(KBDI~Month+Station,FUN="mean",na.rm=TRUE,data=kbdiMonth)
droughtMonth<-aggregate(droughtFactor~Year + Month+Station,FUN="mean",na.rm=TRUE,data=wDF)
droughtMonthlyMean<-
aggregate(droughtFactor~Month+Station,FUN="mean",na.rm=TRUE,data=droughtMonth)

monthlyMean<-
cbind(rainMonthlyMean,tempMonthlyMean[,3],minTempMonthlyMean[,3],kbdiMonthlyMean[,3],
        droughtMonthlyMean[,3])
byMonthMean<-cbind(rainMonth,tempMonth[,3],minTempMonth[,3],kbdiMonth[,3],droughtMonth[,3])
names(monthlyMean)<-c("Year","Rainfall_Month_mean_mm","Max_daily_temperature_Month_mean_C",
        "Min_daily_temperature_Month_C","KBDI_Month_mean","Drought_factor_Month_mean")
names(byMonthMean)<-
c("Year","Rainfall_byMonth_mean_mm","Max_daily_temperature_byMonth_mean_C",

"Min_daily_temperature_byMonth_C","KBDI_byMonth_mean","Drought_factor_byMonth_mean")
write.csv(monthlyMean,"data_weather/figures/monthlyWeatherTrends.csv")
write.csv(byMonthMean,"data_weather/figures/byMonthWeatherTrends.csv")


weatherExperiment<-unique(startDateDF[,c(1,3,4,5,16)])
weatherExperiment$Drought.Factor<-weatherExperiment$KBDI<-weatherExperiment$Temperature.Min<-
 weatherExperiment$Temperature.Max<-weatherExperiment$Rain<-NA
for(i in 1:nrow(weatherExperiment)){
 selectObs<-which(wDF$Station==weatherExperiment$Location[i] &
            wDF$Date>=weatherExperiment$startDate[i] &
            wDF$Date<=weatherExperiment$endDate[i])
 weatherExperiment$Rain[i]<-mean(wDF$rainfall.mm[ selectObs])
 weatherExperiment$Temperature.Max[i]<-mean(wDF$tMax[ selectObs])
 weatherExperiment$Temperature.Min[i]<-mean(wDF$tMin[ selectObs])
 weatherExperiment$KBDI[i]<-mean(wDF$KBDI[ selectObs])
 weatherExperiment$Drought.Factor[i]<-mean(wDF$droughtFactor[ selectObs])
}


# average on weigh in dates
aggregate(Rain~Location.Replicate,data=allData,FUN=mean)
aggregate(Temperature.Max~Location.Replicate,data=allData,FUN=mean)
aggregate(Temperature.Min~Location.Replicate,data=allData,FUN=mean)
aggregate(KBDI~Location.Replicate,data=allData,FUN=mean)
aggregate(Drought.Factor~Location.Replicate,data=allData,FUN=mean)

}

weatherExperiment$rainfall
```

```
### ----------------------
### weather_functions.R

# for when rain has not been interpolated
#   at the moment setting 'rain' to zero for NA rain records throughout,
#   as NA rain records at start of rain record are NAs
#   affects calcET and droughtFactor

# require max temperatures as well
calcET<-function(KBDI,Tmax,R,dT) {
  (203.2-KBDI)*(0.968*exp(0.0875*Tmax+1.5552)-8.30)*dT*1e-3/(1+10.88*exp(-0.001736*R))
}
# dQ = KBDI drought factor (mm)
# Q = KBDI at time t-1; mositure deficiency (mm)
# Tmax = daily maximum temperature (degrees C)
# R = mean annual precipitation
# dT = time increment (1 day)
# Finkele 2006

P.eff<-function(rain) {
  # Finkele text: rain - (interception, runoff)
  #   where interception/runoff is the first 5 mm within consecutive with non-zero rainfall
  #   i.e. , identify where rainfall is consecutive;
  #   then remove first 5 mm
  # Action: have only taken the first 5 mm of multiple consecutives
  #   and also first 5 mm of single days (interception)
  #   not wholly certain if this is what Finkele 2006 means as text is unclear.

  # rain<-wittenoom.rain[,6]

  rain.day<-ifelse(is.na(rain),0,ifelse(rain>0,1,rain))
  rain.lag<-rain.day[-length(rain.day)]
  rain.event<-numeric(length(rain.day))

  count<-0
  if(rain.day[1]==1) {
   count<-count+1
   rain.event[1]<-count
  }
  for(i in 2:length(rain.day)) {
   if(is.na(rain.day[i])){
    rain.event[i]<-NA
    next
   }
   if(rain.day[i]==1) {
    if(rain.day[i-1]==0 | is.na(rain.day[i-1])) {
     count<-count+1
     rain.event[i]<-count
    }else{
     rain.event[i]<-count
    }
```

```r
   }
 }
 #  rain.count<-table(rain.event)
 # table(rain.count[-1])
 #  1  2  3  4  5  6  7  8  9  10  13
 #654 301 129 52 36 20  6  5  2  1  1

 for(i in 1:count) {
   count.which<-which(rain.event==i)
   count.length<-length(count.which)
   if(count.length==1) {
     rain[count.which]<-ifelse(rain[count.which]<5,0,rain[count.which]-5)
   }else{
     rain.temp<-rain[count.which]
     rain.cumsum<-cumsum(rain.temp)
     rain.which<-which(rain.cumsum<5)
     if(length(rain.which)>0) {
       rain.remainder<-5-max(rain.cumsum[rain.which])
       rain[count.which[rain.cumsum<5]]<-0
       rain[count.which[rain.cumsum>=5][1]]<-rain[count.which[rain.cumsum>=5][1]]-rain.remainder
     }else{
       rain[count.which[1]]<-rain[count.which[1]]-5
     }
   }
 }


 return(rain)
}



# Drought Factor
#To determine the significant rainfall event the function x is minimised over the combination of
#rainfall amount P and time in days since it fell N. The rainfall event is defined as consecutive days
#with rainfall amount above 2 mm. The rainfall event amount P is the sum of rainfall within the
#event. The event age N is defined as the number of days since the day with the largest daily rainfall
#amount within the rain event

# how to deal with missing values?

# read BOM rainfall data file
#readBOM<-function(filename) {
#
#}

droughtFactor<-function(KBDI,rain) {
  #        id.list<- number of rainfall events (consecutive days > 2 mm each day)
  #        N<-days since most rain fell within the event that minimises x
  #        P<- sum of rain within the event
  #        x<- calculate for each event within last 20 days
  #        x<- N>=1 & P> 2mm   N^1.3/(N^1.3+P-2)
  #        N=0 & P>2 mm    0.8^1.3/(0.8^1.3+P-2)
  #        P<2 mm              1
  #        DF<-10.5*(1-exp(-(KBDI+30)/40))*(41*x^2+x)/(40*x^2+x+1)
```

```r
#rain<-wittenoom.rain[,6]
rain.day<-ifelse(is.na(rain),0,ifelse(rain>=2,1,0))
rain.lag<-rain.day[-length(rain.day)]
rain.event<-numeric(length(rain.day))

count<-0
if(rain.day[1]==1) {
 count<-count+1
 rain.event[1]<-count
}
for(i in 2:length(rain.day)) {
 if(is.na(rain.day[i])){
  rain.event[i]<-NA
  next
 }
 if(rain.day[i]==1) {
  if(rain.day[i-1]==0 | is.na(rain.day[i-1])) {
   count<-count+1
   rain.event[i]<-count
  }else{
   rain.event[i]<-count
  }
 }
}
# rain.count<-table(rain.event)
# table(rain.count[-1])
# 1  2   3   4  5  6  7  8  9  10 13
#654 301 129 52 36 20  6  5  2  1  1

#rain.20days<-numeric(length(rain))
drought.factor<-numeric(length(rain))

for(i in 20:length(rain)) {
 n.events<-unique(rain.event[(i-19):i])
 n.events<-n.events[n.events>0 & !is.na(n.events)]


 if(length(n.events)==0) {
  drought.factor[i]<-10.5*(1-exp(-(KBDI[i]+30)/40))
  next
 }
 if(length(n.events)==1) {
  days.which<-which(rain.event==n.events)
  days.which<-days.which[days.which<=i & days.which>(i-20)]
  rain.which<-rain[days.which]
  rain.max<-which.max(rain.which)[1]
  n.days<- i-days.which[rain.max]
  if(n.days==0){
   n.days<-0.8
  }
  xx<-n.days^1.3/(n.days^1.3+rain.which[rain.max]-2)
  drought.factor[i]<-10.5*(1-exp(-(KBDI[i]+30)/40))*(41*xx^2+xx)/(40*xx^2+xx+1)
 }else{
```

```r
    xx<-n.days<-numeric(length(n.events))
    for(j in 1:length(n.events)) {
      days.which<-which(rain.event==n.events[j])
      days.which<-days.which[days.which<=i & days.which>(i-20)]
      rain.which<-rain[days.which]
      rain.max<-which.max(rain.which)[1]
      n.days[j]<- i-days.which[rain.max]
      if(n.days[j]==0){
        n.days[j]<-0.8
      }
      xx[j]<-n.days[j]^1.3/(n.days[j]^1.3+rain.which[rain.max]-2)
    }
    xx.min<-which.min(xx)
    n.days<-n.days[xx.min]
    xx<-xx[xx.min]
    if(n.days==0){
      n.days<-0.8
    }
    xx<-n.days^1.3/(n.days^1.3+rain.which[rain.max]-2)

    drought.factor[i]<-10.5*(1-exp(-(KBDI[i]+30)/40))*(41*xx^2+xx)/(40*xx^2+xx+1)

  }
 }
 return(drought.factor)
}


#daily code = 136
#monthy code = 139

#http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_display_type=dailyZippedDataFile&p_stn_num=09
0180&p_c=-1626697865&p_nccObsCode=122&p_startYear=2015

# cross reference start date
bomdata<- function(station,code,startYear){
 for(j in 1:length(code)){
  for(i in 1: length(station)){
    p.url<-
paste("http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_stn_num=",station[i],"&p_display_type=avail
ableYears&p_nccObsCode=",code[j],sep ="")
    download.file(p.url,"test.txt")
    filelist <- list.files(pattern = "test.txt")
    foo<- file(filelist,"r")
    text<- suppressWarnings(readLines(foo))
    close(foo)
    l<- regexpr(":",text[1])
    m<- unlist(gregexpr(",", text[1], perl = TRUE))
    pc<- substr(text[1],l[[1]]+1,l[[1]]+(m[2]-(l[[1]]+1)))
    url<-
paste("http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_display_type=dailyZippedDataFile&p_stn_nu
m=",as.character(station[i]),"&p_c=",pc,"&p_nccObsCode=",code[j],"&p_startYear=",startYear, sep ="")
    suppressWarnings(download.file(url,paste(as.character(station[i]),"_",as.character(code[j]),".zip",sep= ""),
mode = "wb"))
```

```
    unlink("test.txt")
  }
 }
}
### --------------------------------------------
### gross_margin_optimisation.R

library(glmmTMB)
library(XLConnect)

setwd("C:/Users/rohan/Dropbox/Rohan/data and analysis")

load("RData/goat_model_20180319.RData")
load("RData/sexAdjustment.RData")

wbFile<-file.choose()
wb<-loadWorkbook(wbFile)
# wb<-loadWorkbook("../optimisation/Pinklake_mockup_Goat-feeding-margin-calculator
29March17_Springvale_112days-3.xlsx")
worksheetNames<-getSheets(wb)

optInputs<-readWorksheet(wb,sheet=1,useCachedValues=TRUE)

fmInputs<-readWorksheet(wb,sheet=3,useCachedValues=TRUE)
gmInputs<-readWorksheet(wb,sheet=4,useCachedValues=TRUE)

# checks to make sure input data is complete; omitted for mock up purposes
optVars<-optInputs[4:10,2:10]

initialWeightPredict<-as.numeric(optVars[3,4])

meanDF<-as.data.frame(expand.grid(Days=seq(0,180,by=1),SupplementFull=as.factor(optVars[4,4]),
                Feed=seq(0,450, by = 1),Green=as.numeric(optVars[6,8]),
                Yield=as.numeric(optVars[7,8]),KBDI=as.numeric(optVars[4,8]),
                Rain=as.numeric(optVars[1,8]),Temperature.Max=as.numeric(optVars[3,8]),
                Temperature.Min=as.numeric(optVars[2,8]),
                startWeight.log=log(initialWeightPredict),Management.Tag="new"))


meanDF<-as.data.frame(expand.grid(Days=seq(0,180,by=1),SupplementFull="Pellet",
                Feed=seq(0,450, by = 1),Green=as.numeric(optVars[6,8]),
                Yield=as.numeric(optVars[7,8]),KBDI=80,
                Rain=40,Temperature.Max=28,
                Temperature.Min=12,
                startWeight.log=log(initialWeightPredict),Management.Tag="new"))


meanPredict<-exp(predict(f18,newdata=meanDF,allow.new.levels=TRUE)) #,re.form=NA))
#cbind(meanDF,out=round(exp(meanPredict),1))
summary(meanPredict)

# adjustments for male/female
fDFAggregate<-aggregate(growthRate~Feed.Replicate,FUN=mean,data=fDFUnique)
```

```
fMatch<-match(fDFUnique$Feed.Replicate,fDFAggregate$Feed.Replicate)
fDFUnique$growthRateDiff<-fDFUnique$growthRate-fDFAggregate$growthRate[fMatch]


fDFUnique$growthRateDiffSlope<-NA
fDFUnique$growthRateDiffSlope[1:4]<- rep( (fDFUnique$growthRateDiff[3:4]-
fDFUnique$growthRateDiff[1:2])/(fDFUnique$Feed[3:4]-fDFUnique$Feed[1:2]),2)
fDFUnique$growthRateDiffSlope[5:8]<- rep( (fDFUnique$growthRateDiff[7:8]-
fDFUnique$growthRateDiff[5:6])/(fDFUnique$Feed[7:8]-fDFUnique$Feed[5:6]),2)

pelletWhich<-which(meanDF$SupplementFull=="Pellet")
meanDF$femaleAdjustedWeight[pelletWhich]<-meanPredict[pelletWhich]+
                        (fDFUnique$growthRateDiff[2]+

fDFUnique$growthRateDiffSlope[2]*meanDF$Feed[pelletWhich])*meanDF$Days[pelletWhich]
meanDF$maleAdjustedWeight[pelletWhich]<-meanPredict[pelletWhich]+
  (fDFUnique$growthRateDiff[1]+
    fDFUnique$growthRateDiffSlope[1]*meanDF$Feed[pelletWhich])*meanDF$Days[pelletWhich]


lupinWhich<-which(meanDF$SupplementFull=="Lupin")
meanDF$femaleAdjustedWeight[lupinWhich]<-meanPredict[lupinWhich]+
  (fDFUnique$growthRateDiff[6]+
    fDFUnique$growthRateDiffSlope[6]*meanDF$Feed[lupinWhich])*meanDF$Days[lupinWhich]
meanDF$maleAdjustedWeight[lupinWhich]<-meanPredict[lupinWhich]+
  (fDFUnique$growthRateDiff[5]+
    fDFUnique$growthRateDiffSlope[5]*meanDF$Feed[lupinWhich])*meanDF$Days[lupinWhich]



# extract input information - Gross Margins
numberGoats<-as.numeric(optVars[1,4])
sexRatio<-as.numeric(gmInputs[12,2])/as.numeric(gmInputs[14,2])
#sexRatio<-0.5
dressingPercent<-fmInputs[28,7]
stockLoss<-as.numeric(fmInputs[24,2])/100
interestRate<-as.numeric(fmInputs[25,2])/100
commissionRate<-as.numeric(fmInputs[26,2])/100
feedCost.tonne<-as.numeric(fmInputs[27,2])
salePrice.kg<-as.numeric(fmInputs[27,7])
fixedCosts.head<-as.numeric(fmInputs[40:50,2])
names(fixedCosts.head)<-fmInputs[40:50,1]
totalFixedCosts.head<-sum(fixedCosts.head)
startNetValue.kg<-fmInputs[12,8]
day0SalePrice.kg<-fmInputs[3,7]
day180SalePrice.kg<-fmInputs[27,7]
dse<- gmInputs[12,11]

startNetValue.head <- startNetValue.kg*initialWeightPredict

meanPredictSex<-sexRatio*meanDF$maleAdjustedWeight + (1-sexRatio)*meanDF$femaleAdjustedWeight

# accept that salePrice is given for 180 days;
#  interpolate sale price in interm as linear
```

```r
meanDF$salePrice.kg<-  day0SalePrice.kg + (day180SalePrice.kg - day0SalePrice.kg)/180*meanDF$Days
meanDF$startValue<-salePrice.kg*initialWeightPredict
meanDF$saleValue.head<-  meanDF$salePrice.kg*meanPredictSex
meanDF$feedRequired.head<-meanDF$Days*meanDF$Feed/1000
meanDF$feedCost.head<- feedCost.tonne/1000*meanDF$feedRequired.head
meanDF$commission.head<-commisionRate*meanPredictSex*meanDF$salePrice.kg
meanDF$interestStock.head<-interestRate*meanDF$Days/365*initialWeightPredict
meanDF$interestFeed.head<-interestRate*meanDF$Days/365*meanDF$feedCost.head
meanDF$totalCosts.head<-meanDF$feedCost.head + meanDF$commission.head +
        meanDF$interestStock.head + meanDF$interestFeed.head +
        totalFixedCosts.head

meanDF$profit.head<-meanDF$saleValue.head*(1-stockLoss) - startNetValue.head - meanDF$totalCosts.head
meanDF$predictedWeight.kg<-meanPredictSex

# optimise
optimalWhich<-which.max(meanDF$profit.head)
optimalOfftake<-meanDF$Days[optimalWhich]
optimalFeed<-meanDF$Feed[optimalWhich]
predictedGain.kg.head<- meanPredictSex[optimalWhich]-initialWeightPredict
grossMargin<-meanDF$profit.head[optimalWhich]*numberGoats
grossMargin.head<-meanDF$profit.head[optimalWhich]
dse<- 40/(predictedGain.kg.head/2+initialWeightPredict)
grossMargin.dse<-grossMargin.head*dse
grossMargin.ha <-  grossMargin.head*gmInputs[12,11]

optOutputs<-readWorksheet(wb,sheet=2,useCachedValues=TRUE)
optOutputs[,4:7]<-NA
optOutputs[1:8,7]<-round(c(optimalOfftake,optimalFeed,
                predictedGain.kg.head,
        grossMargin,NA,grossMargin.head,
        grossMargin.dse,
        grossMargin.ha),2)
colnames(optOutputs)<-c("OUTPUTS",rep(NA,6))

# save optimisation outputs worksheet
writeWorksheet(wb,optOutputs,sheet=2,header=TRUE)
saveWorkbook(wb)


# Figure: gross margin vs holding period

# meanPredictCentre<-rep(NA,nrow(meanDF))
# for(i in 1:(nrow(meanDF)/10)) {
#   iCount<- ((i-1)*10+1):(i*10)
#   meanPredictCentre[iCount]<-exp(initialWeightPredict)-
exp(meanPredict[iCount[1]])+exp(meanPredict[iCount])
# }
```

Appendix 5: Gross margin spreadsheet calculator

Appendix 6: Model coefficients for models 1-3

Model 1: The model coefficients from a linear mixed model relating treatment to weight of goat by site and time.

Model Terms	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	**0.20738**	**0.0341**	**6.0750**	**1.2e-09**
scale(Days)	0.04369	0.0365	1.1975	2.3e-01
scale(Days^2)	0.16211	0.1507	1.0758	2.8e-01
scale(Days^3)	0.00076	0.1865	0.0041	1.0e+00
SupplementFullPellet	**0.15173**	**0.0078**	**19.4445**	**3.2e-84**
scale(Feed)	**0.07712**	**0.0053**	**14.6602**	**1.2e-48**
LocationEulo	**-0.09021**	**0.0342**	**-2.6403**	**8.3e-03**
LocationDirranbandi	0.00459	0.0343	0.1341	8.9e-01
LocationWarwick	**-0.06966**	**0.0342**	**-2.0385**	**4.2e-02**
scale(Days):SupplementFullPellet	**0.13073**	**0.0164**	**7.9496**	**1.9e-15**
scale(Days):scale(Feed)	**0.05649**	**0.0083**	**6.8454**	**7.6e-12**
scale(Days):LocationEulo	-0.04468	0.0374	-1.1938	2.3e-01
scale(Days):LocationDirranbandi	0.03679	0.0412	0.8935	3.7e-01
scale(Days):LocationWarwick	0.02456	0.0363	0.6760	5.0e-01
scale(Days^2):SupplementFullPellet	**-0.12049**	**0.0331**	**-3.6366**	**2.8e-04**
scale(Days^2):scale(Feed)	0.02719	0.0170	1.5970	1.1e-01
scale(Days^2):LocationEulo	**0.40573**	**0.1551**	**2.6153**	**8.9e-03**
scale(Days^2):LocationDirranbandi	**0.34183**	**0.1653**	**2.0682**	**3.9e-02**
scale(Days^2):LocationWarwick	-0.12237	0.1501	-0.8152	4.1e-01
scale(Days^3):SupplementFullPellet	**0.11087**	**0.0223**	**4.9749**	**6.5e-07**
scale(Days^3):scale(Feed)	**-0.03705**	**0.0127**	**-2.9162**	**3.5e-03**
scale(Days^3):LocationEulo	**-0.58619**	**0.1898**	**-3.0886**	**2.0e-03**
scale(Days^3):LocationDirranbandi	**-0.52670**	**0.1951**	**-2.6991**	**7.0e-03**
scale(Days^3):LocationWarwick	0.00569	0.1861	0.0306	9.8e-01
SupplementFullPellet:scale(Feed)	**-0.05952**	**0.0071**	**-8.4082**	**4.2e-17**
scale(Days):SupplementFullPellet:scale(Feed)	**-0.04305**	**0.0053**	**-8.0713**	**7.0e-16**

Model 1 variance components. Variability in both the intercept and the linear slope coefficient of the growth curves are of the same scale or slightly greater than residual variability (sigma).

Component	Estimate	Lower CI	Upper CI
Std.Dev: Intercept	0.11	0.11	0.12
Std.Dev: scale(Days)	0.17	0.16	0.18
Std.Dev.scale(Days^2)	0.19	0.18	0.20

Sigma	0.05	0.05	0.05

Model 2 coefficients. All terms are contrasted to the lupin supplement response.

Model Terms	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	**0.2044**	**0.0078**	**26.07**	**7.1e-150**
scale(Days)	**0.2305**	**0.0124**	**18.52**	**1.5e-76**
scale(Days^2)	**-0.2074**	**0.0218**	**-9.50**	**2.1e-21**
scale(Days^3)	**0.1189**	**0.0152**	**7.80**	**6.3e-15**
SupplementFullPellet	**0.1040**	**0.0097**	**10.76**	**5.4e-27**
scale(Feed)	**0.0641**	**0.0058**	**11.02**	**3.2e-28**
scale(KBDI)	**-0.0209**	**0.0044**	**-4.80**	**1.6e-06**
scale(Temperature.Min)	**0.0690**	**0.0101**	**6.82**	**9.4e-12**
scale(Temperature.Max)	**-0.0348**	**0.0113**	**-3.08**	**2.1e-03**
scale(Rain)	**-0.0248**	**0.0045**	**-5.45**	**4.9e-08**
SupplementFullPellet:scale(Feed)	**-0.0410**	**0.0078**	**-5.24**	**1.6e-07**
scale(Days):SupplementFullPellet	**0.0680**	**0.0069**	**9.91**	**3.8e-23**
scale(Days):scale(Feed)	**0.0384**	**0.0040**	**9.63**	**6.2e-22**
scale(Temperature.Max):scale(Rain)	**0.0208**	**0.0026**	**7.94**	**2.0e-15**
scale(Days):scale(KBDI)	**-0.0282**	**0.0032**	**-8.70**	**3.2e-18**
scale(Days):scale(Temperature.Min)	0.0116	0.0080	1.45	1.5e-01
scale(Days):scale(Temperature.Max)	0.0082	0.0101	0.82	4.2e-01
scale(Days):scale(Rain)	**-0.0176**	**0.0039**	**-4.47**	**7.7e-06**
scale(Days):SupplementFullPellet:scale(Feed)	**-0.0211**	**0.0054**	**-3.93**	**8.5e-05**
scale(Days):scale(Temperature.Max):scale(Rain)	**0.0161**	**0.0027**	**6.04**	**1.5e-09**

Model 2 variance components. Variability in both the intercept and the linear slope coefficient of the growth curves are of the same scale or slightly greater than residual variability (sigma)

Component	Estimate	Lower CI	Upper CI
Std.Dev: Intercept	0.12	0.12	0.13
Std.Dev: scale(Days)	0.08	0.07	0.08
Sigma	0.08	0.07	0.08

Model 3: The model coefficients from a linear mixed model relating treatment to weight of goat by site and time and sex of goat. Note no standard errors reported, due to non-negative Hessian matrix issue in model convergence.

Model Term	Estimate

(Intercept)	0.11
scale(Days)	0.12
scale(Days^2)	-0.20
scale(Days^3)	0.18
SexM	0.04
Feed0.PelletEarly	0.18
Feed153.PelletEarly	0.08
Feed190.LupinLate	0.09
Feed250.PelletEarly	0.25
Feed307.LupinLate	0.13
Feed363.PelletEarly	0.29
Feed439.PelletEarly	0.13
Feed494.LupinLate	0.10
scale(Days):SexM	0.05
scale(Days^2):SexM	-0.06
scale(Days^3):SexM	0.04
scale(Days):Feed0.PelletEarly	0.13
scale(Days):Feed153.PelletEarly	-0.06
scale(Days):Feed190.LupinLate	0.19
scale(Days):Feed250.PelletEarly	0.09
scale(Days):Feed307.LupinLate	0.07
scale(Days):Feed363.PelletEarly	0.12
scale(Days):Feed439.PelletEarly	0.08
scale(Days):Feed494.LupinLate	0.01
scale(Days^2):Feed0.PelletEarly	0.08
scale(Days^2):Feed153.PelletEarly	0.24
scale(Days^2):Feed190.LupinLate	-0.15
scale(Days^2):Feed250.PelletEarly	0.09
scale(Days^2):Feed307.LupinLate	0.18
scale(Days^2):Feed363.PelletEarly	0.62
scale(Days^2):Feed439.PelletEarly	0.30
scale(Days^2):Feed494.LupinLate	0.75
scale(Days^3):Feed0.PelletEarly	-0.11
scale(Days^3):Feed153.PelletEarly	-0.10
scale(Days^3):Feed190.LupinLate	-0.06
scale(Days^3):Feed250.PelletEarly	0.06
scale(Days^3):Feed307.LupinLate	-0.18
scale(Days^3):Feed363.PelletEarly	-0.66

scale(Days^3):Feed439.PelletEarly	-0.37
scale(Days^3):Feed494.LupinLate	-0.88
SexM:Feed0.PelletEarly	0.03
SexM:Feed153.PelletEarly	0.07
SexM:Feed190.LupinLate	0.04
SexM:Feed250.PelletEarly	0.10
SexM:Feed307.LupinLate	0.04
SexM:Feed363.PelletEarly	0.11
SexM:Feed439.PelletEarly	0.06
SexM:Feed494.LupinLate	0.04
scale(Days):SexM:Feed0.PelletEarly	-0.06
scale(Days):SexM:Feed153.PelletEarly	-0.02
scale(Days):SexM:Feed190.LupinLate	-0.02
scale(Days):SexM:Feed250.PelletEarly	0.04
scale(Days):SexM:Feed307.LupinLate	-0.10
scale(Days):SexM:Feed363.PelletEarly	0.11
scale(Days):SexM:Feed439.PelletEarly	-0.09
scale(Days):SexM:Feed494.LupinLate	-0.03
scale(Days^2):SexM:Feed0.PelletEarly	0.31
scale(Days^2):SexM:Feed153.PelletEarly	0.23
scale(Days^2):SexM:Feed190.LupinLate	-0.05
scale(Days^2):SexM:Feed250.PelletEarly	-0.17
scale(Days^2):SexM:Feed307.LupinLate	0.30
scale(Days^2):SexM:Feed363.PelletEarly	-0.05
scale(Days^2):SexM:Feed439.PelletEarly	0.23
scale(Days^2):SexM:Feed494.LupinLate	0.14
scale(Days^3):SexM:Feed0.PelletEarly	-0.25
scale(Days^3):SexM:Feed153.PelletEarly	-0.17
scale(Days^3):SexM:Feed190.LupinLate	0.15
scale(Days^3):SexM:Feed250.PelletEarly	0.27
scale(Days^3):SexM:Feed307.LupinLate	-0.15
scale(Days^3):SexM:Feed363.PelletEarly	0.02
scale(Days^3):SexM:Feed439.PelletEarly	-0.06
scale(Days^3):SexM:Feed494.LupinLate	-0.10

Model 3 variance components. Variability in both the intercept and the linear slope coefficient of the growth curves are of the same scale or slightly greater than residual variability (sigma)

Component	Estimate
Std.Dev: Intercept (management tag)	0.09
Std.Dev: scale (Days)	0.06
Sigma	0.07