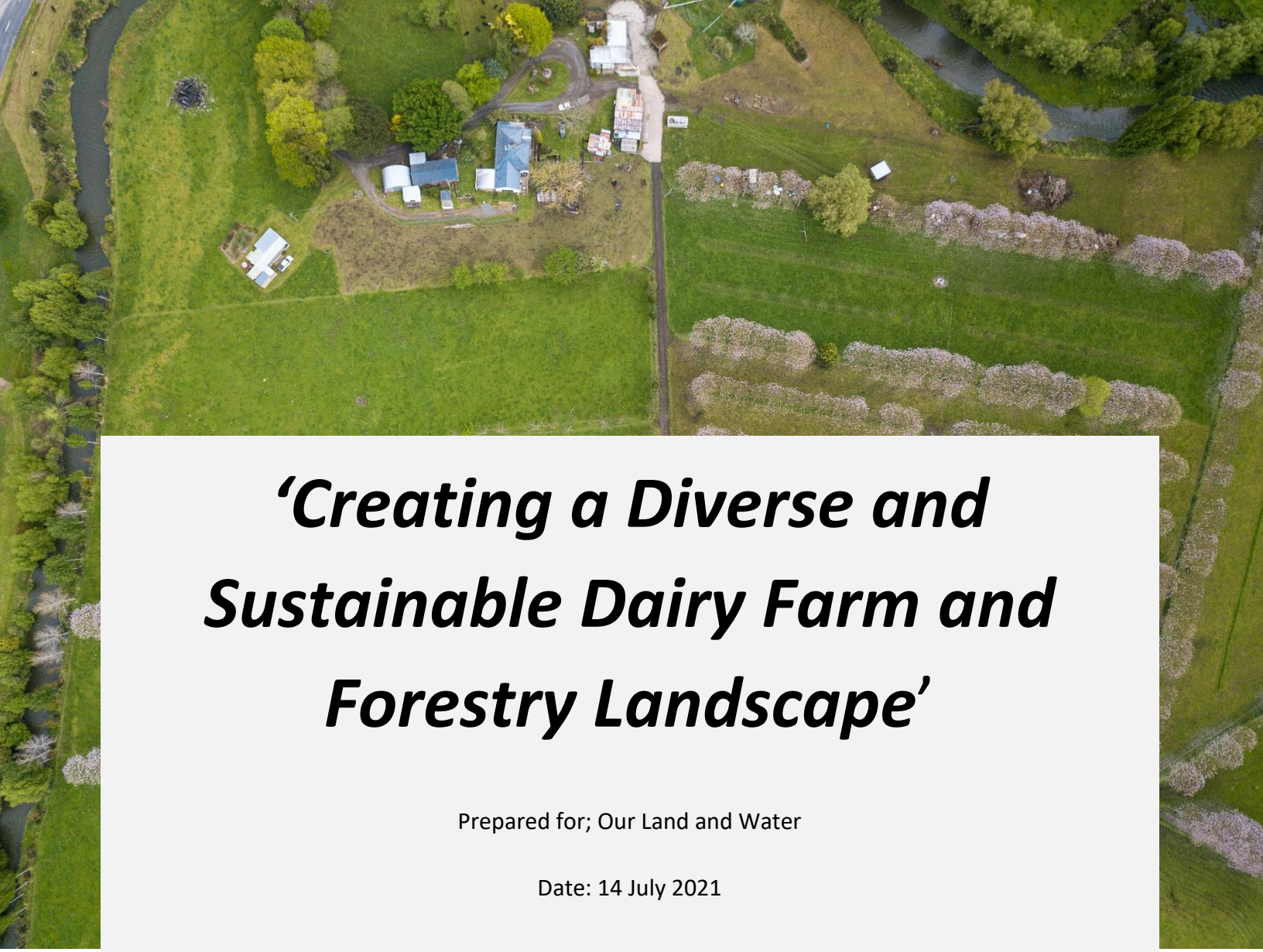

'Creating a Diverse and Sustainable Dairy Farm and Forestry Landscape'

Prepared for; Our Land and Water

Date: 14 July 2021

Completed by

Regan McCorquindale – LIC FarmWise Consultant

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Graham Smith – Miraka Farm Ltd.

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Introduction

Trees in agriculture, and in particular a dairy farming landscape, are a hard sell. Especially when it starts to take up productive area of a paddock, let alone the mess they can make if a storm passes by and creates an entire clean up job. The question for the industry then becomes what other benefits are these trees providing for the farmers stock and pasture?

The greatest perception around trees grown on farm, and in particular a productive pastoral system, is that pasture production will drastically decrease. Previous research has shown that there can be a range of a 15% increase to a 77% decrease in pasture production under trees (Hawke and Tombleson 1993; Devkota et al. 2009**).** This is dependent on a multitude of factors including tree species, planting density and time of year.

This project has looked into two key aspects,

1) Demonstrating the impact of trees on pasture production; and
2) Determine how cows use a grazing space planted with Paulownia trees compared to a typical barren pasture environment.

The pasture production aspect of the trial has been conducted with a Rising Plate Meter (RPM) and pasture sampling at two crucial times of the season for a lactating dairy cow – late spring and early autumn. This was meant to be mid-spring and mid-summer and this is discussed in the limitations section. The grazing behavior division of the trail has been conducted with three different devices measuring activity through, ankle bracelets, collars and thermal ear tags. Using multiple different devices allows for greater accuracy throughout the trial period.

The overarching purpose of this trial was to identify whether there is an animal and pasture production benefit from growing trees in a productive pastoral dairy landscape that is not currently realized, in attempt to encourage the uptake of planting trees in areas that are more productive that allows an inclusive landscape of animals and trees.

The trial was required to be rapidly executed over a 6 month period and so the materials and methods set out below are indicative of a pilot trial around the above two objectives. Further research and study would be required to look beyond the 6 months into a longer length trial period. Change in the primary industry is required now; this is the beginning of finding solutions to the industries sustainable future.

Materials and Methods

Miraka Dairy Farm was identified as the subject farm, as the farm owner Graham Smith has been extensively planting Paulownia trees over the last two decades and created the perfect landscape for this project.

As there are two different aspects to this trial project there are the below two different methods and materials.

PASTURE MONITORING

- Device: Jenquip EC09 Retrofitted digital platemeter. Equation: 500 x 140 Rising Plate Meter (RPM)
- Process: 50 measurements per transect line. Evenly spaced out to either end of the transect.
- Conducted by: Graham Smith – Farm Owner Miraka Dairy Farm.
- Measurement Dates: Appendix 12, See Key to match transect lines.
- Identification of Transect: Pigtail Standards in the fence lines at either end.
- Timeframe: 1 November 2020 – 12 March 2021
- Paddocks Selected: 3 paddocks with established Paulownia Trees with flat topography
- Paddock sizes: 0.8ha (8,000m2). All have been setup the same size under the commercial operation

Method – Three Different Dimensions

1) Identified three different paddocks that had similar perceived performance but with different tree densities and orientation to the sun.
2) Measured out three different transect lines, 1 meter, 5 meter and 20 meter. Mark these with the pigtail standards in the fence line so the stock can't access them and alter the transect line guide.
3) Each transect line was measured with the above RPM both pre and post grazing with the dairy cows and recorded into the notebook.
4) These paddocks were grazed like a commercial dairy farming operation. When the rotation length that the farmer was following dictated a grazing, the paddocks were grazed.

The pasture production part of this trial began on 1 November 2021. This was later than anticipated due to a few logistics around getting the contract sorted for the project and therefore we only were able to capture pasture data for the last month of spring, not our desired outcome.

As shown in Appendix 1, we had three different paddocks selected with three measurement lengths, 1 meter, 5 meter and 20 meters from the trees that were all on slightly different orientations towards the sun. There was no scientific evidence for the three different measurements. The 20-meter distance was set by the fact it was close to half way across the

paddock and where the effect from the tree shading was least effecting the pastures shadowing. Paddocks 4 and 31 received 4 grazing's during the timeframe above and paddock 33 was grazed five times.

Syncing Period

In early December after the initial pasture-sampling period, the farmer had to sync the paddocks that were being used in the animal behavior trial (discussed below) to ensure that they could be grazed in consecutive days. This meant there was a timeframe where the rotation length and paddock selection process changed to best align the paddocks to best represent a typical grazing for the animal behavior part of the trial.

Method – Collecting Pasture Samples

- Equipment: General Household Scissors
- Immediate Storage: Named Plastic Bags
- Transport Storage: Chilly Bin with Ice Packs
- Transport: Delivered to AgResearch Direct

1. The farmer would send through the grazing plan so the pasture sampling could happen the morning of the paddocks being grazed.
2. Pasture samples were collected prior to the cows entering the paddock during the morning milking.
3. 20 snip samples cut to ground level
4. 20 snips were completed evenly along the transect line to the end of the grazing break allocated. These were allocated A, B, C, and D as represented in Appendix 17.
5. Obtain a herbage sample representative of the plot's sward cut with hand shears cut to within 0.5 cm of ground level.
6. Immediately put samples with label into a chilly bin with ice-packs for transport back the AgResearch, Ruakura.
7. In lab, mix the sample thoroughly by lifting some up and "teasing" it apart in different directions down to the table, do this a few times. Then split the samples into four and discard to opposing quarters. Repeat the first mixing step and split into four again and discard opposing quarters, repeat until sub sample has reached approximately 400 pieces
8. Subsample in the lab for NV, place in perforated bags and place directly into the freezer. When possible freeze dry samples, grind with 1mm sieve and send to Hills.
9. Separate remaining sample into:
    a. Ryegrass
    b. Unsown grasses
    c. White clover
    d. Unsown weeds
    e. Dead vegetation
10. Weigh each of the vegetation components
11. Place components into oven tins in a tray – make sure all components have labels
12. Oven dry each of the components at 65°C for 48 hrs.

13. Record dry weight
14. Discard
15. This method is to be repeated each time the cows are entering a new break and a fresh sample is required.

Records include

- Plot number, date
- dry weights of the components

Equipment for lab work

- Record sheets to record weights in the lab
- Perforated bags
- Bags
- Oven trays and tins
- Labels for NV with date and

ANIMAL BEHAVIOUR

- Devices:
  - Cow Manager Ear Tags
  - HOBO Cow Collars
  - GPS Pedometers
  - Weather Stations
  - NAIT Tagging
  - DJI Phantom
- Miscellaneous
  - Spray paint x 2 different colours
- Facilities
  - Cow crush to restrain them to apply collars and tags
  - Yarding to house the cows while devices being applied.
- Collars and Cow Manager Tags Applied by:
  - Graham Smith – Farm Owner
  - Regan McCorquindale – Rural Professional
  - Briar Murphy, Stuart Lindsay and Frankie Huddart – AgResearch
- Application Dates: 4th March 2021
- Animal Behaviour Recording Dates – 11-14th March 2021
- Paddocks Selected: 3, 4,32,33 as illustrated in Appendix 18.

Method

1) The week leading into the trial, the drone was flown over the herd to acclimatize them to the noise it makes to ensure the cows would continue to graze in a normal manner throughout the timeframe of the trial. This was flown at 100 vertical meter above the herd for approximately 10 minutes each day in the week leading in at different times of the day.

2) Three days out from the beginning of the trial the cows were drafted into their groups as part of a habituate process.
3) The 80 cows were milked as per usual and they were then drafted into a random assortment of 2 mobs of 40 cows. Every second cow, in the rows below, received a either 1 of 2 colour spray paints to distinguish which mob they would return to during the trial. This was done by drafting out rows 1, 3, 4, and 6 (first 4 cows). This totaled the 40, which is required for the trial. Each cow had the cow manager tag applied and then all 40 cows then returned to their separate mobs. The reason for this is that the smaller group will mean that the cows will reshuffle their hierarchy, and we need to give them time to do this (i.e. AT LEAST 3 days prior to behaviour observations). The cows then *must* be managed up to the shed in their respective group for milking until after the study is done (i.e. 15 March)
4) The day before the trial began the cows that are receiving the technology had their collars applied during the morning milking in the dairy shed so they could stay in their allocated mobs.
5) Over the four days of trials, there were 8 different grazing breaks as illustrated below in Appendix 6.
6) On the morning of day one of the official trial, one mob had access to the 'shade' paddock and the other mob had access to the 'no shade' paddock. Two breaks being consumed daily, total. The remaining 3 days of the trial, the cows were swapped between 'shade' and 'no shade' until all of the 8 breaks were grazed.
7) The grazing pattern for this trial was 24 hours as the farmer is only milking once a day throughout the entire lactation period.
8) After the last 24-hour period, the collars and GPS anklets were removed during milking time and the cow manager ear tags were removed in the vet race after milking.

Results

The results section is broken down into two different sections: Pasture and Animal behaviour..

DEMONSTRATE IMPACTS OF TREES ON PASTURE PRODUCTION

There were two different dates where the pasture was sampled throughout this trial. The first pasture samples were collected December 4-12, 2020 , followed by 11-13 March, 2021, during the cow behaviour trial.

From the December pasture samples the following results were concluded. The percentage of ryegrass was higher in the 'no-shade' trial site (Figure 1). The maximum percentages were very similar to each other although the median for the shaded pasture was a lot lower and the minimum was appreciably lower under shaded too.

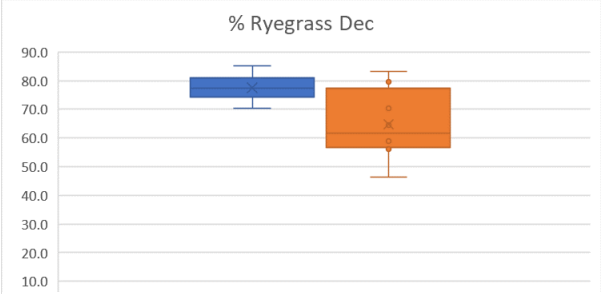

Figure 1 December Pasture Samples. Blue - No Shade, Orange - Shade

The percentage of weeds was notably more under the 'shade' trial than the 'no shade' too (data not shown), however there was a greater percentage of white clover under the 'shade' trial site than 'no shade' in December which is advantageous.

Metabolisable energy (ME) was notably different in the December sampling with 'no shade' average 12.13ME from the 6 different trial sites compared with 11.53ME in the 'shade' paddocks of the trial (Figure 2).

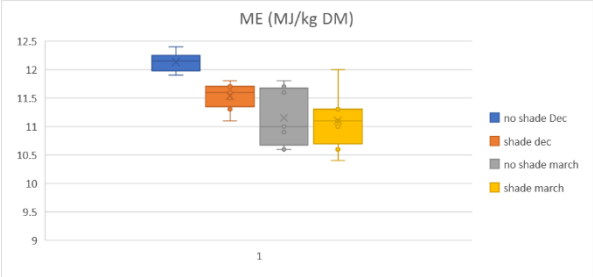

Figure 2 Metabolisable Energy Sampling, December and March

Crude protein, another valuable metric for dairy farmers, averaged 18.7% in the 'no shade' and 22.9% 'shade' in December (Figure 3). The other main metric used is Digestibility of Organic Dry Matter (DOMD), 75.9% was measured in 'no shade' and 72.2% in 'shade March results were also very intriguing with ryegrass in the 'no shade' area far greater than that in the 'shade' paddocks,

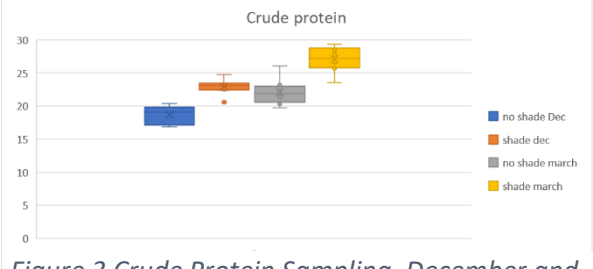

Figure 3 Crude Protein Sampling, December and March

66.07% and 38.23% respectively (Figure 4). This signaled more favourable conditions for ryegrass in the 'no shade' paddocks.

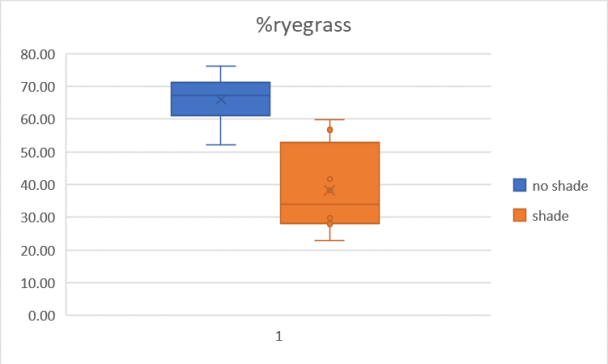

Figure 4 Pasture Sampling in March 2021

White clover was still high in the 'no shade' paddocks at 9.45% of the sward compared against 6.39% in the 'shade' (data not shown). This is the opposite of the December sample, where the white clover was stronger in the 'shade' sample, 12.1% versus 7.0%. The interesting data set is the rapid increase in the percentage of weeds under the 'shade' pasture in the March samples (Figure 5). The percentage of weeds in 'shade' and 'no shade' pastures were 31.26% and 9.52%. This 228% increase in weeds under trees is a notable result from this sample.

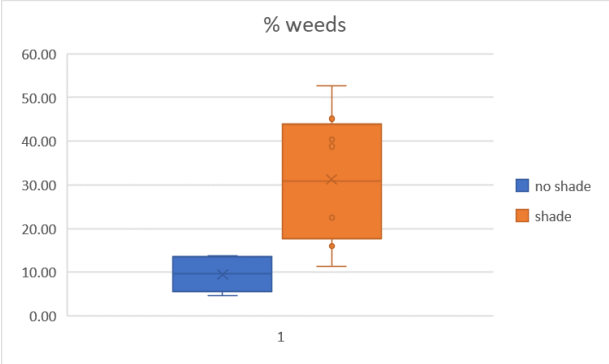

Figure 5 Weed Composition from Botanical Composition Test in March 2021

There is no real difference in ME sampled through March, 11.15ME in 'shade' and then 11.10ME in 'no shade' (Figure 2). Although protein does have quite a notable difference (Figure 3). The 'shade' paddock has 27.04% crude protein content, while 'no shade' is 22.11%. DOMD yields 69.71% under a 'no shade' environment versus 69.24% with 'shade' (data not shown). There is minimal difference here.

From the above data, the clover percentage was higher in December in the shade and crude protein level is the only valuable metric under a 'shade' paddock that has more advantageous results compared to the 'no shade' paddocks. All of the other metrics were in favour of the 'no shade' paddocks. The lack of pasture quantity and the increase proportion of weeds in the 'shade' sample gives evidence to suggest this level of tree population is unfavourable to adopt from a pasture production perspective.

DETERMINING COW GRAZING BEHAVIOURS

As there were, three different devices used throughout the trial there are different outcomes from each device's metrics.

Cows that were grazing pasture with minimal shade from trees moved faster than those who were more protected by the trees shade during their active part of the day (Figure 6). This was consistent with the morning and afternoon as shown in Figure 6 below. It was also noted and

shown in Appendix 13, that the cows spend more time in specific parts of the paddock. There is no statistical data from this trial that was gathered to conclude why this has happened, although if there was spatial pasture maps on a square meter basis this may provide additional clarity.

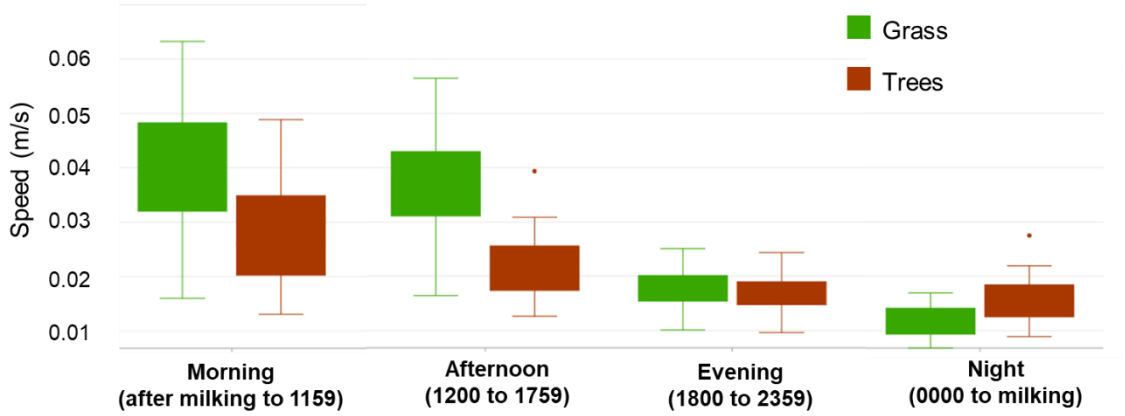

Figure 6 Dairy Cow Speed while Grazing

During the behavioural part of the trial, the farmer was feeding silage to his cows. This is to help keep the diet where it is required for milk production as this is still a commercial farming business. There appears to be no clear relationship with where the silage is being fed out and any preference by the stock.

From the activity collars, the cows also spend more time lying down in the 'no shade' paddocks in comparison to the 'shade' paddocks as Figure 7 illustrates. This was only noted in days 2, 3 and 4 whereas on day one there was no significant difference between lying on grass versus the treed paddocks.

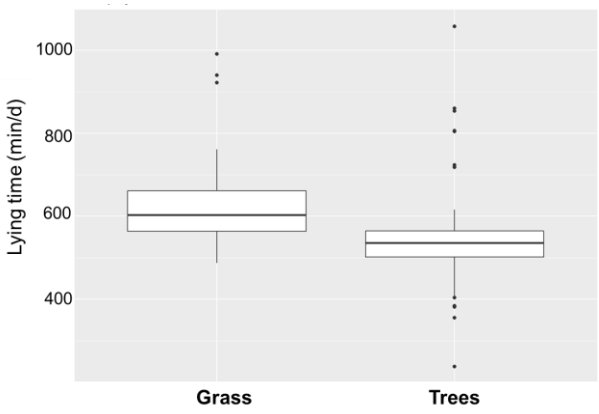

Figure 7 Lying Time for the Two Different Mobs

The CowManager ear tags also confirm that the cows grazing in the 'no shade' paddocks spend less time ruminating than those on trees (Figure 8). Although they spend more timeruminating under trees there is no clear difference in the time cows spend eating under the different grazing regimes. There was a lot of variation between the eating time and there is no evidence to suggest why this is the case at this stage.

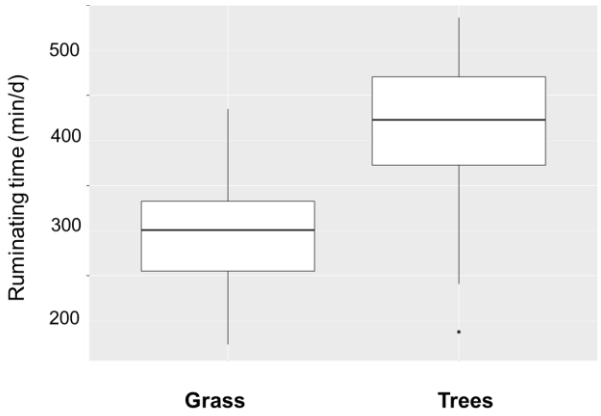

Figure 8 Rumination Time while in Different Paddocks

Discussion

DEMONSTRATE IMPACTS OF TREES ON PASTURE PRODUCTION

Since the completion of the trial and having a greater understanding of the climatic conditions that the season presented, it is no surprise the results are as anticipated. As shown in Appendix 11, the perceived benefit of the trees is lost in the ability for the 'no shade' area to thrive. Compared to the 2020 season, February and March this year respectively received 28.7 and 166mm versus 19.7mm and 69.7mm. This is 104.3mm more rainfall this season compared to last over a 59 day timeframe. The density of the trees exceeds 120 stems per hectare (SPH) which is far greater than that required for the minimum canopy cover to meet the requirements for carbon credit application. Observations from the summer and autumn on this farm last year were drastically different from what has been seen this season. Underneath the 'shade' in comparison to the 'no shade' paddocks there was a significant difference in the amount of pasture and in-fact, visually only, very high quality pasture to that of the 'no shade' pastures. This is what initially inspired this trial, however, with a strong summer and autumn with favourable growing conditions**;** this was not seen and would therefore back up the opinion of many farmers that would say trees in agriculture reduce your pasture production. For the length of this trial yes, although further research would be required to accurately calculate this quantitatively.

Observations from having been involved in this farm for a few years now would indicate that there is a huge opportunity for further research, especially with a warming climate. Ryegrass being the predominant pasture species does not thrive well under high temperatures and that is where the trees provide their true benefit. What would the results have looked like if done last year in the drought, I would say a lot more favourable for our hypothesis. Less trees will be required, between the rural professional and the farmer, they concluded that the tree population is too high and the desired count for this situation would likely be between 60-80 stems per hectare.

COW BEHAVIOUR

The above results validate what was initially anticipated that rumination is greater under a shaded grazing regime where there is less heat stress on the dairy cow (Corazzin, 2021). The fact that the cows were moving faster under the 'no shade' based system can only be left to assumptions at this stage due to the limitations of the trial. With limited data, my early assumptions would be the cows in the 'non shade' are having to move faster to harvest the most readily available pasture and then go back to consume the rest later. Eating time is very similar but does this mean that the stock are moving faster to find the best pasture and consume that as early in the allocated grazing time, then grazing down to residual later in the day? At present, we do not have enough information to disseminate this further.

The cows that have access to shade are more active throughout the entire day. From an animal welfare perspective, I would anticipate the 'shade' environment gives the cows more flexibility to graze when they desire. More activity, equals more heat for the cows that are in the 'non

shade' paddocks so hence they are spending more time lying down than those with access to shade. This would also back up the evidence from this trial that the cows are spending less time ruminating in the 'non shade' paddocks as there is too much heat created from rumination so the cows appetite for dry matter intake decreases.

Limitations

Due to the nature of the funding available for this trial there is a significant number of limitations that create more questions than answers and so further research and analysis is required to attain the most reliable data. In no particular order,

- The 'no shade' paddocks used in this trial are not representative of a 'barren' landscape as described in the funding application. There are still trees to the south-east and north-west end of the paddock which means the cows still had access to a form of shade, it was just a lot less than the 'no shade' paddocks.
- Silage was fed to both the mobs throughout the entire trial. This was not fed at consistent times throughout the 4 days, let alone the amount offered in kgDM/mob as there is no scales on the farmer's machinery.
- Pasture covers recorded were very limited to transect lines for the study. There is a lot of variation within one paddock and so this provides only a very limited scope. However, the same method is completed between the different trial sites.
- The benefits initially hypothesised about this trial were identified in the 2019/20 drought where pasture covers and quality were a lot stronger under the 'shade' than those in the 'non-shaded' paddocks. The summer and autumn of 2021 received a lot more rain than the year prior (National Climate Database (CliFlo)). This allowed the paddocks with greater exposure to the sunlight to perform better than those shaded paddocks that were limited.
- The trial ideally needs to be over an extended timeframe to include multiple years to capture the variation in weather conditions. There is too much information withheld by not including the winter months. Favourable results from this timeframe would only provide a small picture to an overall farm systems approach so regardless of the outcomes from this trial, a 3 year minimum is actually required.
- Pasture sampling was not taken at the timeframes initially set out. There was meant to be a pasture sample taken in October/ November, this did not happen until December due to contracts taking longer than anticipated and then the time required getting the trial paddocks in the round length.
- Another valuable metric to take which would be quite easy to achieve is to herd test the herd every day throughout the trial to see if there is an milk production gains from being in the 'shade' paddocks, regardless of the dry matter intake being less. This would entice a lot more farmers to consider growing more trees on farm.

Conclusion

Analysis of the results and discussion indicates that our hypothesis did not eventuate. There was not the increase in pasture production in the 'shade' environment as anticipated which was has answered some of our perceptions, but it has also created more questions going forwards for our industry. If the population of trees grown in this pilot trial are too dense, then where is the equilibrium that still allows trees to be grown in productive pastoral landscapes but does not compromise on pasture production to the same extent.

The animal behaviour division of the trial still provides some very clear gains from a welfare point of view. An increase in rumination in the 'shade' environment being the greatest factor. Coincide this information with the correct planting population per hectare that doesn't compromise pasture production to the same extend, and carry out some milk monitoring and I am confident that we might be a step closer to finding an overarching solution for our industries sustainability.

This trial period has set a fair example and representation for what the future of farming and creating a diverse and sustainable dairy farm and forestry landscape really portrays. This was an outlier of a year with the weather experienced. This is the greatest contributor to this trial in either succeeding with our set out hypothesis or, suggesting we as an industry do not need to grow any more trees on farms.

If a trial like were to be conducted at an annual and more scalable approach, the following would need to be taken into consideration.

- Less trees per hectare for the 'shade' paddock
- The 'no shade' paddock must be exactly that
- Pasture samples need to be collected at each grazing throughout the year, at the minimum
- Milk production data per mob is sampled

Trees absolutely have their place in agriculture and the future of farming. Finding the optimal amount of stems per hectare that aligns with offering shade to the cows and the hypothesized increase in pasture production through dryer summers must be evaluated to further influence the uptake of trees on farms in the New Zealand pastoral landscapes.

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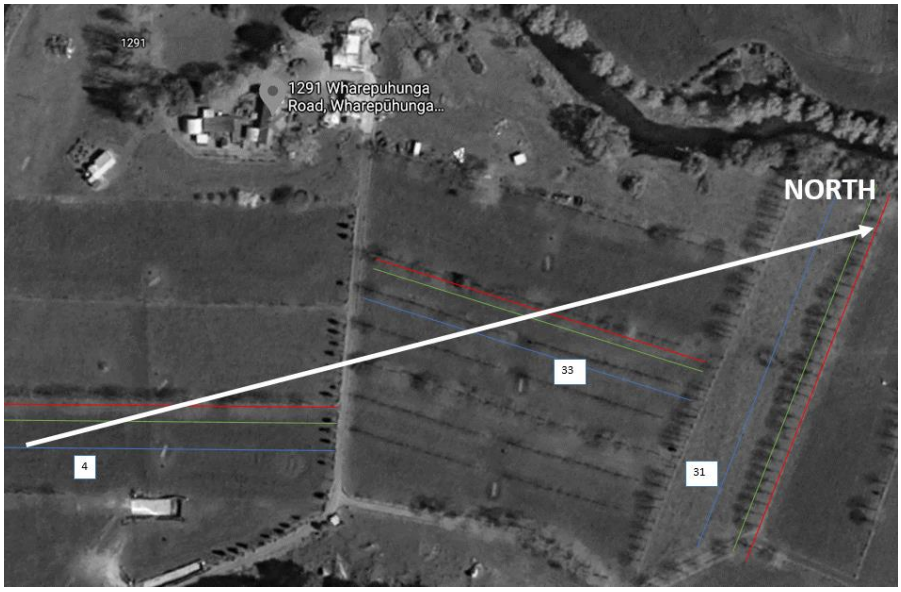
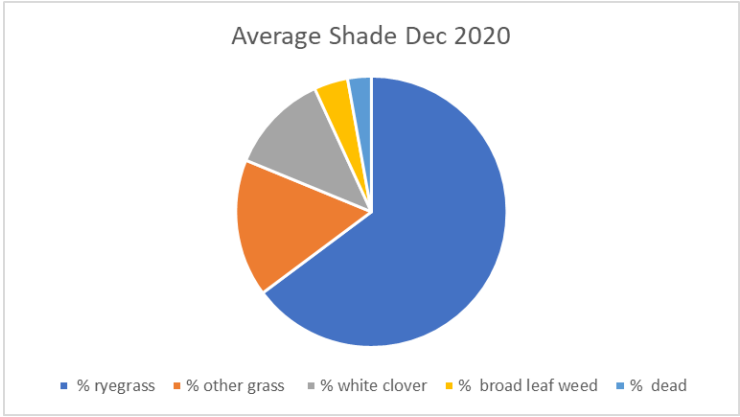
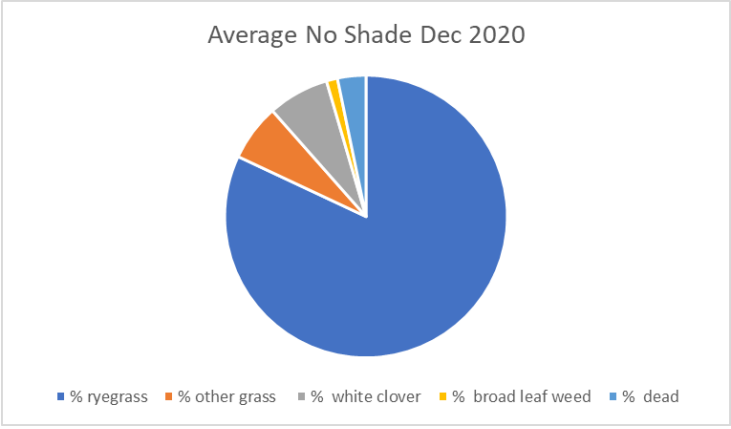
Appendix



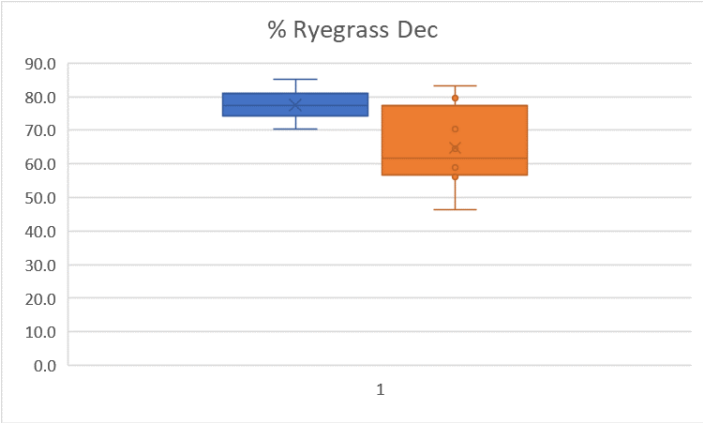
Appendix 1 Pasture Sampling Paddocks and Orientation



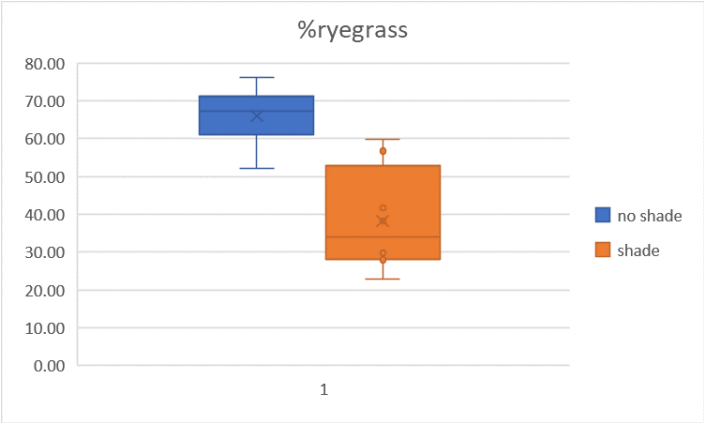
Appendix 2 Botanical Composition Test from December 2020



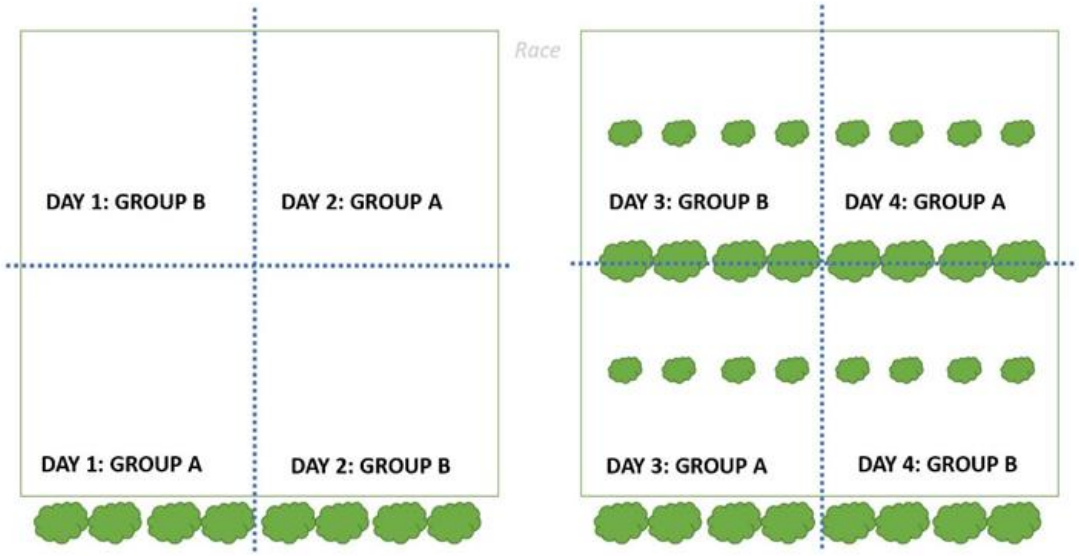
Appendix 3 Botanical Composition Test from No Shade December 2020



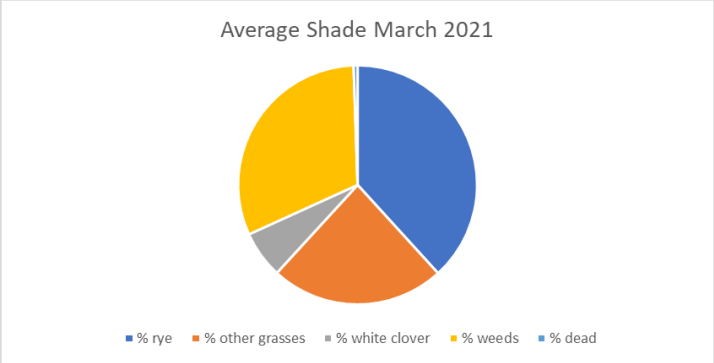
Appendix 4 Ryegrass and Weeds Percentages for December



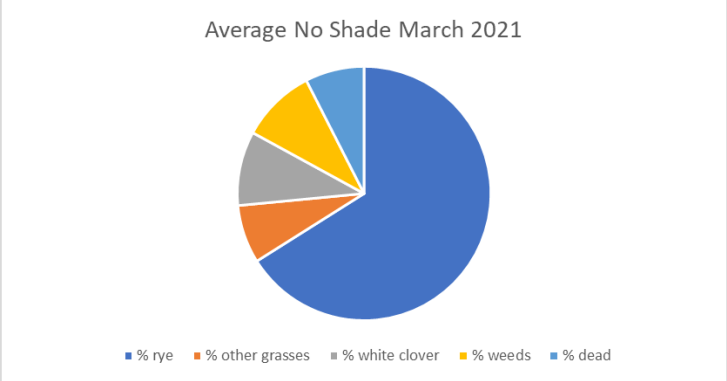
Appendix 5 Ryegrass and Weeds Percentages for March



Appendix 6 – Diagram showing how the cow mobs will rotate between the breaks

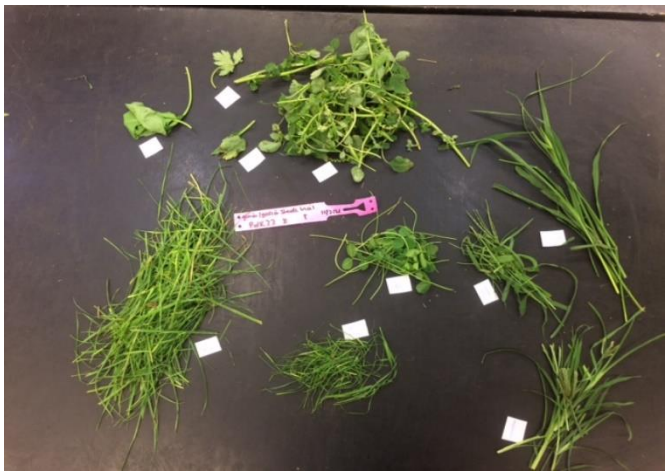


Appendix 7 Botanical Composition March 2021 Shade

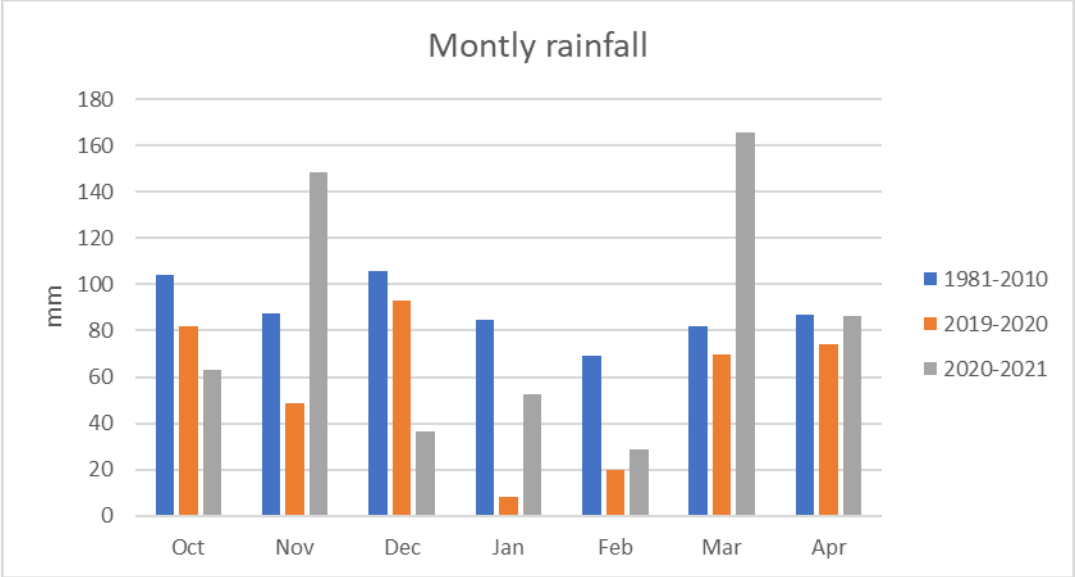


Appendix 8 Botanical Composition March 2021 No Shade

Appendix 9 – No Shade Example March 2021



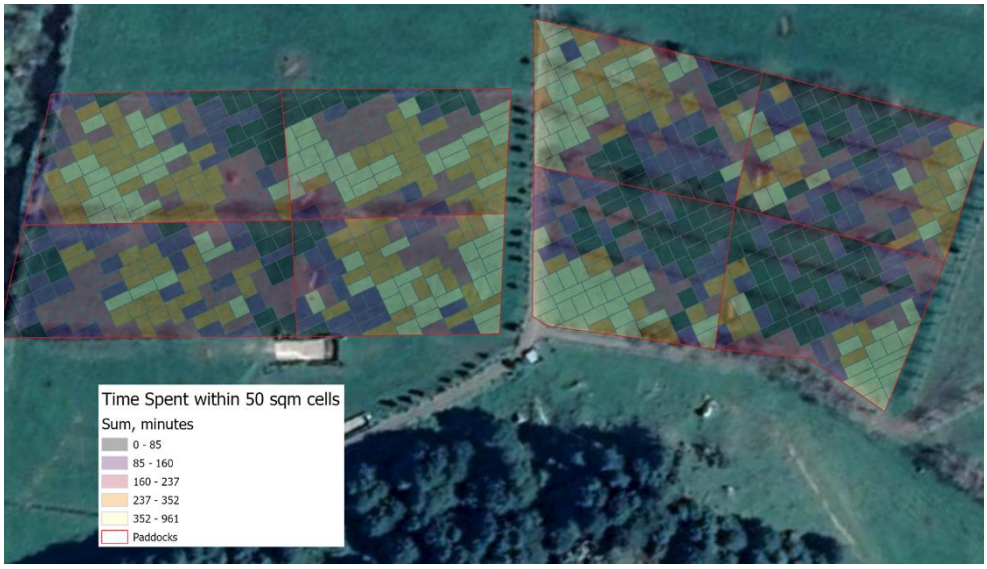
Appendix 10 - Shade Example March 2021



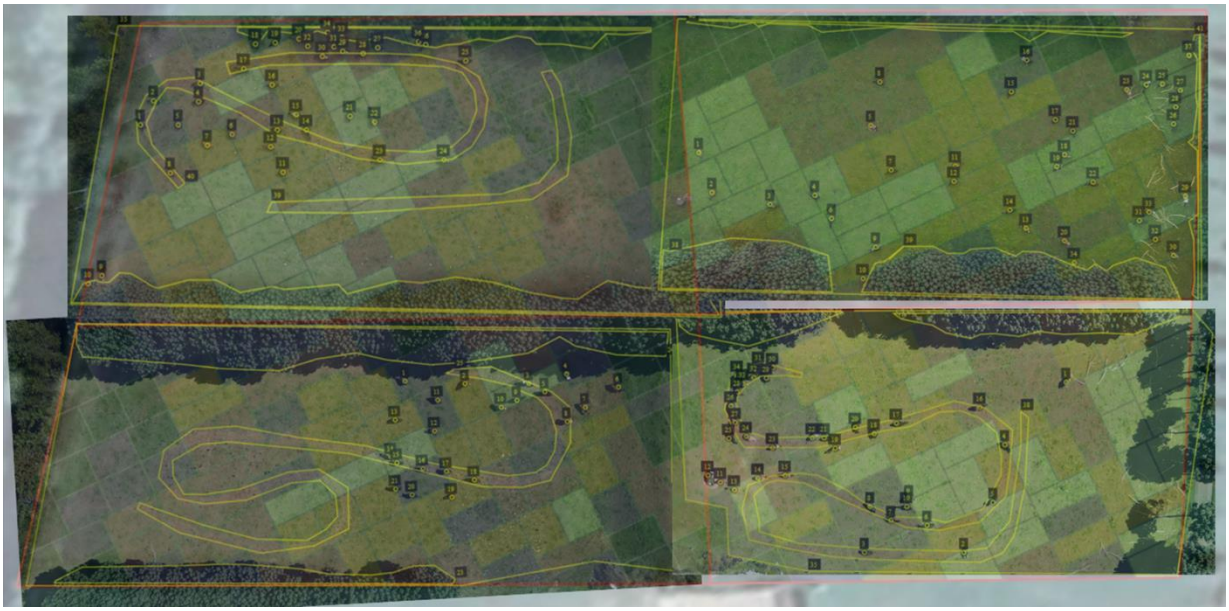
Appendix 11- 30 Year Average Rainfall (blue) compared with this trial period (grey) and the previous drought year (orange). Waikato Data (Cambridge, Station no. 2125) Source: National Climate Database (CliFlo)

Pd 4					Pd 31					Pd 33			
Date	A-1m	B-5m	C-20m		Date	A-1m	B-5m	C-20m		Date	A-1m	B-5m	C-20m
1/11/2020	3360	3510	3170		9/11/2020	2894	3132	3230		11/11/202	2460	2614	2640
2/11/2020	1424	1452	1576		10/11/202	1410	1452	1452		12/11/202	1420	1435	1440
29/11/2020	2320	2572	2838		29/12/202	2278	2264	2516		12/12/202	2110	2054	1942
30/11/2020	1480	1480	1648		31/12/202	1214	1368	1396		13/12/202	1340	1354	1340
3/1/2021	2550	2866	3370		27/1/2021	2138	2390	3034		3/01/2021	1438	1466	1368
4/01/2021	1368	1480	1564		29/01/202	1326	1368	1410		4/01/2021	1144	1214	1186
4/2/2021	2278	2824	2712		18/2/2021	1620	1998	1946		3/2/2021	1774	2152	1690
6/2/2021	1284	1340	1466		19/2/2021	1354	1438	1348		5/2/2021	1088	1032	1144
										11/3/2021	1312	1564	1326
										12/3/2021	1110	1130	1130

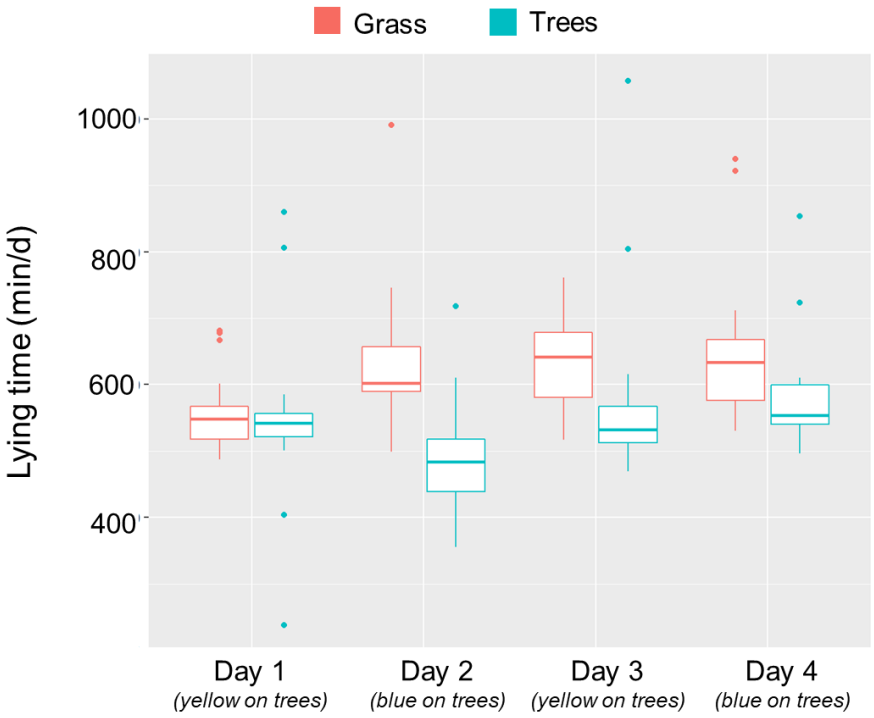
Appendix 12 – Pasture Cover Readings from Different Transects



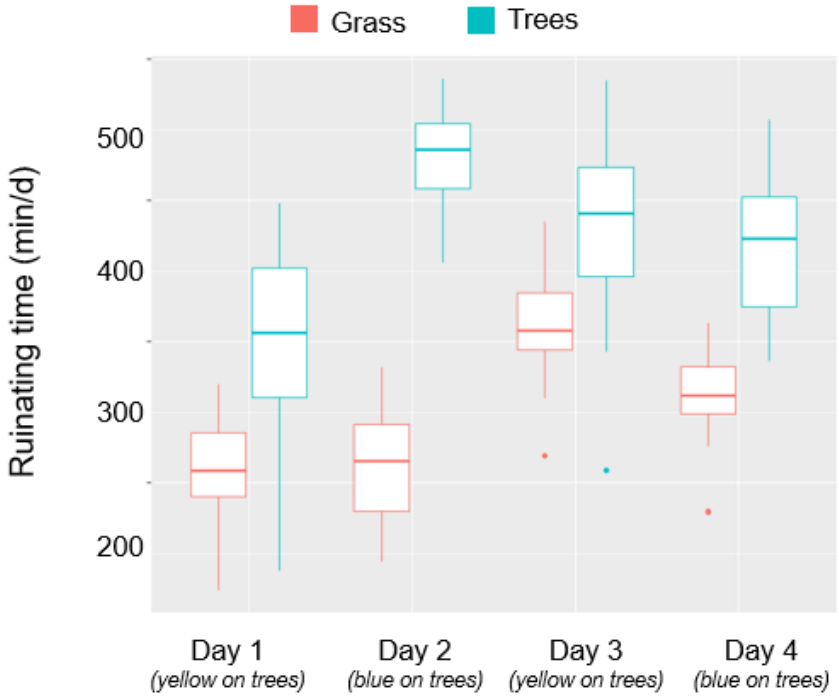
Appendix 13 The Cow Spending Time in Designated Areas



Appendix 14 The Silage Fed Out and Location of Cows



Appendix 15 – Dairy Cows Lying Time between Trees (Shade) and Grass (No Shade)



Appendix 16 - Dairy Cows Ruminating Time between Trees (Shade) and Grass (No Shade)

Appendix 17 – Transects where pasture samples were taken for all four paddocks

Appendix 18 – Paddock Numbers utilised for the animal behaviour trial.