LRZ AFO Calibration Report

Region characteristics

Rationale

Merredin (Figure 1) has been selected as the region to base the LRZ calibration off. This is for several reasons:

1. Merredin is an agricultural dominated region.
2. The future of sheep farming in Merredin is uncertain and thus it is a focus of the future sheep project to examine if/how mixed farming can remain economically viable in the region.
3. DPIRD have a Merredin office which has resources to support the calibration process.
4. Previous farm models have been produced of the Merredin region. Providing valuable insights to draw on.

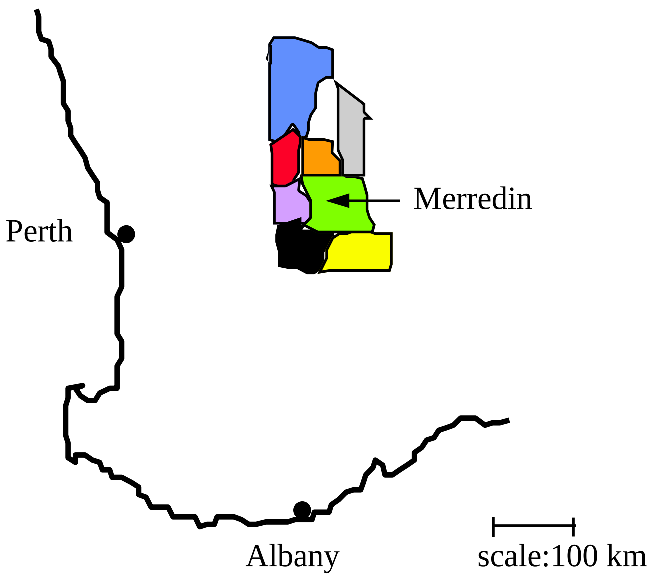

Figure 1: Merredin region in WA

General

Average farm size in the region is 6093 ha (Planfarm 2022), most of which is cleared and arable. On average 77% of the farm area is cropped and 23% is used for pasture and livestock. Wheat yields average 1.8t/ha and average sheep numbers are approximately ~3000/farm.

Climate

The Merredin region is characterised by a Mediterranean climate. Annual rainfall in the region averages around 300 mm, with most rain falling from May to October, usually followed by a summer drought from December to March. Crops are sown in May to July and harvested in November and December.

Modelling the intricacies of weather events leads researchers to experience the "curse of dimensionality" where myriads of different weather events are possible (Burt, 1982). To lessen dimensionality problems associated with representing weather events and their effect on pasture and crop growth, discrete weather states were defined in AFO based on their potential to affect farm management.

The classification of weather-years arose, first, from discussions with Alan Peggs (farm advisor) to identify which features of weather-years most influenced their main farm management decisions. Alan identified that early season and September rainfall were key drivers for management decisions. Early season rainfall drives summer spraying, sowing and stocking rate decisions while late season rainfall drives sale and summer grazing decisions.

The second part of the process involved detailed examinations of the meteorological and farm production characteristics of actual seasons from 1980 to 2024, using the crop growth simulation model, APSIM (Holzworth et al., 2018). With the assistance of Dr Imma Farre (DPIRD), APSIM was calibrated using weather records from the Merredin region. The fertiliser management (amount and timing) employed in APSIM was set based on Planfarms regional benchmarking survey which indicated that farmers are applying about 47 kgs N/ha. To validate APSIM the simulated yields were compared to Planfarms benchmarks for the Merredin region (Figure 2). The results showed an 82% correlation providing confidence that APSIM is accurately representing the effects of weather variation on estimated crop yields.

Several soil types with varying plant available water capacity were also tested and showed no major differences (the change in yield between years was relatively similar for each soil type tested).

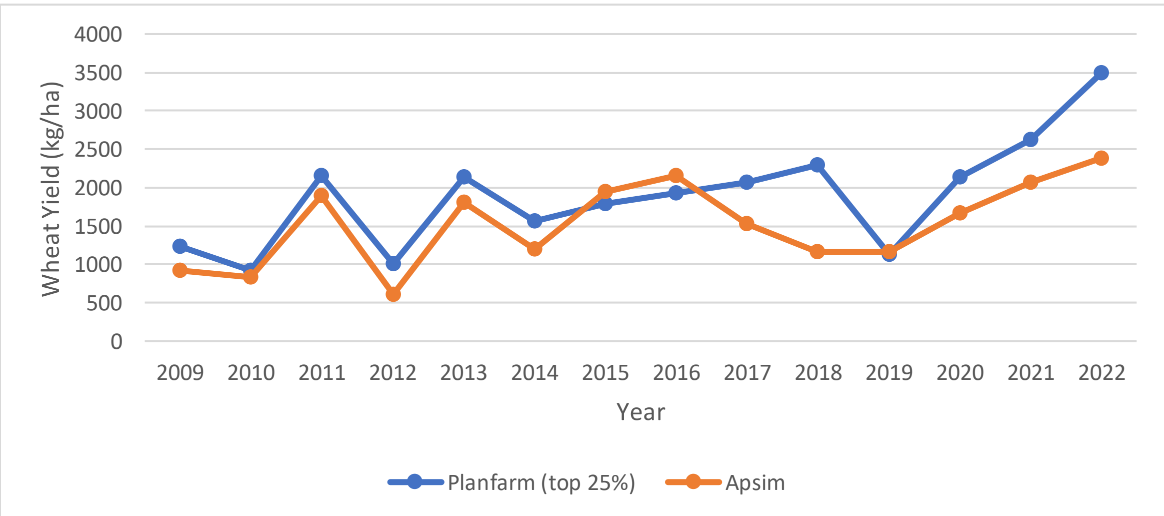

Figure 2: APSIM predicted wheat yields compared to the top 25% of producers in the Merredin region based on Planfarms regional benchmarking.

Using the weather records and simulated yields for Merredin between 1980 and 2024, a statistical regression analysis was used to identify the key weather component driving yield. The results were in agreeance with Alans expectation and showed that rainfall in all months between January and September were significant ($p<0.05$) drivers of yield.

Given key management decisions are being made at the beginning and end of the growing season, we examine the weather indicators that can be used at those times to explain production variance. After significant testing we arrived at the following indicators:

1. Late summer and early autumn rainfall (January to April) – Rainfall during this period is a significant yield driver and is known at the time of sowing therefore can be used to alter decisions.
2. Quality of the break – The indicator used to identify the quality of the break was FOO on June 15. The aim was to capture information about the season such as timing of break (early break seasons will have more growing time and thus FOO), the quantity of rain at the break of season (seasons the have a big rain at the break of season will withstand less follow up rains) and presence of follow up rains (false breaks or seasons with little follow up rain will have reduced FOO). At this point in the season crops have been sown so there are few cropping decisions that can be made however, from a pasture and livestock point of view, knowledge of the quality of the break can drive pasture management, grazing and sale decisions.
3. Winter and early spring rainfall (15th of June to 1st September) – Rainfall during this period is a significant yield driver and can be used to alter decisions harvesting, grazing and sale decisions.

These indicators explain 78% of the yield variation between years (Figure 3). Note: when tested, date of break of season was not a big driver of crop yield in the Merredin region.

```
Residuals:
    Min      1Q  Median      3Q     Max 
-510.86 -154.42  -22.34  155.59  443.89 

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)    
(Intercept)         342.13383  127.33720   2.687   0.0105 *  
seasonData$early      4.72452    0.75482   6.259 2.04e-07 ***
seasonData$foo15june  0.50632    0.09879   5.125 7.94e-06 ***
seasonData$late2      6.12584    1.07144   5.717 1.18e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 221.5 on 40 degrees of freedom
Multiple R-squared:  0.7996,	Adjusted R-squared:  0.7846 
F-statistic:  53.2 on 3 and 40 DF,  p-value: 5.044e-14
```

Figure 3: Regression output when using early (late summer, early autumn) rainfall, foo15june (FOO on the 15th of June) and late (winter and spring) rainfall to explain yield variation between years.

The resulting weather-years are shown in Table 1. These weather-years are similar to those defined by Kingwell (1996) for the MUDAS model, with a slight modifications to improve the representation for pasture.

Table 1: Merredin weather-years

Code for weather-year	Definition of each weather-year	Probability of occurrence	Growing season rainfall	Crop yield scalar[4]
Z0	Good early rain with a good break and good winter and spring rainfall[3].	9%	283	1.43

Z1	Good early rain with a good break and low winter and spring rainfall[3].	16%	230	1.19
z2	Good early rain with a poor break[2] and good winter and spring rainfall[3].	14%	256	1.27
z3	Good early rain with a poor break[2] and low winter and spring rainfall[3].	11%	198	0.99
z4	Poor early rain with a good break and good winter and spring rainfall[3].	11%	254	1.00
z5	Poor early rain with a good break and low winter and spring rainfall[3].	14%	191	0.70
z6	Poor early rain with a poor break[2] and good winter and spring rainfall[3].	16%	232	0.83
z7	Poor early rain with a poor break[2] and low winter and spring rainfall[3].	9%	167	0.58

[1] Good early rains; above 53ml of rain between January to April.

[2] Poor break: FOO is less than 725 kg/ha on the 15th of June for seasons with good early rainfall. FOO is less than 245 kg/ha on the 15th of June for seasons with poor early rainfall.

[3] Good winter and spring: above the 103 ml rainfall for the period from 15th of June to 1st September; Low winter and spring: bellow 103 ml rainfall for the period from 15th of June to 1st September.

[4] Yield scalar is the relationship between yield in the given weather-year and the average yield. This was calculated using the output of APSIM modelling from 1980 - 2023.

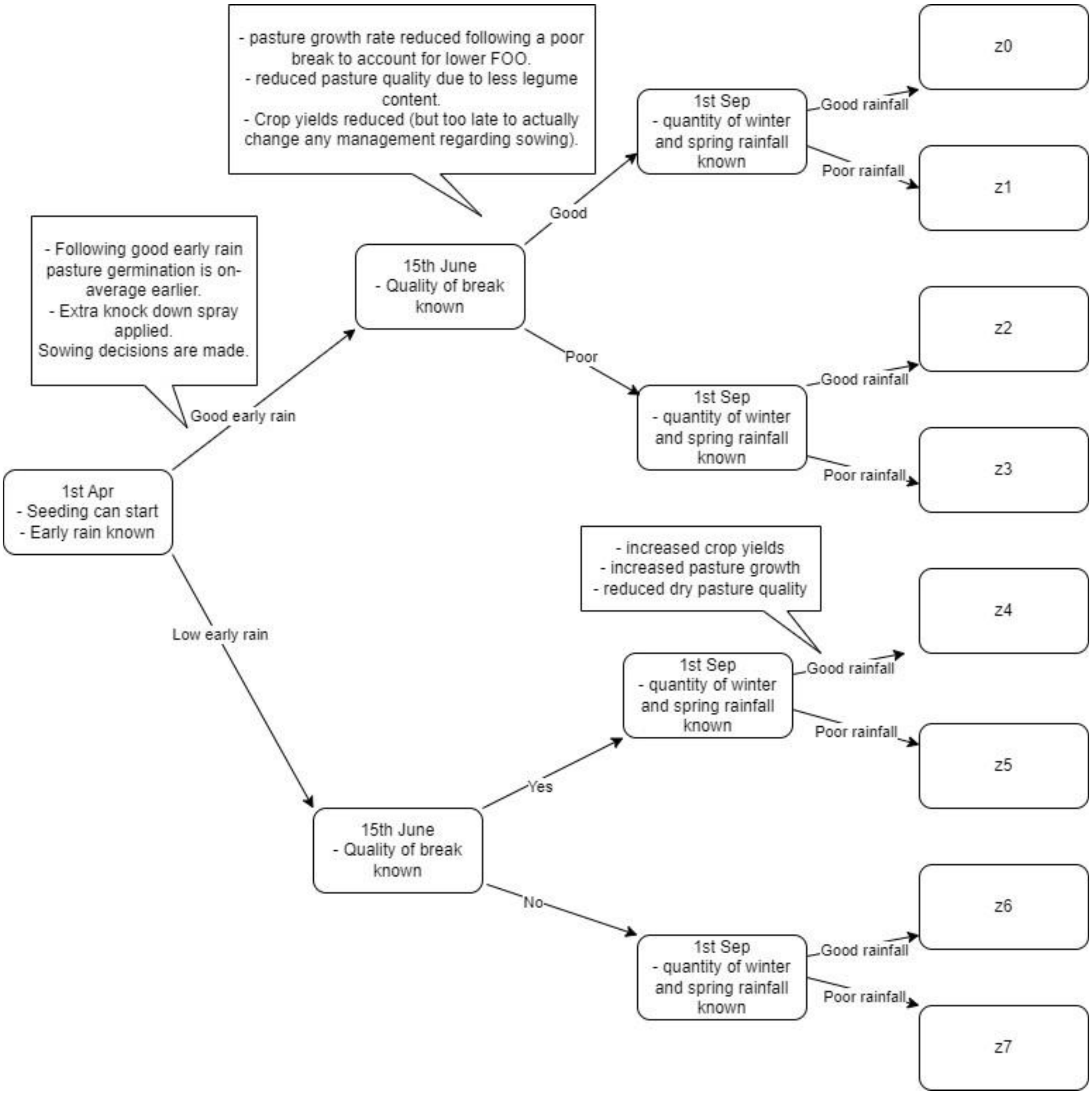

Figure 4: Visual representation of the weather-years and key differences between them.

Soils

The ancient soil landscape of Merredin is summarised in Figure 5. The district is known for its subdued uplands, broad trunk valleys with alkaline red brown heavy soils and its network of salt lakes. Soils are highly weathered and some are infertile. More information can be found here.

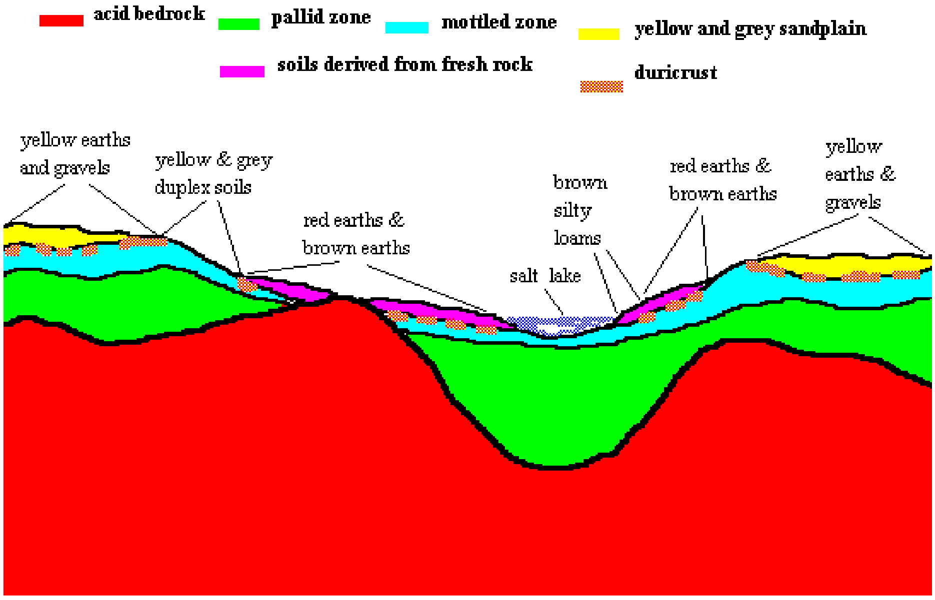

Figure 5: Merredin soil landscape (source Kingwell 1996).

For modelling and farm planning purposes the landscape is grouped into land management units. A land management unit (LMU) is defined as either a single soil type or a group of soil types, with similar properties influencing productivity, land use and degradation hazards. LMUs are particularly useful for farm planning.

Most farms include a mix of soil types with different production parameters and management requirements. In previous MIDAS modelling seven land management units were identified. These were reviewed by current experts in the region and deemed to still be accurate with the addition of a saline soil LMU (Table 2). However, the area of each LMU was increased to reflect current farm sizes. The variation in production between soil types (Table 3) was determined from discussions with multiple agronomists in the region and cross checked by the original values use in the MIDAS model. Furthermore, it was noted by agronomist that the performance of a given soil type is partly dependant on the weather-year experienced. To account for this a second scalar was included (Table 4). This reflects that light soils do relatively better in poor season while heavy soils do relatively better in good seasons.

Table 2: AFO LMUs for Merredin region.

Soil class	Description	Ph Range	(ha)
S1 (Acid sands)	Yellow, loamy or gravelly sands. Native vegetation is wodgil with sheoak and banksia on deep white sands.	<5.5	1097
S2 (Sandplain)	Deep, yellow-brown loamy sands. Native vegetation is grevillea and tamma.	5.5-6.0	1097
S3 (Gravelly sands)	Yellow-brown gravelly sands and sandy gravels. Native vegetation is tamma.	5.5-6.0	548
S4 (Duplex)	Grey, sandy loams, loamy sands, gravelly sands and sand over white clay with yellow or red mottles. Native vegetation is mallee.	5.5-6.5	548

S5 (Medium heavy)	Red-brown, sandy loam over clay sub- soil. Native vegetation is salmon gum and tall mallee.	6.0-7.0	823
S6 (Heavy non-friable)	Dark red-brown, sandy clay loams.Native vegetation is gimlet, morrel and salmon gums.	>6.5	1097
S7 (Heavy friable)	Previous S6 soil treated with gypsum.	>6.5	274
S8 (Saline soil)	Mild to moderately saline. Generally unusable without saltbush.	8-8.5	609

Table 3: Production scalars by soil type for an average season.

Soil (see definitions above)	Production scalars (%) Cereals	Canola	Pulse	Pastures
1	67%	75%	78%	72%
2	92%	100%	115%	90%
3	102%	113%	104%	102%
4	100%	100%	100%	100%
5	97%	97%	95%	108%
6	82%	73%	88%	99%
7	81%	77%	89%	89%
8	56%	56%	56%	56%

Table 4: Soil production scalars of each weather-years (compared to an average season).

Soil (see definitions above)	Weather-years Z0	Z1	Z2	Z3	Z4	Z5	Z6	Z7
1	98%	98%	94%	94%	103%	108%	110%	113%
2	98%	98%	94%	94%	103%	108%	110%	113%
3	98%	98%	94%	94%	103%	108%	110%	113%
4	98%	98%	94%	94%	103%	108%	110%	113%
5	102%	102%	106%	106%	97%	92%	90%	87%
6	102%	102%	106%	106%	97%	92%	90%	87%
7	102%	102%	106%	106%	97%	92%	90%	87%
8	98%	98%	94%	94%	103%	108%	110%	113%

Cropping

The below inputs were derived with in collaboration with Dani Whyte from Braeleigh Consulting who has a decade of experience consulting in the eastern wheatbelt region, Sud Kharel from DPIRD, Imma Farre from DPIRD and Wyatt Verhoogt from ConsultAg.

The average yield, fertiliser cost and chemical cost (Table 5) was determined from a combination of expert guidance and 10-year average Planfarm data. The production and cost of each crop changes based on the season. To account for yield variation due to weather conditions the average yields were scaled by a weather-year factor derived from APSIM modelling (Table 1). The impacts of weather-year on fertiliser application have been represented as follows:

1. Fertiliser applied at seeding is the same each year because there is not enough information known about the season.
2. Post seeding fertiliser is increased by 15 units (200%) of nitrogen if there has been good summer/autumn rainfall and it was a good quality break.
3. Post seeding fertiliser is not applied if there was little summer/autumn rain and a poor-quality break.

The impacts of weather-year on chemical application have been represented as follows:

1. Weather-years with above average summer/autumn rainfall get an additional knock down spray and a 15% cheaper in-season chemical package.
2. Fungicide application is correlated with rainfall.

Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
150%	100%	100%	50%	100%	50%	50%	0%

The assumption is that each crop is affected equally by weather conditions. This is an assumption that may need further investigation for the LRZ (if information becomes available) because, for example, in seasons with high early rain farmers are trending towards very early canola sowing so that it can utilise the early moisture. Whereas wheat is not sown as early due to frost risk.

Table 5: Average crop yield, fertiliser and chemical for the common land uses in the LRZ.

Land use	Yield (kg/ha)	Herbicide ($/ha)	Fungicide ($/ha)	Fertiliser pre seeding ($/ha)	Fertiliser at seeding ($/ha)	Fertiliser post seeding ($/ha)
Barley	2000	$90 (over 4 applications)	$10 & $5 seed treatment	-	$78	$19
Dry Sown Barley	2000	$105 (over 3 applications)	$10 & $5 seed treatment	-	$78	$19
Lupin	1000	$130 (over 5 applications)	-	-	$58	-
Oats	1800	$80 (over 4 applications)	$10	-	$78	$19
Dry Sown Oats	1800	$95 (over 3 applications)	$10	-	$78	$19
Oats Fodder - Less Weed Control	3600	$30 (over 2 applications)	-	-	$78	$19
Wheat	1800	$90 (over 4 applications)	$10	-	$78	$19
Dry Sown Wheat	1800	$105 (over 3 applications)	$10	-	$78	$19
Canola	1000	$110 (over 4 applications)	$5 (seed treatments only)	$18	$78	$25
Dry Sown Canola	1000	$130 (over 3 applications)	$5 (seed treatments only)	$18	$78	$25
Pasture (only sprayed if	-	$15 (over 1	-	-	$20	-

followed by a crop)	applications)

In a cropping system, the preceding land uses can have an impact on the current year production and management. For yield, there were several significant rotation factors that impact production. In drier years, where moisture is an even bigger limitation, the yield benefits of a favourable rotation history was reduced. The rotational factors represented for yield include:

1. 15% yield increase following a well-managed (spray topped) pasture phase.
2. 20% yield increase following a legume phase.
3. 5% cereal yield increase following a canola due to increased mineralisation.

The rotational factors represented for fertiliser are outlined in Table 6.

Generally, farmers do not adjust their herbicide package based on the rotation. The only rotational adjustment included is that a crop after a poorly management pasture (non-spray topped), incurs a 20% increase in herbicide cost. However, fungicide application is highly dependent on the quality of the rotation. The quality of the rotation is dependent on the number of years since the same land use was in the paddock (Table 7).

Table 6: Change in fertiliser application based on rotation history.

Landuse 2yrs ago	Landuse last yr.	Change in fertiliser for current year
-	Fodder	No Change
Pasture	Non-legume Crop	No Change
Pasture	Legume Crop	Down 10 N
Non-legume Crop	Pasture	Down 8 N
Pasture	Pasture	Down 10 N
Legume crop	Non-legume Crop	No change
Non-legume Crop	Legume Crop	Down 8 N

Table 7: Change in fungicide cost based on the rotation quality (years since the same land use).

Years since same crop	0	1	2	>=3
Fungicide cost adjustment	150%	100%	50%	0%

Late sowing penalty was calculated from APSIM modelling and validated by research findings. For the Merredin region a yield penalty is incurred for every day seeding is delayed after the break of season. On average the penalty is 10.5 kg/ha/d for cereals and 20 kg/ha/d for canola's. Furthermore, APSIM results suggest that late seeding is 16% greater in years with above average early rainfall. From a practical point of view this makes sense because it is important to capture any early moisture to get plants established. Particularly in the Merredin region where growing season rainfall is often low.

Pasture

The biology and logistics of pasture growth rate that are represented in AFO are:

- Pasture growth rate (PGR) is dependent on pasture leaf area, which is quantified by the level of feed on offer (FOO, kg of DM/ha). Additionally, PGR for each pasture type varies with the phase during its life cycle, soil moisture, sunlight and level of growth modifier applied. All are quantified by their land management unit (LMU), time of year and weather-year.
- The average FOO during a feed period depends on FOO at the beginning of the period, the grazing intensity and the PGR during the period.
- The mobilisation of below-ground reserves (germination) of annual pastures at the break of season is dependent on the seed bank. The seed bank is controlled by the rotation in which the pasture is grown and varies with LMU.
- The mobilisation of below ground reserves of perennial pastures at the break of season can also be adjusted by rotation. However, perennials usually are not grown in rotation with crops.
- The maximum intake of animals grazing pasture depends on FOO and diet dry matter digestibility (DMD). Intake can be less than maximum which implies that the optimum solution can include rationing of animal intake via rotational grazing.
- The digestibility of the diet selected by animals grazing green pasture depends on the sward digestibility and the animal's capacity for selective grazing. Sward digestibility varies depending on the pasture species, the time of year, the LMU and the FOO of the pasture. Selectivity depends on FOO and grazing intensity.
- Dry pasture that is not consumed is deferred to later in the year, with a reduction in both its quality and quantity. Livestock can select a higher quality diet when first grazing the dry pasture but quality reduces with extra grazing.
- Livestock trample both green and dry pasture while foraging in proportion to the amount consumed.
- The risk of resource degradation increases when ground cover is lower so there is a user defined minimum limit to ground cover during both the green and dry phases of the year.

To reflect the detail listed above, the following key inputs are required:

1. Pasture growth rate at different FOO levels during the year (e.g. Table 8).
2. Germination and the effect of rotation history on germination (Table 9 & Table 11).
3. Reseeding and time to first grazing.
4. Average quality of green and dry feed during the year (Table 10).

5. Spread of quality within the available FOO.

To complicate the process, these inputs need to be differentiated by weather-year to represent the impact of weather on pasture production. Given this level of data is not readily available from trial work, pasture production was simulated using AusFarm (Moore et al., 2007). The simulation modelling followed a process developed by Young et al (2023) with some adjustments suggested by GrassGro expert Paul Sanford. The results were validated using several methods including (i) expert insights from Alan Peggs, Kevin Foster and Clinton Revell; (ii) pastures from space satellite data (Figure 6). However, PfS does not differentiate between pasture and crop paddocks so our confidence in this validation method was low.; (iii) CSIRO modelling data from the Merredin region.

The key weather-year effects represented were:

1. Good early season rainfall increases PGR and germination.
2. Poor quality break reduces PGR.
3. Growing season is longer for weather-years with a favourable winter/spring.
4. Dry pasture quality is reduced in weather-year with a favourable winter/spring.

Table 8: PGR during each weather-year for a laxly grazed pasture on duplex soil (S4).

	z0	z1	z2	z3	z4	z5	z6	z7
5-Apr	0	0	0	0	0	0	0	0
18-May	9.3	9.3	9.3	9.3	9.1	9.1	9.1	9.1
15-Jun	14.9	14.9	9.7	9.7	11.5	11.5	7.5	7.5
7-Aug	44.9	44.9	44.9	44.9	25.7	25.7	25.7	25.7
20-Sep	46.2	0	46.2	0	33.1	0	33.1	0.0
6-Oct	0	0	0	0	0	0	0	0
15-Nov	0	0	0	0	0	0	0	0
1-Jan	0	0	0	0	0	0	0	0
1-Feb	0	0	0	0	0	0	0	0
1-Mar	0	0	0	0	0	0	0	0

Table 9: Germination in each weather-year on duplex soil (S4).

Season type	Germination (kg/ha)
z0	146
z1	146
z2	146
z3	146
z4	102
z5	102
z6	102
z7	102

Table 10: Average dry feed quality (DMD) at the start and end of the dry period for each weather-year.

	z0	z1	z2	z3	z4	z5	z6	z7
Start	64%	68%	64%	68%	64%	68%	64%	68%

End	50%	50%	50%	50%	50%	50%	50%	50%

Table 11: Rotational impacts on pasture germination.

Two years ago land use	Last years land use	Germination scalar
-	Pasture	100%
-	Spraytopped pasture	80%
Pasture	Canola	38%
Pasture	Cereal	38%
Pasture	Pules	58%
Pasture	Fodder	70%
Crop	Canola	20%
Crop	Cereal	20%
Crop	Pulse	40%
Crop	Fodder	70%

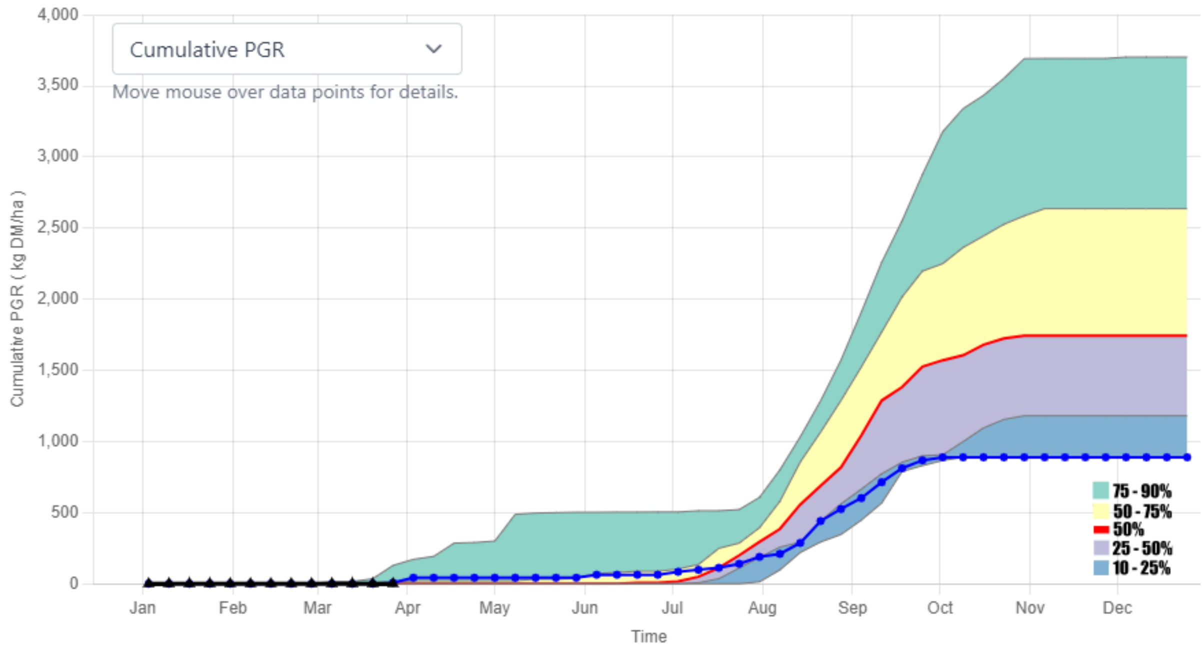

Figure 6: Cumulative PGR percentiles for Merredin farm over a 20 year period.

Possible future improvements

1. Addition of a fallow land use.
2. Two pasture options (i) average volunteer pasture (ii) improved pasture.
3. Currently all crops are equally affected by weather-year. However, maybe this needs to be updated. For example, in a season with lots of early rain, canola will do relatively better than wheat because it can be sown earlier to better utilise the additional moisture.