Stored water, summer rainfall and the impact of summer fodders
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Take home messages

- Rainfall on winter crop stubble is 'lost' and could be used by fodders with no effect on the next winter crop.
- In most years the 'depleted' soil profile will be refilled by the end of August.
- Summer fodders for grazing can provide good weed control.

Out of growing season rainfall contributes a noteworthy amount to annual rainfall in South west Victoria. While this varies between locations in the South west, long term analysis of rainfall at Lake Bolac from December to April indicates about 25% of average annual rainfall is received in these five months (table 1). Even in the past two decade of fluctuating rainfall, the out of season precipitation still contributes 25% of the total.

Table 1: Average rainfall from December to April (the non winter growing season) for Lake Bolac.

Rainfall from the start of December through to end of April	Average (mm)	Most frequent (mm)[1]	% of annual rainfall
Long term (1913 to 2014)	137	106	25%
Last 20 years (1994 to 2014)	140	94	25%

If the rainfall data is analysed further, it indicates precipitation is not evenly distributed around the average but is skewed (figure 1). This is the result of occasional very high rainfall periods e.g. 2010/2011 that increase the average. The most frequent amount of rainfall for this period is 23% below the long term and 33% lower than the average over the past 20 years.

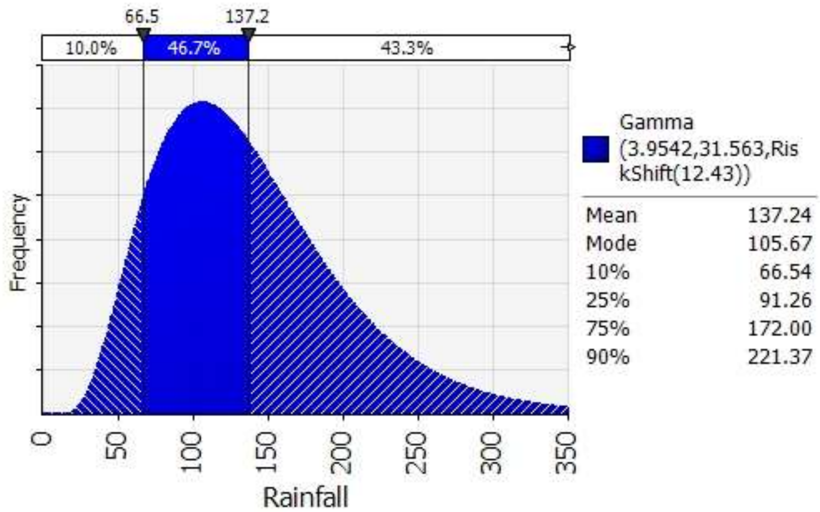


Figure 1: Long term rainfall distribution for Lake Bolac in December to April from 1913 to 2014.

[1] From @risk distribution fitting

Irrespective of whether we use the average or most frequent values, there is still a useful proportion of rainfall we receive that on first glance we may not be using as productively as possible.

Storage of summer rainfall

Storage of summer rainfall to use by the next winter crop is critically important in the lower rainfall zones. In most years the capture and retention of summer rainfall contributes to the yield of the next winter crop (GRDC, 2012). Understandably maintaining stubble cover and weed control are vital tactics. However it would appear the same assumptions may not apply to the high rainfall zone.

Examination of soil moisture probe data from a Grain and Graze grazing trial at Lake Bolac conducted from late 2010 to early 2014 would suggest soil moisture is still lost from the soil surface, even with very good weed control and a reasonable amount of stubble cover (table 2, figure 2).

Table 2: Change in stored soil moisture (0 - 100 cm) on fallow from December 1 to April 30, with corresponding rainfall and estimated groundcover.

Year	Rainfall (mm)	Approx change in soil moisture (mm)	Groundcover (t/ha)[#]
2010 - 2011	329	+80	3.7
2011 - 2012	88	+22	7.5
2012 - 2013	64	-13	6.3
2013 - 2014	41[*]	-2	3.9

= Estimated from grain yield and assumed harvest index
* = Dec and Jan only

While some of the rainfall over the December to April period may have run off, a large amount infiltrated into the soil. Yet by the start of the winter sowing season (May 1), virtually all of the rainfall over the summer period was lost.

The most probable cause of this loss is through evaporation at the soil surface due to capillary rise. This effect is created when the suction caused by dry air at the soil surface draws soil water out of the pore spaces. The evaporative effect ceases when the 'hold' on the soil water by gravity and pore size equals the evaporative 'pull' of the dry air. Soils with higher clay content have greater potential to lose soil water from capillary rise that sandy textured soils.

The line in figure 2 indicates that even though there is approximately 230 mm of moisture in the soil profile over summer, this is the lower limit. Capillary rise or the previous winter crop has been unable to extract any more moisture from the soil.

Figure 2 also enables an estimate of the upper limit for this soil type. This is approximately 380 mm, giving a bucket size of around 150 mm in the top 1 metre of soil. It shows that in 2011, 2012 and 2013 there was sufficient rainfall in May, June and July to roughly fill the soil bucket. Rainfall in these three months was 155, 176 and 186 mm respectively. Given evapotranspiration during this period is usually very low, the probability of not receiving 150 mm from the start of May to the end of August is 16.7% (1 year in 6) and of receiving 120 mm or close to field capacity only 4.4% (1 year in 23) (Figure 3).

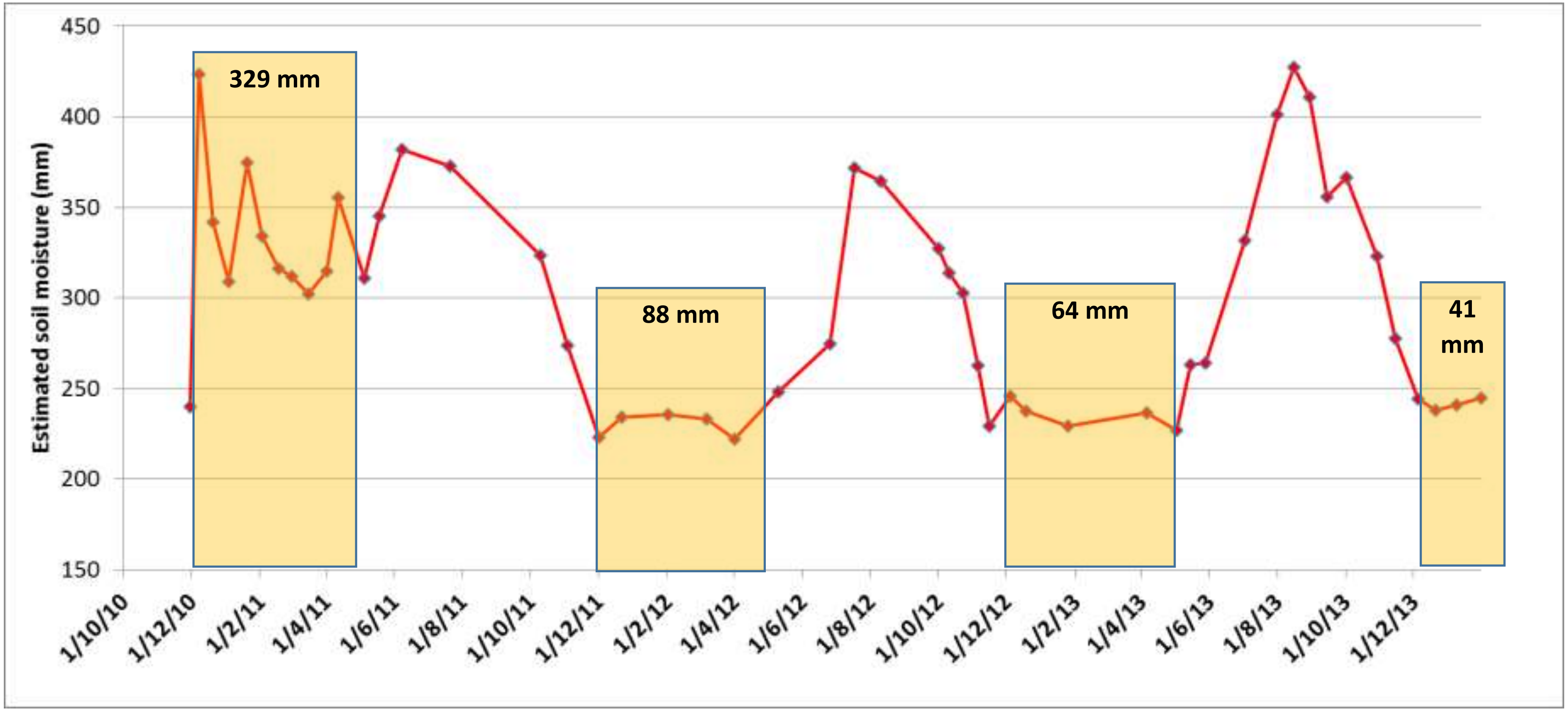


Figure 2: Estimated soil moisture from December 2010 to Feb 2014 (0 - 100 cm).

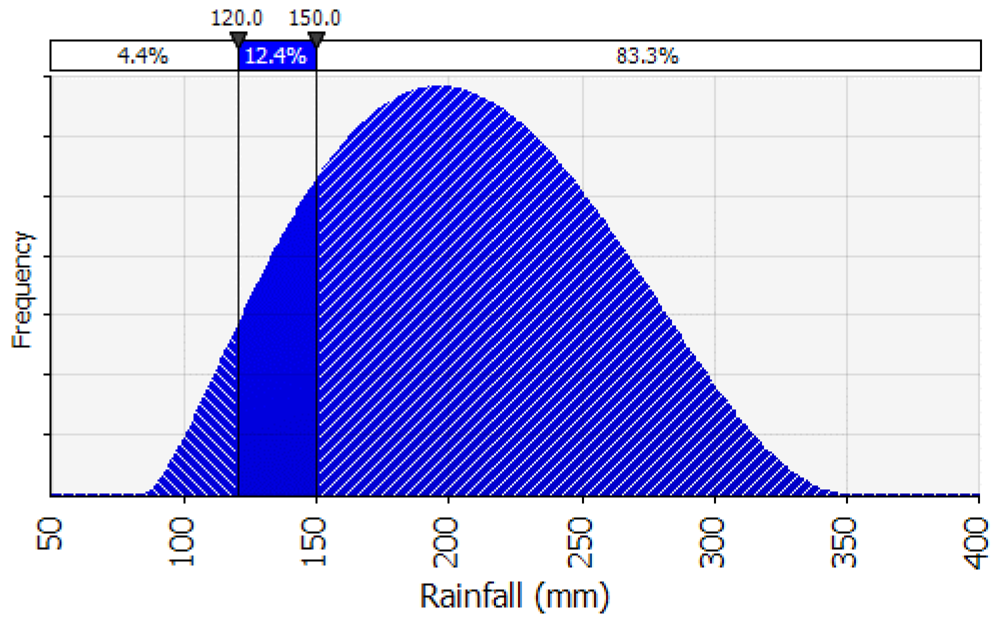


Figure 3: Rainfall distribution from May to August for Lake Bolac 1913 to 2014).

Summer fodders

Despite losing most of the summer rainfall to evaporation, does a summer fodder 'drain' the soil even more? To appreciate this possible effect an established lucerne stand was monitored for soil moisture along with a crop fallow (similar to the trial in figure 2) (figure 4). Established lucerne was likely to be the most aggressive type of summer fodder to extract soil moisture, so this makes an extreme comparison. Two observations are worthy of comment.

Firstly the established lucerne was able to extract more moisture than the fallow however the difference was not as great as expected. The additional 'loss' in soil moisture from the lucerne compared to the fallow was 40 mm in 2010, 43 mm in 2011 and 21 mm in 2012. The probability of not reaching 190mm (150 mm fallow deficient plus the 40 mm extra lucerne deficit) from May 1 to the end of August increased to 42% (2 years in 5).

Secondly the upper and lower limit of the fallow are similar to figure 2, with the same evaporation effect over summer. This confirms the observations in figure 2 that soil moisture is lost from the soil under fallow.

However lucerne is a perennial and after a few years it would have a well-established root system. Most annual summer crops would not have had the chance, or have the plant characteristics, to create such a root system. Therefore the additional loss may not be as great in annual sown summer fodders as lucerne.

To explore this further data from eight trials conducted at three locations (Werneth, Skipton and Winchelsea) are examined. They cover the 2010/2011 and 2011/2012 seasons. As described previously there were contrasting summers for rainfall, with the summer fodder period in 2010/2011 at Werneth 41% (+97 mm) above long term average (160 mm in January) but 46% below the long term average in the 2011/2012 summer period (-108 mm). Skipton was 36% below average (-140 mm) in the summer of 2011/2012, but Winchelsea was only 6% (-11 mm) below average (figures 4 to 6).

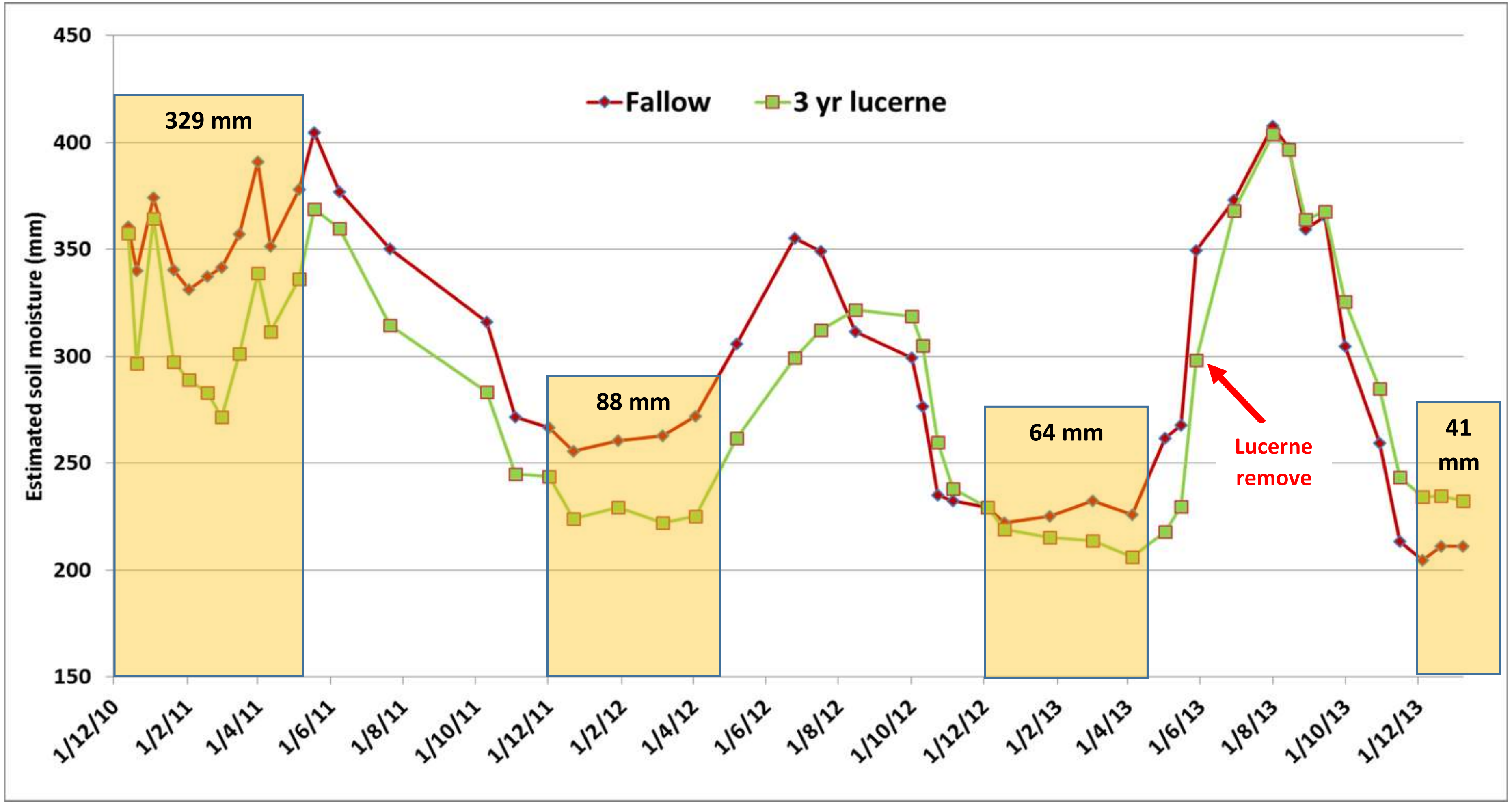
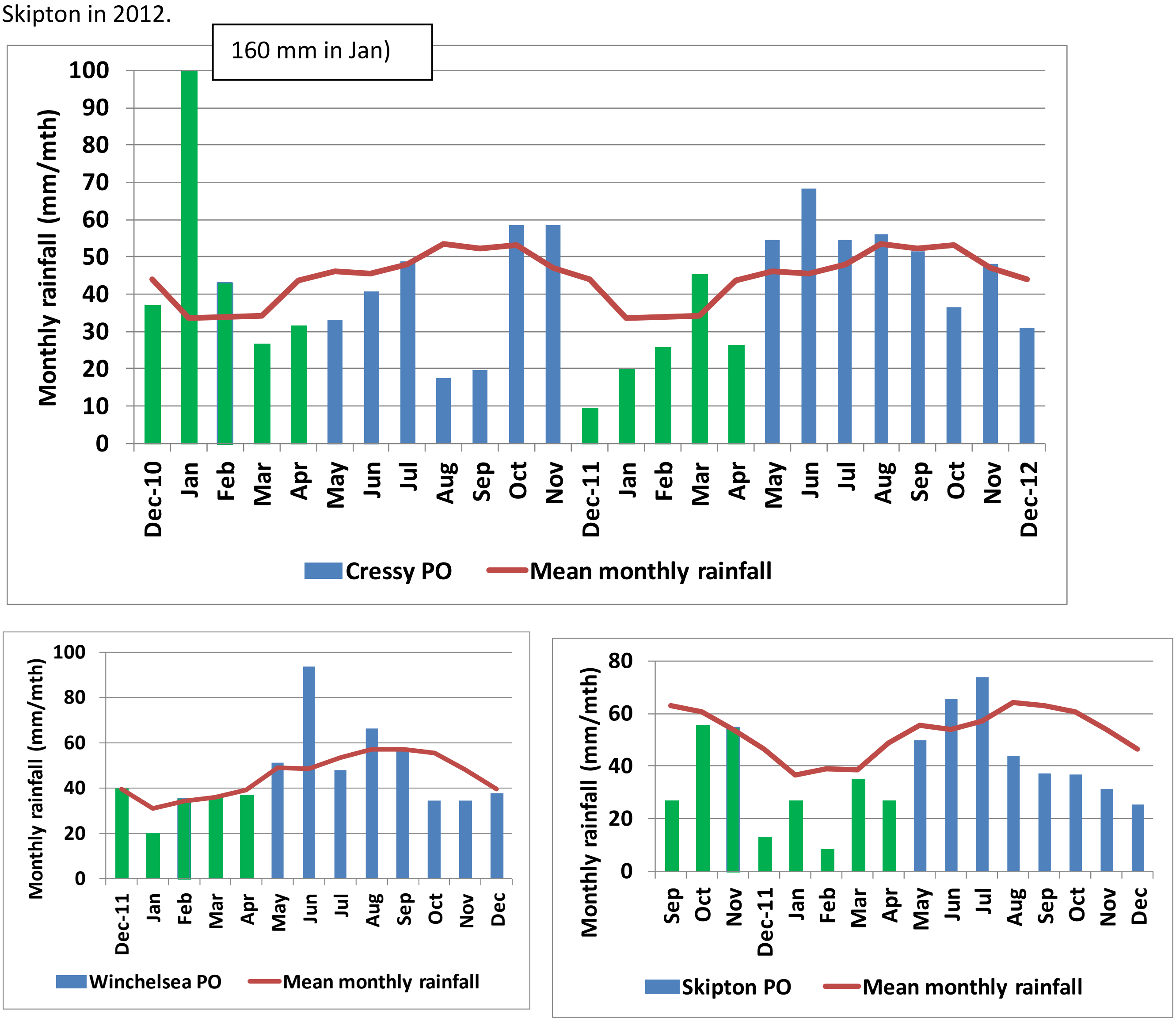


Figure 3: Estimated soil moisture from December 2010 to Feb 2014 (0 - 100 cm) at Lake Bolac for a fallow compared to lucerne:

Below average winter crop rainfall (May to November) was experienced at Werneth in 2011 and Skipton in 2012.



Figures 4 to 6: Monthly rainfall for Cressy, Winchelsea and Skipton during the summer and winter crop rotation trials (green bars indicate the summer fodder months, blue the winter crop months).

Production from summer and the next winter crops

All trials were sown with a summer crop, four for grain, three for fodder and one for fodder and grain (spring sown *Taurus* canola). The fodder value obtained from these crops is presented (table 3). Seven of the eight trials were followed by a winter grain crops, the eighth continuously grazed. There was no yield penalty by growing a fodder (or failed grain) crop in the previous summer for any winter crop (table 3).

Table 3: Yield of summer fodder crop and following winter crop (2010/2011 & 2011/2012).

Year	Location	Summer crop	Yield of summer crop (t/ha)	Winter crop	Yield of winter crop (t/ha)
2010/2011	Werneth	Sunflowers	0.46	Barley	1.84
		Unsown	0		1.85
					NS
	Werneth	Sorghum	Not harvested	Barley	2.11
		Unsown	0		2.46
					NS
2011/2012	Winchelsea	Forage sorghum (cv Feedex)	16.1 DSE/ha across 33 ha (240 weaner cattle for 10 wks, 160 cows for 1 wk)	Grazing wheat	Wheat grazed over winter so no yield available
		Unsown	0		
					N/A
	Skipton	Fodder rape (cv Winfred)	7.4 DSE/ha across 65 ha (1500 lambs for 60 days)	Wheat	7.20
		Unsown	0		7.14
					NS
	Skipton	Dual purpose rape (cv Taurus)	4.7 DSE/ha across 65 ha (1500 lambs for 38 days)	Canola (Taurus)	0.64[2]
		Unsown	0		0
					N/A
	Werneth	Corn	0.39	Wheat	Trial harvested by mistake
		Unsown	0		
					N/A
	Skipton	Peas	0.3	Canola	1.48
		Unsown	0		1.53
					NS
	Skipton	Maize	1.0	Wheat	2.69
		Unsown	0		2.50
					NS

If the summer crops sown for grain are excluded, the grazing value from some fodder options are considerable (table 4).

Table 4: Value of summer fodder grazing option (valued at 60c/DSE/week)

Location	Summer crop	Agistment value ($/ha)
Skipton	Dual purpose rape (cv Taurus)	$69
Skipton	Fodder rape (cv Winfred)	$119
Winchelsea	Forage sorghum (cv Feedex)	$388

1. Spring sown canola struggled under high weed pressure

Soil moisture, soil nitrogen and weeds

Results in table 3 clearly shows that growing a summer fodder crop does not have an impact on the next winter crop. Soil moisture in the top 60 cm taken by gravimetric measurement were similar on the sown or unsown treatments at the start of the summer fodder crops (+/- 12 mm except for the peas which was + 24 mm in the unsown). At the end of the summer crop, there were no large differences in the soil moisture where the summer crop had been grown compared to the fallow areas (figure 7).

In five of the eight trials, soil moisture was *higher* in the summer crop treatments than the fallow (biggest increase was +35 mm). Of the three trials where soil moisture was *lower* in the fodder crop the deficit was only 4, 13 and 16 mm.

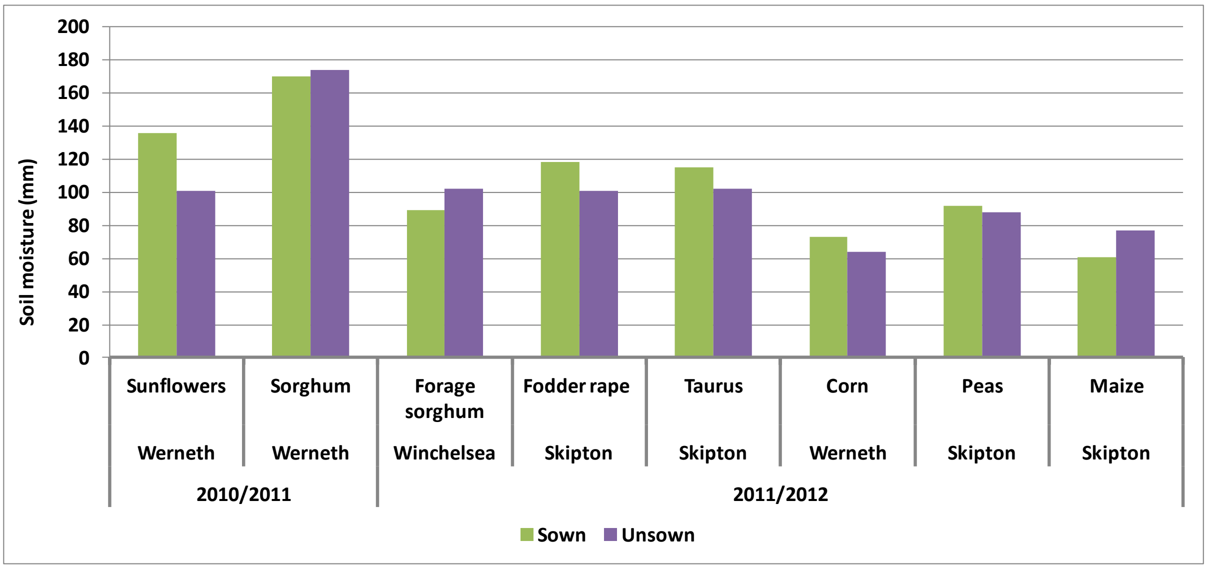


Figure 7: Soil moisture (0 - 60 cm) at the start of the winter cropping season under various summer fodder crops compared to no crop (fallow).

Examination of the soil water after the 2012 winter crop shows similar amounts of soil moisture in the treatment that had a summer crop and the fallow treatment. The results shown in figure 7 would partly explain why there were no significant differences measured in the next winter crop, as the starting soil moisture in May was similar despite growing the summer fodder crop.

These results are again surprising, given the rainfall over the summer growing period was 93 mm above average at Werneth in 2010/2011 (235 mm overall) and about average at Winchelsea in 2011/2012. The summer rainfall at Skipton in 2011/2012 was 33% or more than 100 mm below long term average yet the differences in the crop and fallow areas were less than 20 mm.

Soil nitrogen

The dry matter produced from the summer crops was likely to reduce soil nitrogen. Soil nitrogen was monitored on all trials at the start of the summer crop and again at the time of sowing the winter crop. Total soil nitrogen at the start of the winter cropping phase increased on all fallow treatments and decreased where the summer crops had been sown (figure 8), except for one site where peas were grown and the Winchelsea site that had 10 m^3/ha of pig manure applied.

Mineralisation of organic matter and use by the fodder crop is likely to be the reason for the differences in soil nitrogen.

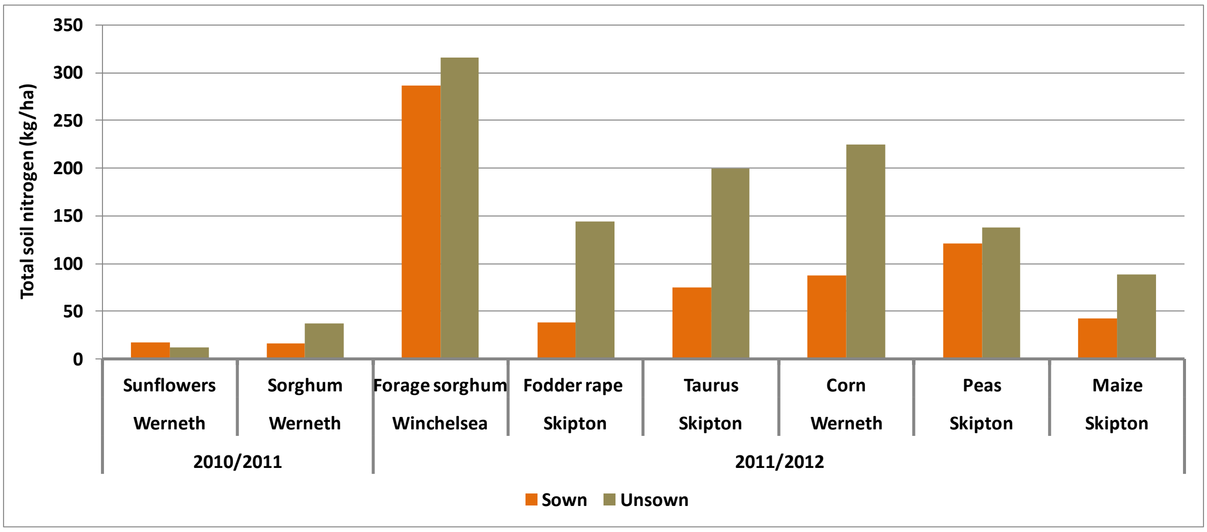


Figure 8: Change in soil nitrogen under summer crops or fallow treatments

The magnitude of this 'loss' in soil nitrogen as a result of the summer fodder crops is considerable. If the 'lost' nitrogen is valued by replacing it through urea application, then the cost may outweigh the grazing benefits obtained (table 5).

Table 5: 'Loss' of soil nitrogen and cost under various summer fodder options compared to no crop (fallow).

Location	Crop	'Loss' of soil nitrogen under crop (kg/ha)	Cost of lost nitrogen ($/ha)[3]
Werneth	Corn	-139	-$163
Skipton	Maize	-177	-$207
	Peas	+19	+$22
	Winfred rape[4]	-182	-$213
	Taurus canola[1]	-156	-$183
Winchelsea	Forage sorghum[1] (If pig manure benefit removed)	+32[5] (-152)	+$37 (-$178)

Conventional thinking would dictate that this 'lost' nitrogen would need to be replaced in the next winter crop otherwise a yield penalty would be incurred. The corn, *Winfred* rape and *Taurus* canola at Skipton received between 180 and 200 kg/ha of urea (90 to 100 kg N/ha). This was also applied to the fallow areas. While this application of nitrogen would not replace all the 'lost' nutrient, it means the fallow had very high levels of nitrogen, maintaining the discrepancy between the two

[3] Urea valued at $550/t

[4] 5-10 kg N/ha will be lost through export in animal product when grazing a fodder crops and some N tied up in manure will eventually be returned to the soil via degradation.

[5] Pig manure @ 10 m^3 / ha would supply 180 kg N/ha

treatments. Despite this large change in soil nitrogen between where the summer crops had been established and the fallow, it did not affect crop yields or grain protein.

Weeds

Weeds were measured in the summer crop and in the fallow at the end of the growth period. There was no significant difference in the weeds at in any of the summer crops that were taken to grain (i.e. not grazed). However all three of the summer crops used for grazing showed a significant reduction in weeds compared to the 'fallow' treatment (table 6).

Table 6: Weeds in summer crops at end of growing season.

Year	Location	Summer crop	Weeds (pl/m^2)	Main weeds
2010/2011	Werneth	Sunflowers	27.5	Marshmallow, wireweed, loosestrife
		Unsown	25.8	
			NS	
	Werneth	Sorghum	11.9	Marshmallow, wireweed, loosestrife
		Unsown	15.7	
			NS	
2011/2012	Winchelsea	Forage sorghum (cv Feedex)	14	Clover, rye & capeweed
		Unsown	49	
			16	
	Skipton	Fodder rape (cv Winfred)	10	Clover, rye & capeweed
		Unsown	100	
			67	
	Skipton	Dual purpose rape (cv Taurus)	23	Rye, capeweed & toadrush
		Unsown	103	
			41	
	Werneth	Corn	3	Canola, witch grass, mature annual ryegrass
		Unsown	4	
			NS	
	Skipton	Peas	11	Small thistles, immature annual ryegrass
		Unsown	11	
			NS	
	Skipton	Maize	28	Annual ryegrass, thistle, wild radish
		Unsown	42	
			NS	

These results indicate that summer crops sown for grain will not suppress weeds however those sown for grazing significantly reduce weed numbers compared to a fallow. This is most likely due to competition for light, moisture and nitrogen either before and/or after grazing.

In summary

Our understanding of the role of summer fodders in a winter cropping system is only in the early stages for the high rainfall zone of Southern Australia. Despite the limited amount of trial data, there appear to be some emerging ideas that both confirm and challenge traditional thinking.

The soil moisture issue defies intuition. It could be expected a summer crop would dry the soil profile more than a fallow. This was not the case, with similar amounts of soil water being lost on a fallow but with no productive gain.

Nitrogen was 'lost' with the growth of the summer crops but subsequent grain yield was not affected. Again this defies intuition however the yields of the winter crops were not large and the grain protein was similar, suggesting there was sufficient soil nitrogen to meet crop requirements, especially after the in crop application of nitrogen. Further many of the fodders were grazed, meaning much of the dry matter would have been returned to the soil ion dung and urine. This probably wasn't picked up in the initial deep N testing but may become available later in the winter cropping period. Still this does raise the question whether the simple calculation to replace the nitrogen 'lost' is adequate for optimum decision making.

Finally the weed response was also different to expectations. It was assumed summer crops grown for grain would compete against weeds and therefore reduce weeds. Instead weed reduction was only measured in the summer crops used for fodder and grazed.

References

GRDC 2012. Summer fallow management – Making weed control a priority. GRDC Fact Sheet Canberra