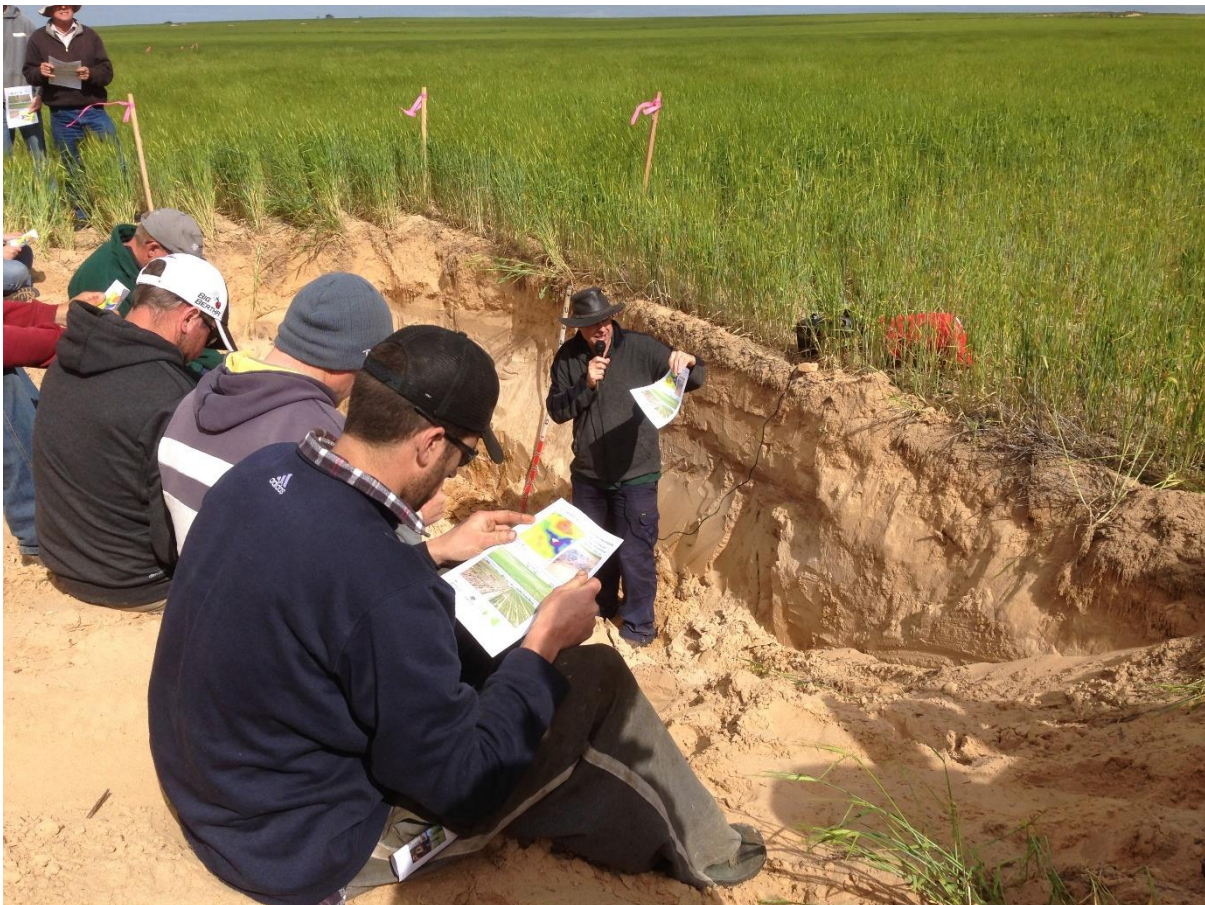


Murraylands and Riverland Landscape Board
**Primary Production Emergency
Preparedness and Response Plan**

*“Sustaining our Soil Asset in a Changing
Climate”*



Executive Summary

“Australia’s soil is recognised and valued as a key national asset by all stakeholders. It is better understood and sustainably managed, to benefit and secure our environment, economy, food, infrastructure, health, biodiversity, and communities – now and in the future”.

The above is the vision within the *National Soil Strategy 2021 – 2041* that was released in May 2021 and acknowledges that soil is an integral part of the Australian landscape. It supports us all, no matter where we live, and provides essential ecosystem and production services that contribute to Australia’s economic, environmental and social wellbeing -

<https://www.agriculture.gov.au/agriculture-land/farm-food-drought/natural-resources/soils>

In the development of this Emergency Preparedness and Response Plan we have elected to focus on the sustainable management of the soil asset within the region. Primary production accounts for over 70% of land use in the region and is a key driver of the regional economy and supporting the sector to be resilient and adaptive to future climate challenges is a key area of focus.

While drought and extreme weather events are not new to the region with climate change projected to increase the frequency and severity of drought and extreme weather events it has never been more important to work in partnership with regional land managers and service providers to plan for and respond to these future challenges.

This Emergency Preparedness and Response Plan recognises that significant investment is currently occurring consistent with the above intent, including through the Australian Government’s new Climate Smart Agriculture Program (CSAP). Regional coordination and collaboration within and across programs and projects is therefore critical to ensuring the complementarity of investment across the region and that the outcomes delivered through this investment are maximised.

This plan highlights some of the key future challenges for the region that will need to be managed in the context of emergency preparedness and response and includes a number of case studies to highlight proactive monitoring and management activities that contribute to this objective.

1. Introduction

The Murraylands and Riverland region forms the south-western portion of the Murray-Darling Basin catchment into which the River Murray flows. The River Murray supports highly productive horticultural industries as well as supplying the majority of the water needs for the city of Adelaide and many other towns in the state.

The Murraylands and Riverland region is a landscape dominated by an impressively diverse range of agricultural systems - from irrigated perennial and annual horticultural crops and viticulture, through to cutting-edge dry land cropping and grazing systems. With 70% of the region being privately owned, land managers play a pivotal role in managing the region's natural resources.

The main productive land uses in the region are:

- Annual cropping and mixed farming throughout the Mallee, Murray Plains, and Upper South East.
- Irrigated horticulture (particularly grapes, citrus, nuts and stone-fruit along the River Murray, irrigated dairies in the Lower Murray, and potatoes and onions in the Southern Mallee).
- Grazing of native and modified pastures including large pastoral leases in the rangelands area of the region and around the Lower Lakes.

There are numerous processing businesses associated with primary production including wineries, juice manufacturers, packing companies and many others that are important to the economic prosperity of this region.

The people in the Murraylands and Riverland region are known for their resilience and innovative capacity. In this dry region, drought is an inevitable feature and is a recurring and challenging experience for farmers and rural communities.

Projections for a warming and drying climate represent a dual threat to natural resource management and production levels across South Australia's dryland (rain-fed) cropping regions. Within an already largely moisture limited environment, a further decline in rainfall has the potential to bring (i) less reliable grain production and (ii) increasing incidence of soil erosion risk due to reduced crop biomass levels.

2. Potential Impacts of Climate Change

Climate change projections for the dryland agricultural regions of SA indicate that annual average temperatures will increase by 0.4°C to 1.8°C by the year 2030, and between 0.8°C and 5.5°C by 2070¹. As shown in Figure 1 there has been a strong trend towards warmer conditions in South Australia in the recent climate record.

Rising average temperatures can also translate to shifts in extreme events, such as longer or more intense heatwaves and more intense rainfall events which is important when considering emergency preparedness and response.

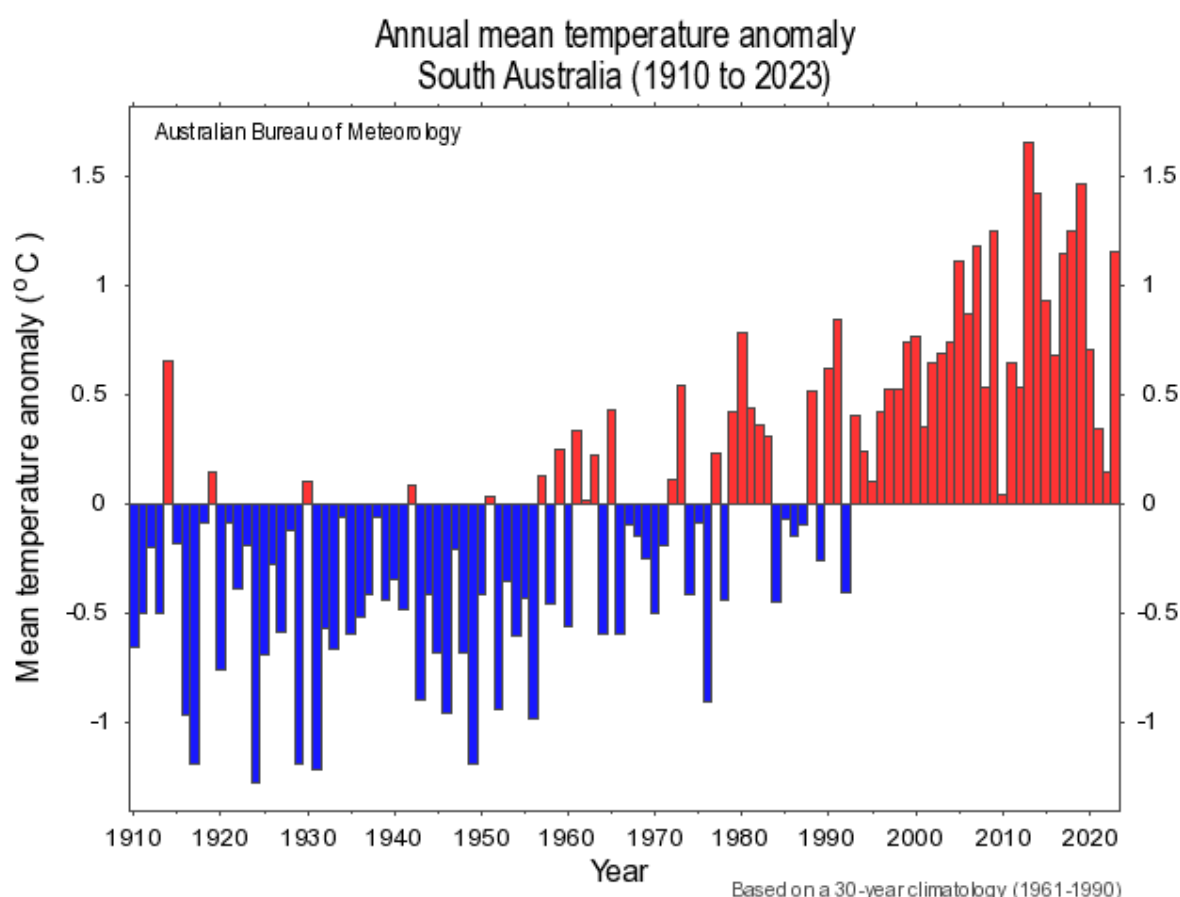


Figure 1: Annual Mean Temperature Anomaly – South Australia

Average annual rainfall may decrease by as much as 15% by 2030 and by 45% by 2070 (Suppiah et al. 2006). As rainfall is already a limiting factor across the majority of South Australia's agricultural zone, including the *Murraylands and Riverland* region if climate change brings further climatic warming and drying as projected the impact is expected to be primarily negative, and exacerbated on the drier fringe (e.g. in already marginal and low return cropping land such as the Murraylands and Riverland region).

Under such a trend, impacts are likely to include, but are not limited to:

- Less growing season rainfall (with predicted declines mostly in winter and spring)
- Increased frequency of low rainfall years
- Increased evaporative water loss combined with reduced water availability
- Longer dry spells between rainfall events
- Higher frequency and severity of droughts
- Increase in bush fire risk (20-30% increase by 2050)

- Accelerated crop growth due to warmer temperatures
- The need for different crop variety selections to adapt to changing conditions (e.g. warming and/or potential declines in spring rainfall)
- Reduced viability for crops sensitive to dry conditions (e.g. canola and some pulses)
- Restricted options and times for crop rotation
- Reduced crop and pasture yields in warmer, low rainfall areas (where reductions in rainfall are expected to outweigh any benefits from increased CO₂ concentrations)
- Possible yield increases (due to increased CO₂) where rainfall or soil constraints are not limiting; this may also occur with faster crop development (with warmer temperatures) shifting the grain filling period into a wetter part of the season
- Production may increase in cooler or wetter areas due to (i) warmer winter temperatures and (ii) reduced waterlogging and reduced nutrient leaching
- Reduced grain and pasture protein quality resulting from increased nitrogen use efficiency under higher CO₂ levels
- Reduced maturation time prior to harvest (under hotter and drier conditions) which may affect grain quality, e.g. grain cracking or small grains
- Where rainfall is limiting, farms dominated by fine textured (more clayey) soils are likely to see much stronger negative effects of declining rainfall than farms dominated by more sandy soils
- Possible higher vulnerability of sandy soil types to reduced crop yields under high temperatures (although in low rainfall settings, moisture stress in heavy soils is likely to be a bigger problem)
- Increased rainfall intensity, which may increase opportunities for water harvesting, but also lead to higher incidences of flooding, erosion and storm damage
- More intense and frequent heatwaves (however for cropping the risk of heat stress will tend to be offset by faster crop development with flowering and grain fill during cooler periods)
- Increased heat stress in livestock due to heatwaves
- Reduced availability and quality of water for livestock
- Migration and changes in the competitiveness of pest plants, animals and diseases
- Problems with changed timing and/or strength of climatic indicators (or triggers) used by plant and animal species, and potential mis-matches in the development of synergistic species – which may impact on ‘ecosystem services’ such as pollination, pest control, etc.
- Reduced ground cover protection for erosion control
- Salinity increases in soils and groundwater resulting from warmer, drier conditions and less flushing by rainfall
- Potential reduction in watertable-induced salinity due to lowering of watertables
- Reduced recharge to groundwater and aquifers.

While the above represents an extensive list of potential climate change driven impacts on agricultural systems this plan focuses more specifically on the management of the regional soil asset in the context of a changing climate.

Soils are a vitally important natural resource, requiring sound management to protect their productive capacity and vital ecosystem services (including storage and cycling of carbon, water and nutrients). This is underscored by the fact that we are witnessing ever-increasing pressures on the natural resource base. A key issue is the protection of soils from wind and water erosion, which is seen as critical to the long-term sustainability of agricultural land, farming businesses and the condition of the environment.

Loss of precious topsoil degrades soil fertility, carbon content and water holding capacity, as well as causing off-site impacts. There has been a major improvement in the protection of soil from erosion over the last 10 years due to the widespread adoption of no-till farming, stubble retention and improved grazing management.

However, if declining rainfall reduces average grain yields and crop biomass available to protect soils, this will have important implications for farm businesses, land management and land use strategies in the affected areas. It is also recognised that adverse impacts to farm businesses will reduce the capacity of land managers to deliver a range of important natural resource management (NRM) outcomes in regional areas.

3. Implications for the Management of the Regional Soil Asset

Projections and modelled simulations of future climate conditions show that low rainfall regions, such as the Murraylands and Riverland will experience the highest percentage reduction in production and therefore will have the greatest need for land managers to adapt and respond to a drying climate.

Figure 2 (a) shows a simulation of average wheat yields in the MRLB region based on historic climate and highlights that large areas of the region, especially the Northern Mallee are already low yielding/marginal production environments and therefore inherently vulnerable.

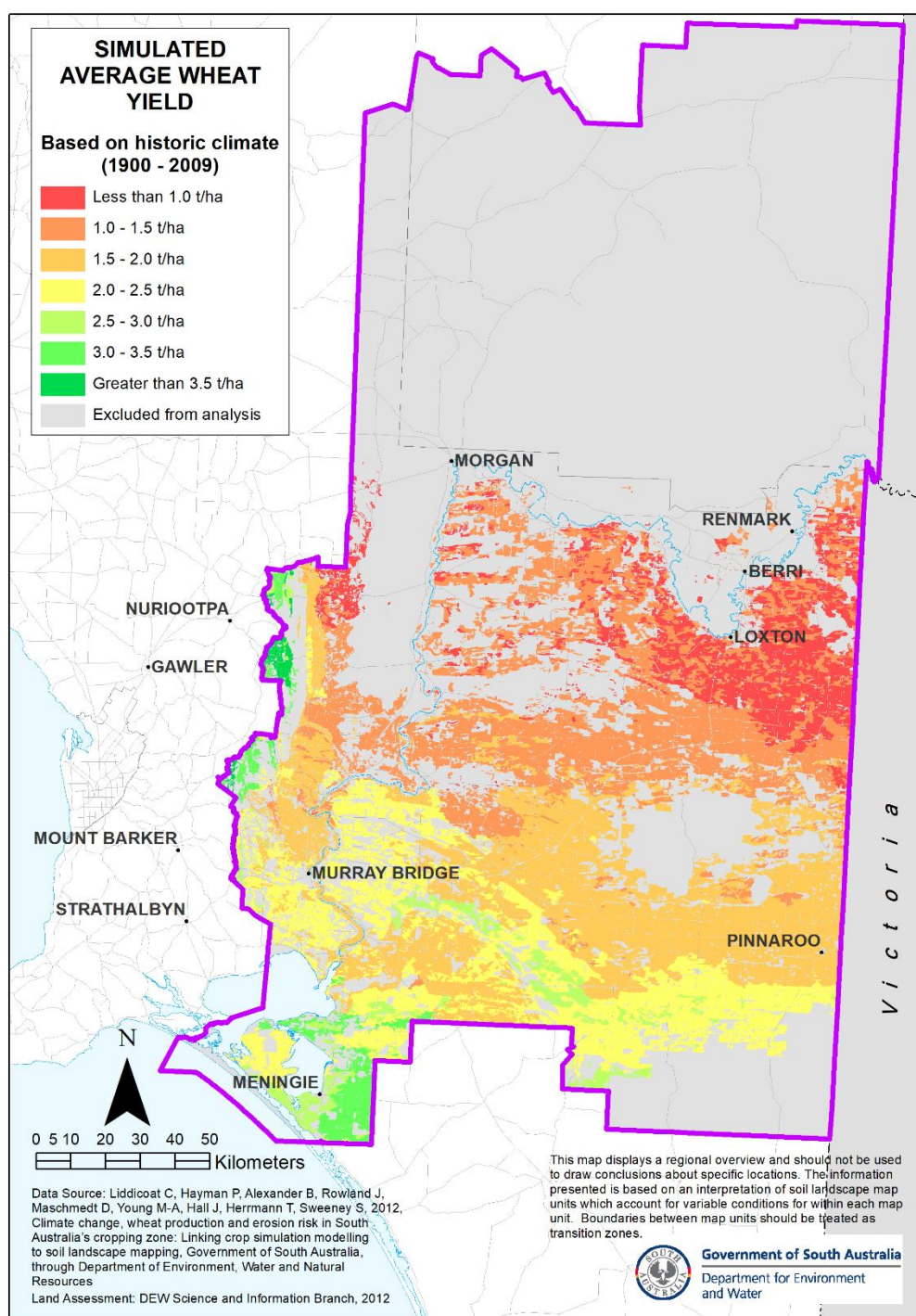


Figure 2 (a): Simulated Average Wheat Yield – Historic Climate

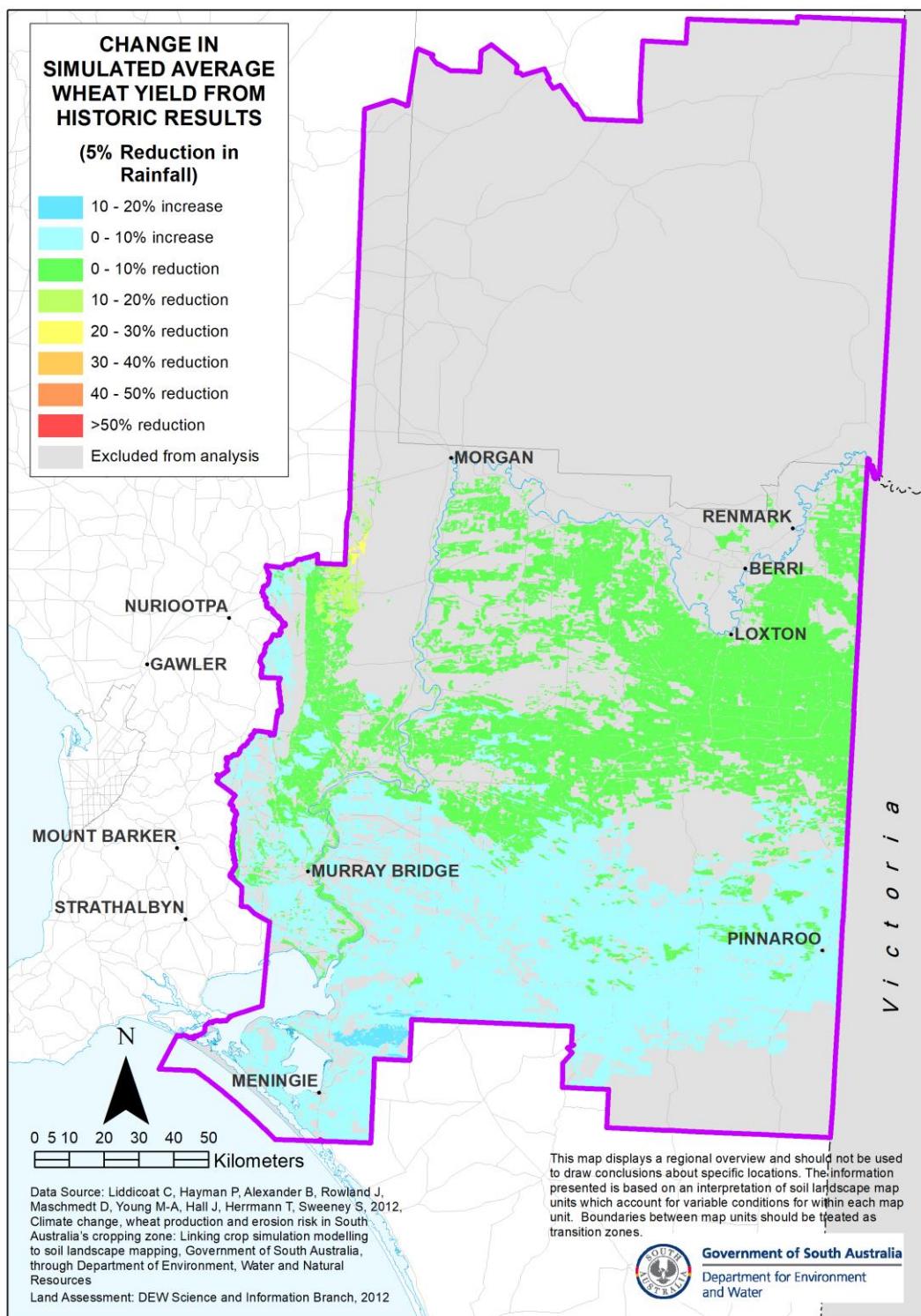


Figure 2 (a): Change in Simulated Average Wheat Yield (5% reduction in rainfall)

It is also worth noting that isolated parts of the region are projected to experience potential yield increases under low to moderate level climate change as highlighted in Figures 2 (a) & (b) however these tend to be restricted to areas that are not currently rainfall limited.

Conversely as drying scenarios intensify the relationship between rainfall and yield reduction becomes more pronounced – Figure 2 (c).

This has real implications for soil condition and land management practices with the increased risk of soil erosion discussed in more detail in following sections.

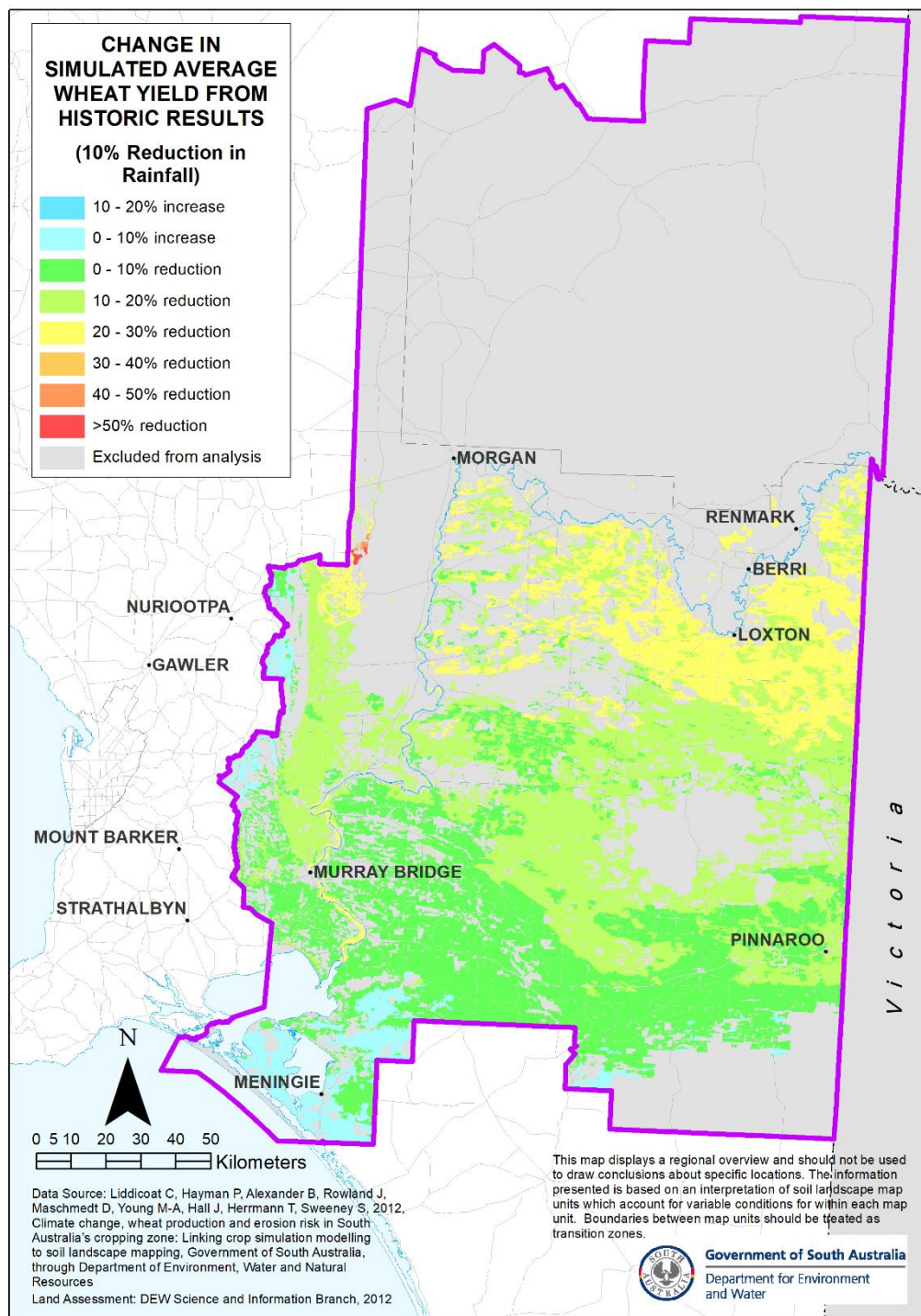


Figure 2 (b): Change in Simulated Average Wheat Yield (10% reduction in rainfall)

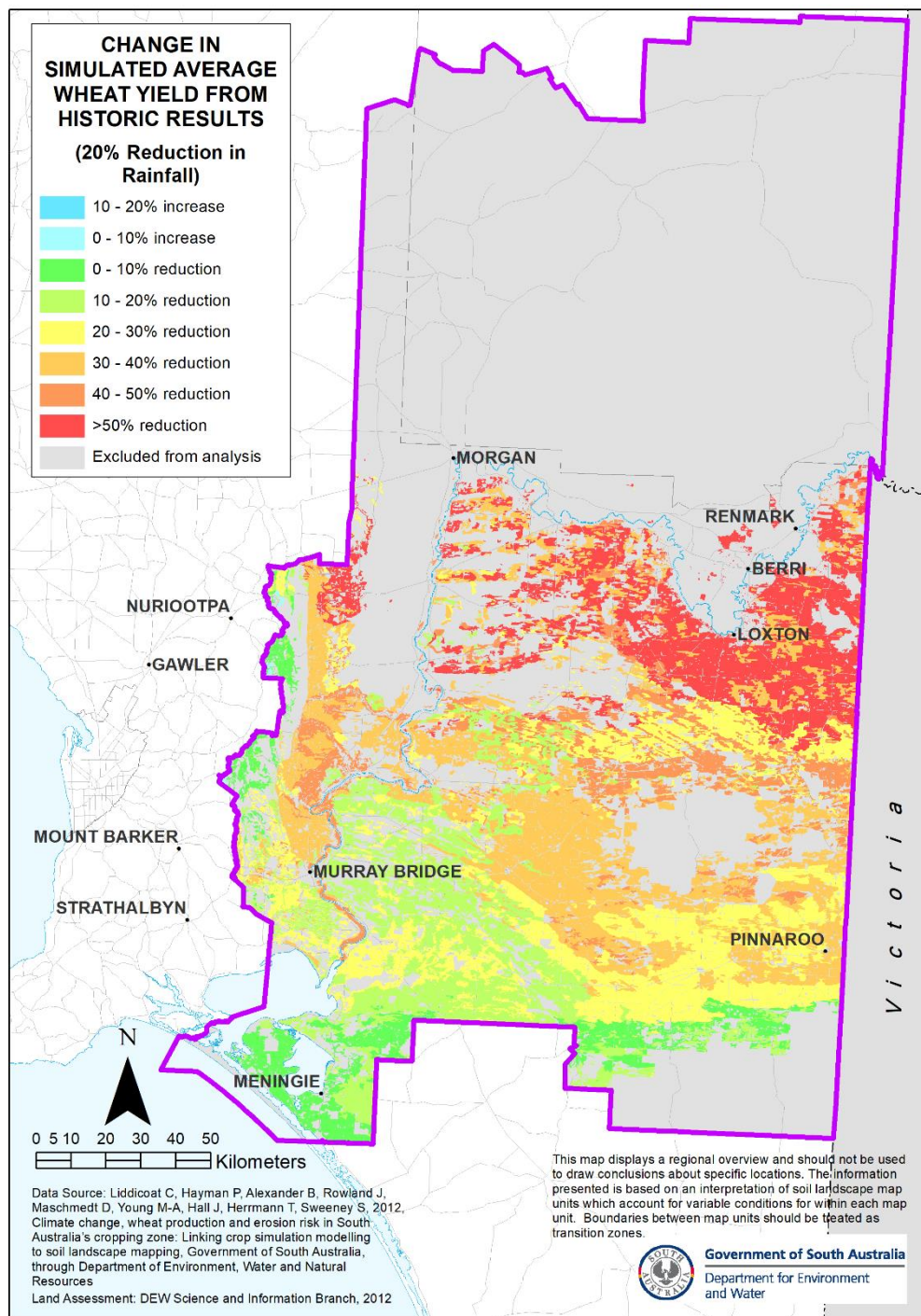


Figure 2 (c): Change in Simulated Average Wheat Yield (20% reduction in rainfall)

4. Developing a Response and Management Plan for the Soil Asset

As has been discussed in previous sections a drying climate presents a significant challenge for the protection of the regional soil asset into the future. With a strong correlation between yield (t/ha) and post-harvest biomass levels any reduction in yield has the potential to increase the extent of the soil asset at risk from erosion.

Figure 3 (a) below highlights that the Murraylands and Riverland landscape is high risk when it comes to the potential for soil erosion due to land not having sufficient cover. Not surprisingly there is a very strong correlation between low yielding areas and the risk of wind erosion and this is significantly exacerbated under a drying climate as shown in Figure 3 (b). While the 20% reduction in rainfall represents the high end of climate change projections it does present a particular challenge for the region and one which requires a coordinated plan and response to effectively manage.

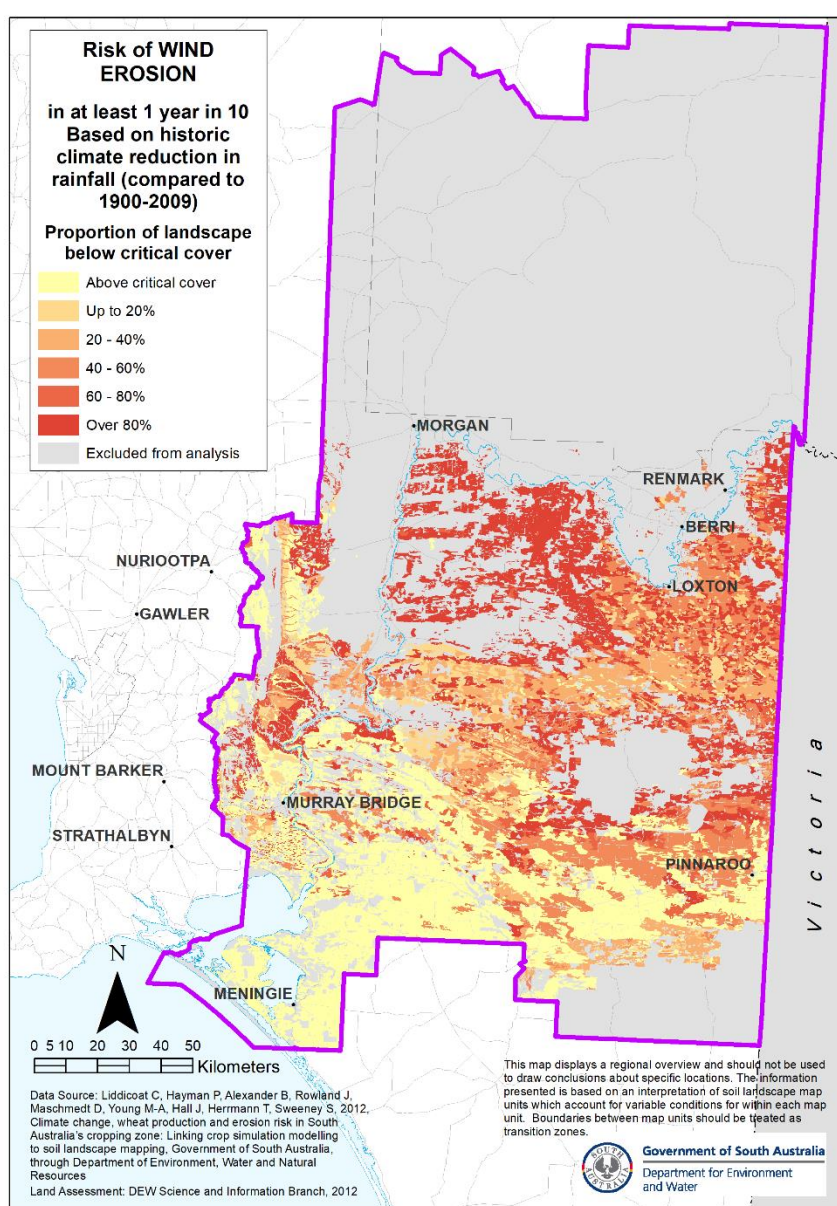


Figure 3 (a): Risk of Wind Erosion – Historic Climate reduction in rainfall

As expected when the simulation is produced for a 20% reduction in rainfall as displayed in Figure 3 (b) below a much greater area of the region is projected to have inadequate soil cover to prevent soil erosion.

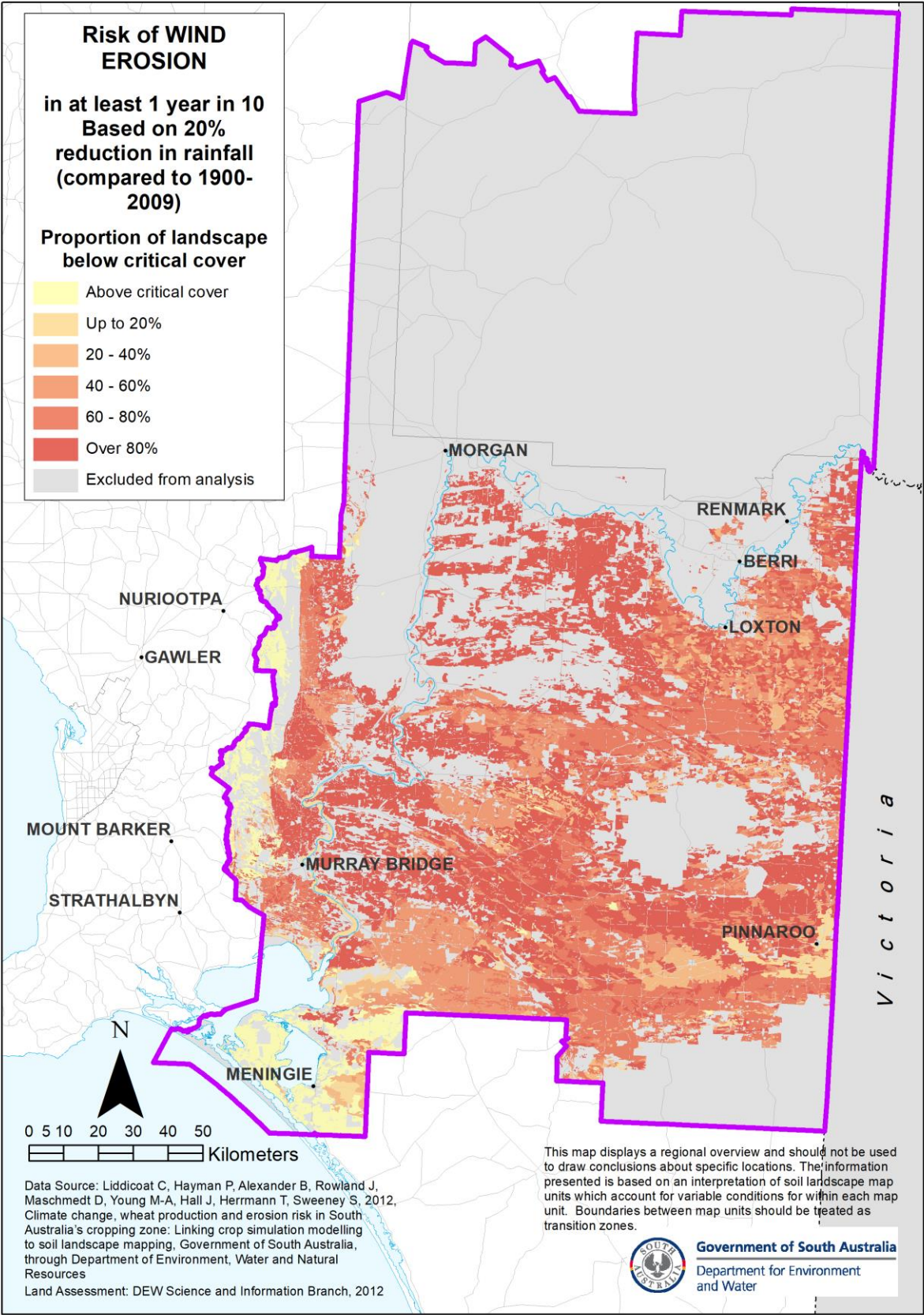


Figure 3 (a): Risk of Wind Erosion – 20% reduction in rainfall

While protecting and sustaining the regional soil asset will continue to be an area of challenge into the future it highlights the need for collaboration and coordination to assist land managers to respond to the challenge.

Significant investment has, and continues to be made recognising the fundamental role soil plays in assuring food and fibre production, human and environmental health, biodiversity, food security and climate change adaptation and resilience is recognised globally -

<https://www.agriculture.gov.au/agriculture-land/farm-food-drought/natural-resources/soils>

The 2023-2028 Soil Action Plan is the first five year investment in the implementation of the National Soil Strategy and it will be important to align regional effort to the priority actions within the Plan which include:

1. Develop an agreed national framework to support the measurement, monitoring, mapping, reporting and sharing of soil state and trend information, to inform best practice management, decision making and future investment in soil;
2. Partners to develop a holistic policy and strategy approach where soil function is recognised, valued, and protected for the environment, economy, food, infrastructure, health, biodiversity, and communities;
3. Accelerate the adoption of land use and management practices that protect soil and improve soil state and trend; and
4. Identify and develop the soil workforce and capabilities needed to meet current and future challenges.

5. Case Studies

As described previously drought and extreme weather events are not new to the region however with climate change projected to increase the frequency and severity of drought and extreme weather events it has never been more important to work in partnership with regional land managers and service providers to plan for and respond to these future challenges.

The approach to drought management is now very much proactive and focused on building adaptability and resilience into farm businesses so that when the next drought does occur they are well prepared to manage and respond.

The case studies in this section highlight some of the practical monitoring and management activities that have been implemented within the region that build the resilience and adaptability of the primary production sector and that assist with identifying at risk areas.

Case Study 1 – Soil health and condition monitoring to assess risk

Soil wind and water erosion is the highest priority threat to agricultural soils in South Australia. Without intervention, soil erosion can have adverse social, economic and environmental impacts. Soil erosion depletes the productive capacity of land as it removes nutrients, organic matter and clay from soil, which are most important for plant growth.

Soil erosion has a wide range of costly off-site impacts including damage to roads, disruption to transport and electricity supply, contamination of wetlands, watercourses and marine environments, and human health impacts caused by raised dust.

Monitoring soil erosion by direct measurement is technically impractical. Instead, the condition of the soil surface in agricultural lands is assessed for relative protection (historically from visual survey of vegetation cover and more recently using satellite remote sensing) from the risk of wind and water erosion over time.

Soil protection is expressed as the average number of days per year that agricultural cropping land is adequately protected from (or at risk of) erosion. There has been an overall improving trend in erosion protection over the last 20 years, despite several years of very dry seasons and other challenging management issues.

The Department for Environment and Water (DEW) soils unit works collaboratively with Primary Industries and Regions SA (PIRSA)/South Australian Research and Development Institute (SARDI) and the regional Landscape Board's to produce a monthly report of ***Seasonal conditions and erosion risk on agricultural land***.

The monthly reports are compiled and distributed for internal government (non-public) information-sharing, to monitor and highlight current, or emerging issues regarding soil erosion risk and sustainable agricultural land management in SA's main dryland cropping regions.

As the reports have been collected over a long period of time (circa 1999) it enables a quantifiable assessment of land at risk to be accurately made. More recently the reports have incorporated earth observation techniques to assist with improving the efficiency of data collection and archiving past conditions to enable comparison with current seasons.

Examples of these products are provided in the following graphics and highlight the visual assessment and the near real time risk management of soil erosion that is adopted.

(Source: DEW Soils Unit: <https://www.environment.sa.gov.au/topics/soil-and-land-management>)

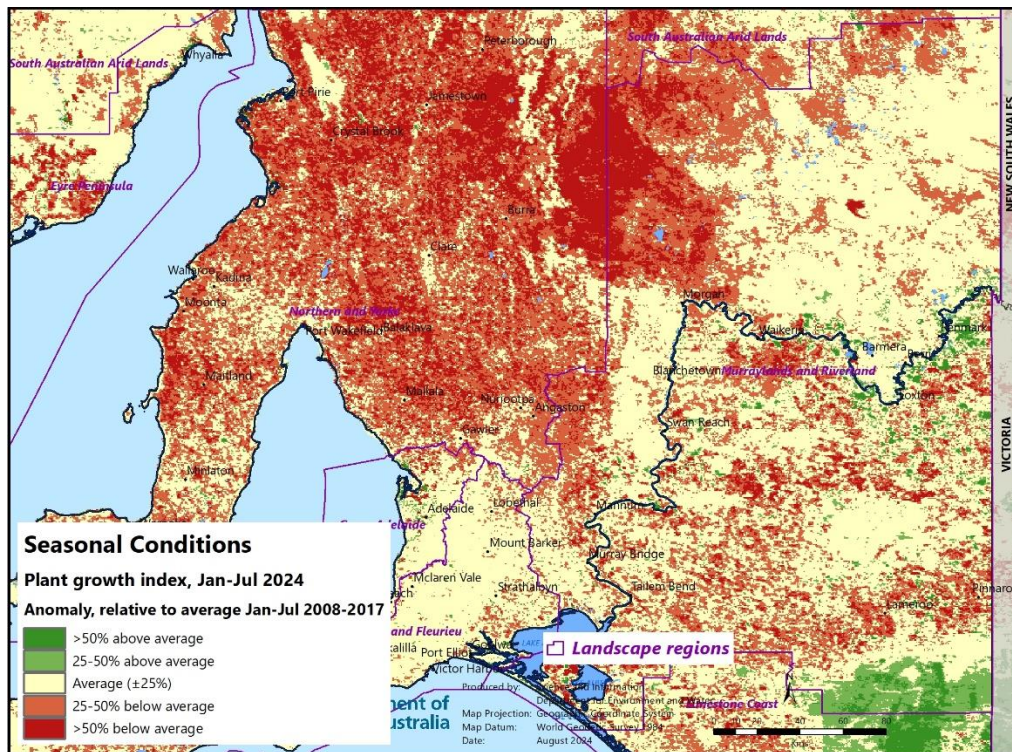


Figure 1: Plant growth index: January - July 2024

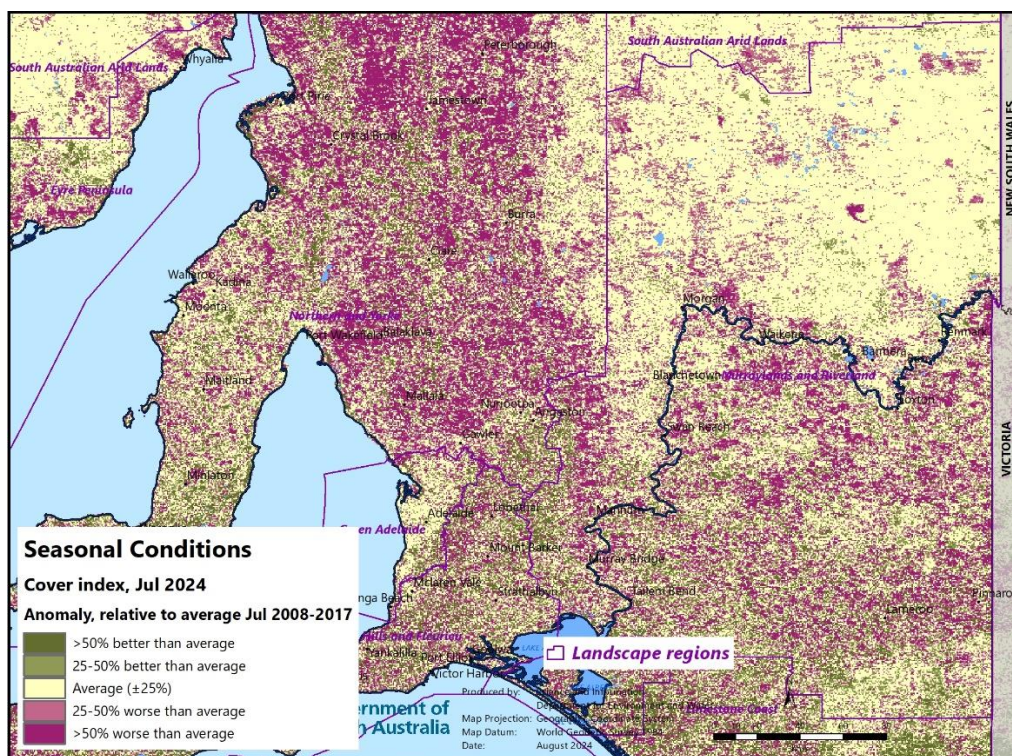


Figure 2: Cover index: July 2024

DEW changed to using a method of monitoring soil erosion risk that uses satellite data in approximately 2021. While this method does not assess other factors that affect erosion risk such as soil disturbance (looseness) which the previous field surveying did it covers all of the landscape rather than just the transects observed in the field surveys. Smaller scale field surveys are still conducted on an ongoing basis to ground-truth the accuracy of the modelled data. This is a good example of evolving approaches as new tools and techniques become available that assist decision support.

Case Study 2 – Applying risk management to effective legume break crop options in high wind erosion risk drift sands

1.1 Issue

The Murraylands and Riverland Landscape Board, Mallee Sustainable Farming, and Mallee farmers have identified that legume crops grown on sandy soils in the South Australian Mallee are providing sub-optimal levels of yield and vegetative groundcover. The consequence of this is that the soil condition benefits usually provided by the legume crop during the growing season are rapidly lost due to wind erosion. This can leave the soil vulnerable to ongoing erosion and can lead to reduced productivity and groundcover protection of subsequent crops.

The cultivation of legume crops offers a potential three fold benefit to farmers – firstly the prospective higher value grain legume grain yields open up improved incomes per t/ha, secondly legume crops develop root cultures that fixate atmospheric nitrogen into the topsoils, these being potentially fixed sufficiently long to enable mineral N resources for following cereal crops and thirdly offering up once in the overall rotation cycle opportunity for targeted grassy weed control using selective herbicide control.

As such the opportunities generated by legume crops is of significant value both the landholder and the overall cropping system. The potential risks however for both establishment and successful yield and the consequences for soil erosion stemming from both failed crops and the variable nature of grain legume stubbles in providing secure soil cover by comparison to a cereal crops makes the overall investment risky.

With projected changes in climate the use of both legume and brassica break crop options is becoming significantly more important to investigate. A key driver to legume crop failure overall is hardpan, a universal barrier to effective annual crop production in the region. Hardpan at ~200 mm generally restricts root growth but more importantly restricts the overall moisture availability in the sandier soil types, triggering early senescence and poor biomass productivity and grain yield. Key treatments in this project have evaluated the overall risk and cost of deep ripping to overcome hardpan against the prospects for both grain yield and biomass/stubble generation, developing in turn a risk profile for each legume species trialled against the apparent associated risks around each stubble type. The project as such directly addresses a number of risks, including those likely to stem from a reduced rainfall scenario as a result of potential climate change impacts.

1.2 Trial works and case study development

The case study results are drawn from the most conclusive year of plot trialling a number of grain legume crops in sandy soil cultivation near Lameroo South Australia in a region known as Kulkami. The soil province determined in the trials is situated in the Bews Land System (Land System Report, DEW Soils) specifically within the 'OUA' classified sub-component, that being largely comprised H3 (SA Soils System Classification) siliceous drift sands as part of the sandy rise/swale land systems of that region. The drift sands which have been extensively cultivated since after the First World War period are in the absence of groundcover extremely mobile under wind drift influence and in this scenario largely devoid of anything approaching an organic horizon, this further exacerbating crop establishment and economic yield.

This case study has focussed on refining the emergent success with deep ripping across a range of grain legume species, characterising the results of yield and biomass against the identified risks and risk profiles per crop type. State based erosion management guidelines have been applied to assessing stubbles and erosion risk, see appendix 1.

In 2020 the emphasis has been on trialling different soil amelioration activities. As the site has some non-wetting soil characteristics similar to the 2019 site, spading has been included as well as deep ripping in the treatment list. The same crop types will be assessed for their responses to the different treatments. A detailed trial plan is provided in table 3. This details the crop variety list with sowing rates.



Figure 1: Implementing spading (left) and deep ripping (right) treatments at the demonstration site.

Table 1. Average soil test results for the 2020 trial site

Analyte	0-10cm	10-30cm	30-60cm	60-90cm	90-120cm
pH (CaCl ₂)	5.8	6.6	7.5	8.1	8.4
Organic Carbon (%)	0.4				
Nitrate - N (mg/kg)	6.7	3.9	2.0	1.7	1.7
Ammonium - N (mg/kg)	9.2	0.6	0.0	0.0	0.0
Colwell Phosphorus (mg/kg)	28.7				
PBI	11.0				
Colwell Potassium (mg/kg)	78.0				
KCl Sulfur (mg/kg)	7.0	4.9	4.0	3.0	4.7
Chloride (mg/kg)	7.3	1.7	1.7	2.0	2.7
EC 1:5 (dS/m)	0.1	0.0	0.1	0.1	0.2
Boron (mg/kg)	0.4	0.3	0.6	4.2	8.9
Iron (mg/kg)	15.0				
Manganese (mg/kg)	3.4				
Copper (mg/kg)	0.2				
Zinc (mg/kg)	2.0				
Clay (<2 micron) (%)	0.6	0.6	4.6	16.3	18.6
Sand (>20 micron) (%)	99.4	99.3	90.0	80.3	75.4
Silt (2-20 micron) (%)	0.0	0.1	5.3	3.3	6.0
Aus. Soil Texture	Sand	Sand	Loamy Sand	Sandy Loam	Sandy Loam

Preparatory inputs at the site pre-sowing have consisted of a knockdown herbicide spray of 1.5L/ha glyphosate + 75ml/ ha carfentrazone-ethyl, pre-emergent application of 60ml/ha diflufenican on the lentil, vetch and field pea plots, 200g/ha simazine + 200g/ha diuron on the faba bean and lupin plots, 200g/ha simazine + 200g/ha diuron + 50g/ha Isoxaflutol and no pre-emergent herbicide on the vetch + canola and field pea + canola plots.

All treatments received 48kg/ha Granulock.

Inoculants were applied as follows:

- Field Pea, Fababean, Vetch, Field Pea: Tagteam Granular Group E/F (15 g/plot)
- Chickpea: Tagteam Granular Group N (15 g/plot)
- Lupin: Nodulator Granular Group G (15 g/plot)

Table 2: 2020 trial plan

Murraylands and Riverland LB Pulses trial 2020									
		Rep					North	→	GPS Run
0	0		Buffer						60
2.4	1	1	Nil	Chickpea	Beans	Field Pea	Field Pea + Canola		59
4.8	2	1	Spade	Chickpea	Beans	Field Pea	Field Pea + Canola		58
7.2	3	1	Deep Rip	Chickpea	Beans	Field Pea	Field Pea + Canola		57
9.6	4	1	Deep Rip+Spade	Chickpea	Beans	Field Pea	Field Pea + Canola		56
12	5	2	Deep Rip+Spade	Chickpea	Beans	Field Pea	Field Pea + Canola		55
14.4	6	2	Spade	Chickpea	Beans	Field Pea	Field Pea + Canola		54
16.8	7	2	Nil	Chickpea	Beans	Field Pea	Field Pea + Canola		53
19.2	8	2	Deep Rip	Chickpea	Beans	Field Pea	Field Pea + Canola		52
21.6	9	3	Deep Rip+Spade	Chickpea	Beans	Field Pea	Field Pea + Canola		51
24	10	3	Deep Rip	Chickpea	Beans	Field Pea	Field Pea + Canola		50
26.4	11	3	Nil	Chickpea	Beans	Field Pea	Field Pea + Canola		49
28.8	12	3	Spade	Chickpea	Beans	Field Pea	Field Pea + Canola		48
31.2	13		Buffer						47
	14		Buffer						46
33.6	15	1	Nil	Lentil	Lupin	Vetch	Vetch + Canola		45
36	16	1	Spade	Lentil	Lupin	Vetch	Vetch + Canola		44
38.4	17	1	Deep Rip	Lentil	Lupin	Vetch	Vetch + Canola		43
40.8	18	1	Deep Rip+Spade	Lentil	Lupin	Vetch	Vetch + Canola		42
43.2	19	2	Deep Rip	Lentil	Lupin	Vetch	Vetch + Canola		41
45.6	20	2	Deep Rip+Spade	Lentil	Lupin	Vetch	Vetch + Canola		40
48	21	2	Nil	Lentil	Lupin	Vetch	Vetch + Canola		39
50.4	22	2	Spade	Lentil	Lupin	Vetch	Vetch + Canola		38
52.8	23	3	Nil	Lentil	Lupin	Vetch	Vetch + Canola		37
55.2	24	3	Deep Rip+Spade	Lentil	Lupin	Vetch	Vetch + Canola		36
57.6	25	3	Deep Rip	Lentil	Lupin	Vetch	Vetch + Canola		35
60	26	3	Spade	Lentil	Lupin	Vetch	Vetch + Canola		34
62.4	27		Buffer						33
Lameroo Seeps Trial Site									

1.3 Establishment

Early plant establishment was monitored as part of a general groundcover assessment from late May onwards. On June 4, 2020 additional monitoring showed that full crop establishment was still not evident and some species such as canola had not yet emerged. Evidence of moderate soil drift was present at this monitoring.

This had mainly occurred on the sandiest areas of the rise and had in some cases drifted against the emergent crop drills. Emergent crop did not appear to be greatly impacted by the drift but it was difficult to establish the magnitude of any damage with the crop not yet fully emerged. Examination of emergent species showed promising root establishment and this, from comparison to the 2019 trial, may be in part linked to the inoculations undertaken. Chickpeas which performed dismally in 2019 showed much better emergence.

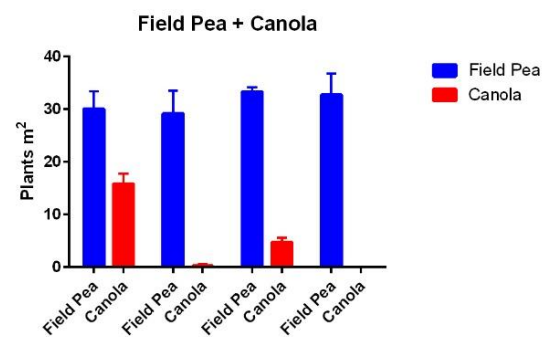
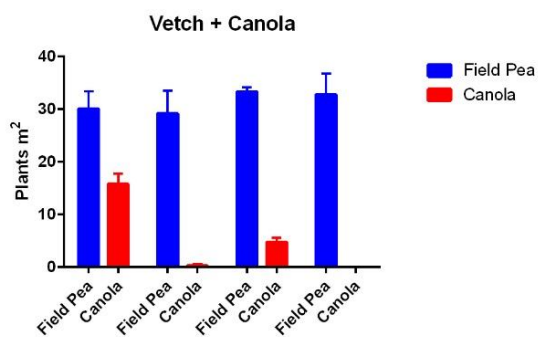
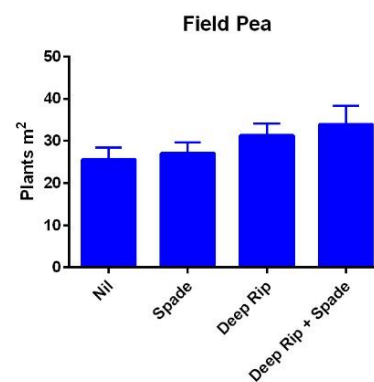
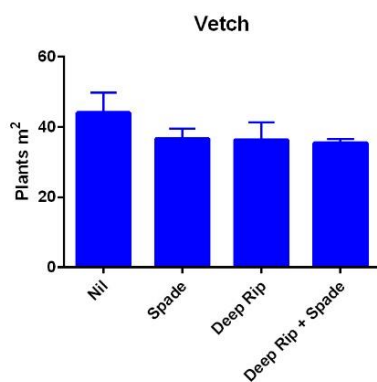
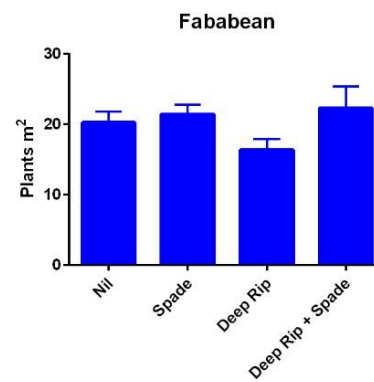
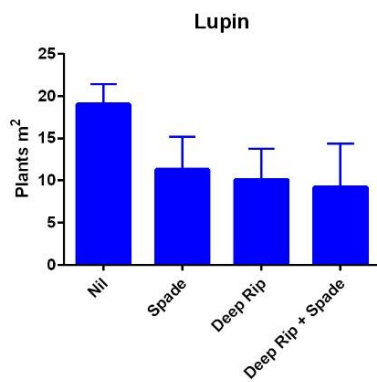
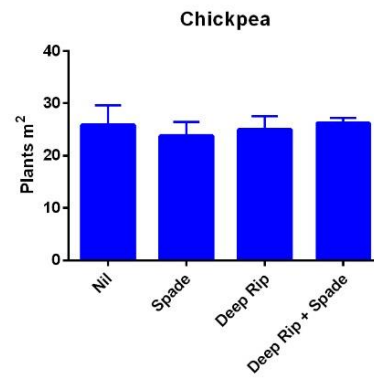
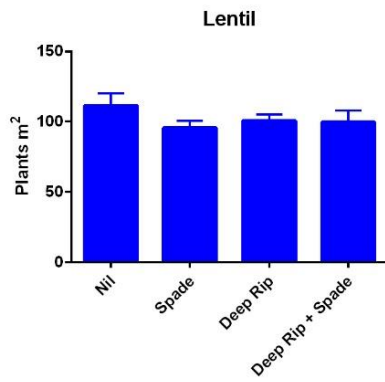


Figure 3: Crop establishment for each crop type and soil amelioration treatment. Error bars are standard errors.



Figure 4: Emergent lentil (above), lupin (centre) and chickpea (right) as at June 4, 2020

Other species such as the field peas and beans were still in the early stages of emergence were exhibiting no obvious issues. Plant establishment was again monitored on the 1/7/2020 and the data is provided in Figure 4. The majority of crop types established had adequate plant populations however the plant density was slightly less than the initial target population (figure 3). Lentils, chickpea, faba bean, field pea, faba bean and vetch have hypogeal germination are able to establish from deeper soil depths than lupins and canola that have an epigeal germination habit.

The soil management treatments of spading and deep ripping significantly impacted the germination of lupin and canola relative to the unmodified soil treatments. This was due in part to strong winds experienced soon after seeding which infilled furrows requiring crops to variably emerge from greater depths than originally sown. In the case of the lupins alkaline sub-soil sediments contributed to a retarding of germination and growth. This scenario exacerbated drift risk in the early part of the season for all crop types.



Figure 5: View of a lentil spaded treatment in July, August and September 2020 show the early season drift potential that hampered the emergence of some crop types

1.4 Seasonal conditions – 2020/21

In 2019/20 observations from the nearby Wilkawatt weather station showed that, during the out of season cropping period from 1 November 2019 to 31 March 2020, a total of 82.4 mm of rainfall was received. This compared to 99.2 mm received in the same period in 2018/19.

Rainfall in the period 1 April 2019 to 9 June 2019 (sowing and final report development) was 45.2 mm compared to 78.6 mm received in the same period in 2020. In 2021 the same period produced only 26.2 mm representing very dry conditions which combined with windy conditions exacerbated soil stability when combined with low groundcover levels. At the new 2021 rotational trial site crops were dry sown in late May pending the start-up of the season. It is these kinds of immediate pre sowing conditions that prove the most challenging for undertaking both sowing and soil amelioration activities such as deep ripping on vulnerable sandy soils.

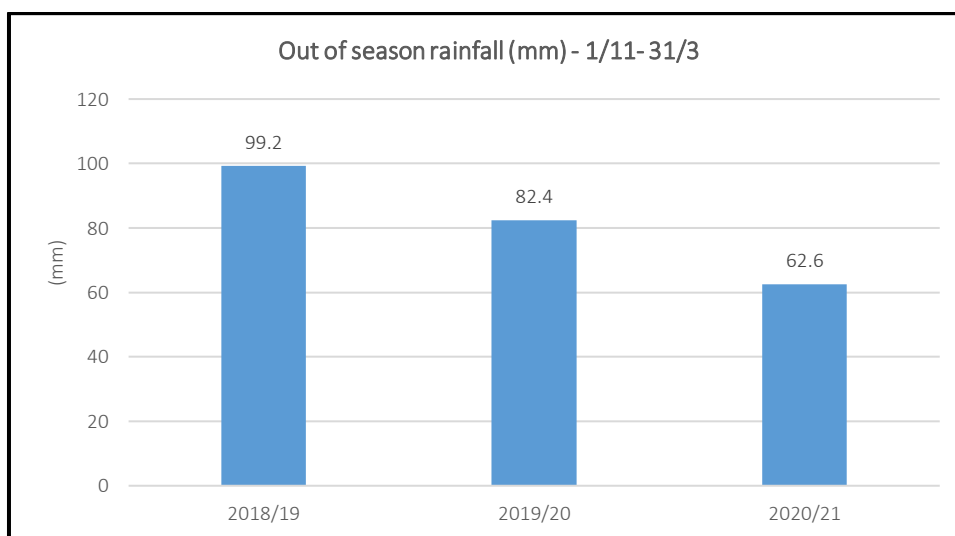


Figure 6: Out of season rainfall (mm) at Wilkawatt for 2018/19, 2019/20 and 2020/21

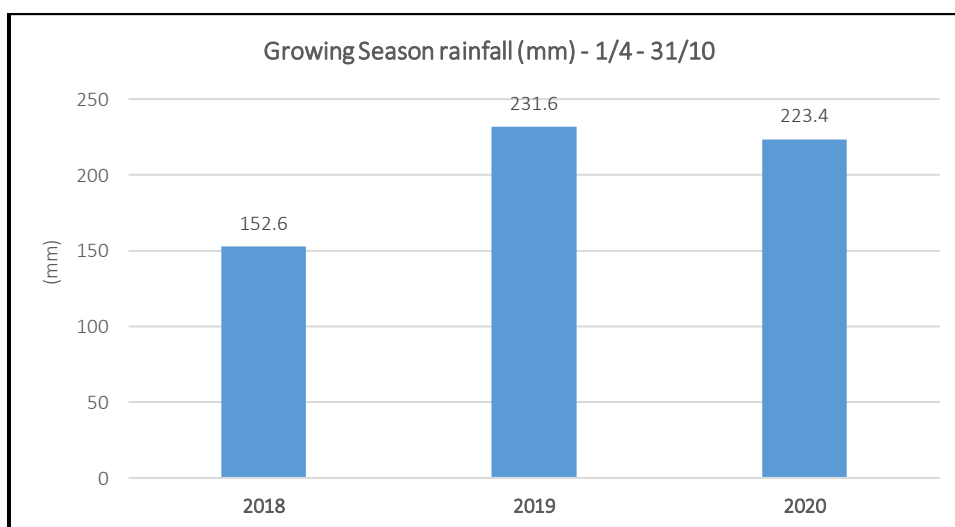


Figure 7: Growing season rainfall (mm) at Wilkawatt for 2018, 2019 and 2020

Out of season rainfall in figure 6 shows the profound difference between seasons with the current 2020/21 year being the most lean. Growing season rainfall between 2019 and 2020 were largely on par and early season indications for 2021 suggest after a drier than average autumn period that there is some optimism that the winter period will be average to slightly below average.

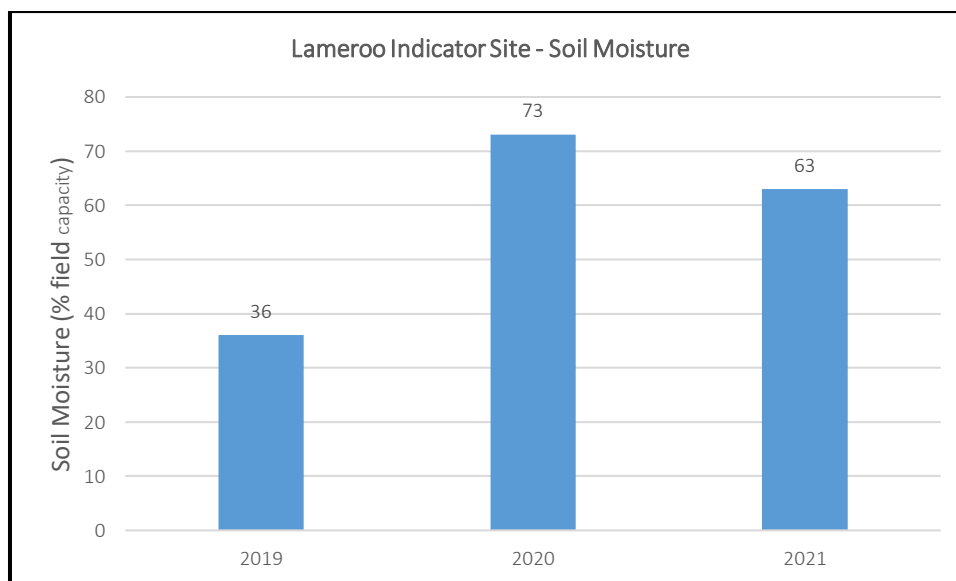


Figure 8: Growing season rainfall (mm) at Wilkawatt for 2018, 2019 and 2020

A review of opening season soil moistures at the nearby Lameroo indicator site showed that surprisingly due to some recent rainfall events in late May and early June 2021 that opening season soil moistures were some 63% of field capacity (sandy rise) compared to 73% at a similar time in 2020.

Wind conditions at the site in 2020 relative to sowing and soil amelioration activities, spiked after sowing on 17 May 2020 and between 20 May and 2 June. During this period maximum wind gusts rose to a maximum of 51.9 km/hour on 20 May before tapering. After a period of several days maximum wind gusts rose to this level again between 31 May and 2 June.

This was enough to cause moderate soil drift where soil had been exposed through soil amelioration activities such as spading. Where groundcover had been retained and even where less soil disturbing activities such as ripping had been undertaken, the residual groundcover improved soil drift reduction.

Comparing wind conditions between 2019 and 2020 it was possible to review current data against historical standards for sandy soil drift potential and to classify wind days. Traditionally maximum wind run days of above 480 km/day have been considered as detrimental to Mallee soils, particularly where the soil type is sandy, unsecured and prone to drift. What the daily wind run (*Wanbi research station field records 1973*) consists of is an aggregation of daily average wind speeds which are summed to provide an indication of current daily conditions against the risk threshold.

Reviewing annual wind data from the Murraylands and Riverland Landscape Board's weather station network (Wilkawatt station) for both 2019 and 2020 produced a regular finding that days that have maximum wind gusts of over 30 km/hour generally have daily wind run totals in excess of 500 km/day. This has made it a relatively straightforward exercise to determine the number of days per annum that the trial site soil type will be at heightened risk irrespective of groundcover as a first step in risk rating.

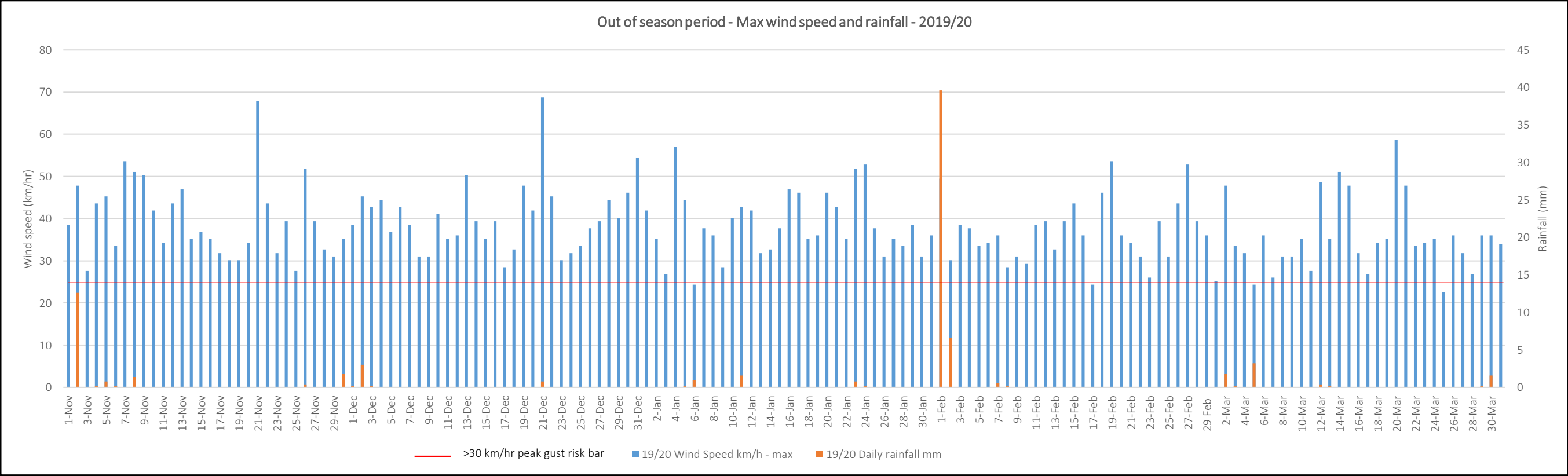


Figure 9: Average daily wind speed (km/hour) and daily rainfall at trial site – 1/11/19 – 09/06/20

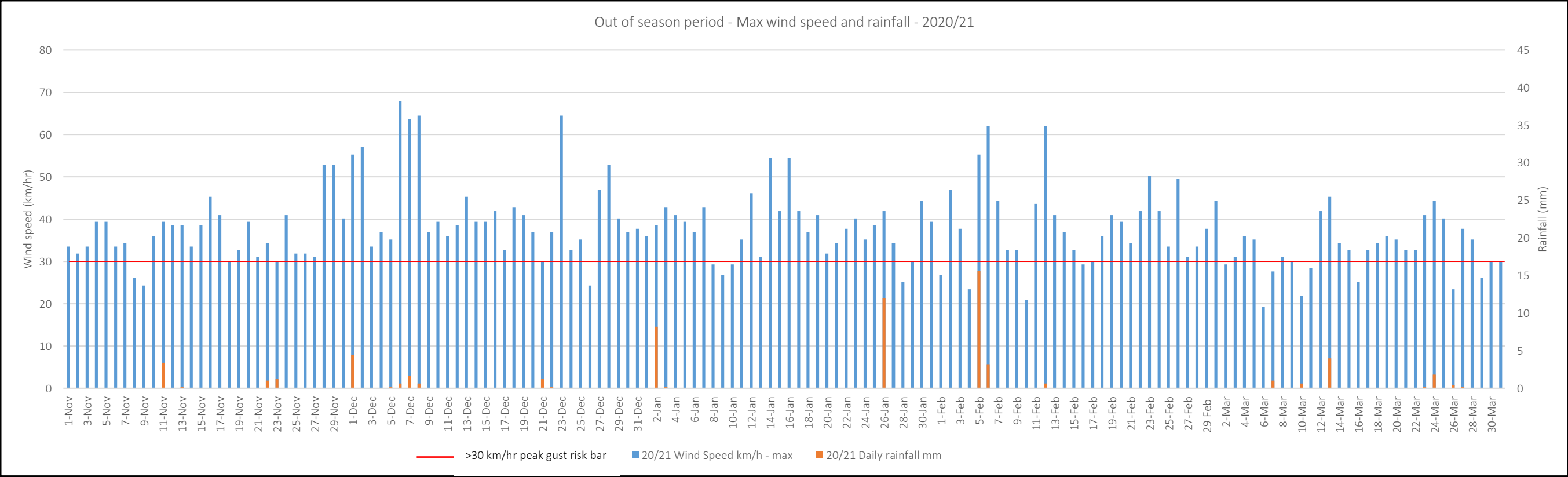


Figure 10: Average daily wind speed (km/hour) and daily rainfall at trial site – 1/11/20 – 09/06/21

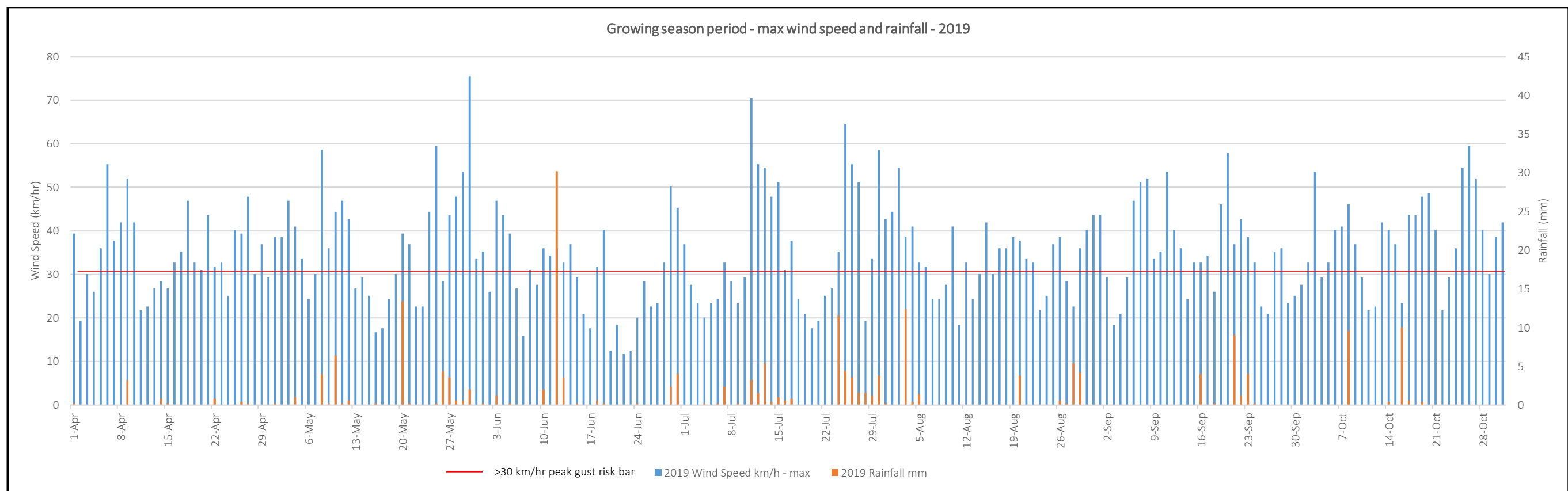


Figure 11: Average daily wind speed (km/hour) and daily rainfall at trial site – 1/11/19 – 09/06/20

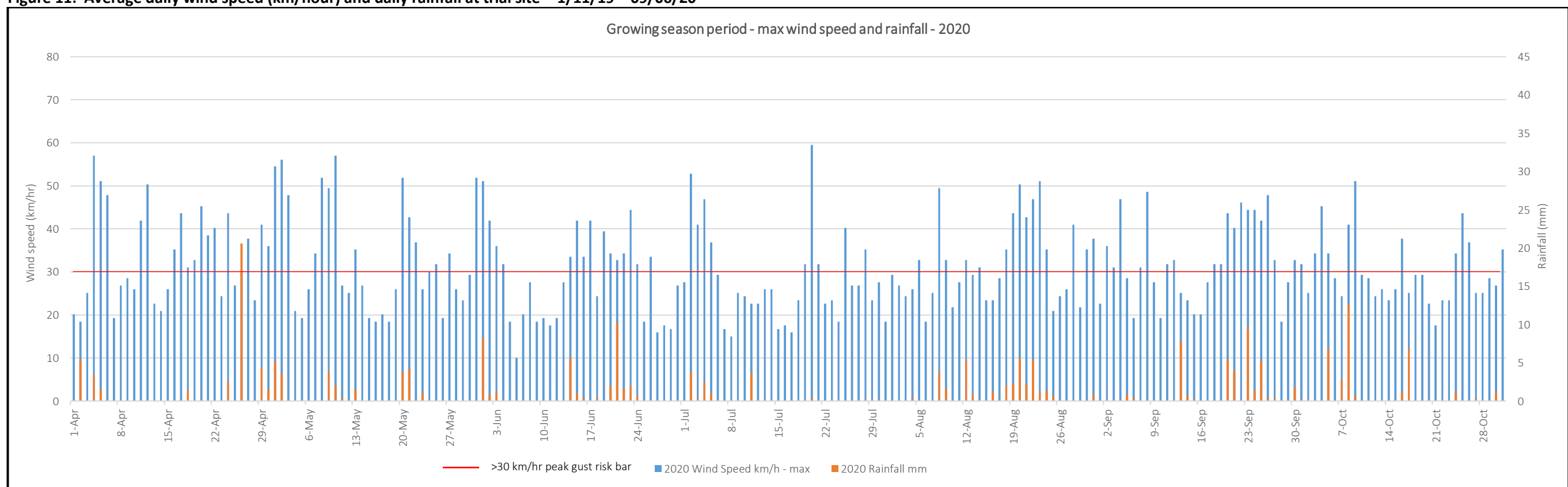


Figure 12: Average daily wind speed (km/hour) and daily rainfall at trial site – 1/11/20 – 09/06/21

The out of growing season periods (Figures 9 and 10) show that days in excess of 30 km/hour maximum gusts far exceed those experienced in the growing season (Figures 11 and 12). This of course is the traditional problem that in periods of low groundcover the most extreme wind conditions generally persist contributing to soil erosion risk.

Reviewing the 2019 and 2020 years further found that for the out of season period that:

Table 3: Out of season days with above 30 km/hour maximum wind gusts

	Total days	Days above 30 km/hour max	Percentage (risk period)
2019/20	152	114	75%
2020/21	151	111	73.5%

The results in table 200 show a fairly consistent result between the two years monitored thus far for the Lameroo district. What the result basically shows is that regardless of groundcover there is heightened risk for three quarters of the time during the out of season period (1 November – March 31), and that in the potential absence of meaningful groundcover there is a 100% guarantee of soil drift in these high risk periods. For the growing season the climatic trend of the Mallee is that wind conditions generally moderate between April and June in the presence of groundcover – essentially the opposite risk scenario but with the major caveat that seasonal conditions and crop germinations have to be conducive to successful cover generation in what is a lessened period of wind erosion risk comparatively. This review found that:

Table 4: Growing season days with above 30 km/hour maximum wind gusts

	Total days	Days above 30 km/hour max	Percentage (risk period)
2019	214	128	60%
2020	214	89	41.5%

The results in table 201 show that 2020 was a lesser erosion risk than the preceding 2019 year but essentially with relatively high risks for both out of season and growing season periods there will be drift events around sowing, soil amelioration and harvesting events which will intensify as groundcover diminishes.

3 Groundcover monitoring

A major focus of this project is identifying which legume crop type will not only produce the highest levels of in-season biomass and reproductive potential but also the longest lasting and most resistant stubble loadings per hectare. Legume stubbles with their higher nitrogen content break down much more rapidly than comparable cereal stubbles and it is this quality that makes it difficult for the landholder to integrate legumes into a rotation on vulnerable ground where a cereal break is sought. The post-harvest management of the site is also much more difficult in these scenarios.

In 2020 a detailed recording of on ground cover levels was undertaken to enable the development of a much more intact assessment of overall yearly risk to soil erosion risk between crop types and around trial site treatments. The major soil amelioration treatments designed to boost root penetration and biomass production yield employed were deep ripping, deep ripping + spading and spading against nil treatment. A trial site plan is detailed in table 3.

The method used to monitor and assess groundcover levels was directly derived from the Department for Environment and Water's soil erosion protection manual (*Forward, G 2015*) which

assigns a consistent approach to monitoring soils against erosion risk through wind and water by estimating groundcover in and out of growing season periods. This is done in conjunction with considerations of, slope/topography and soil type.

In practice field data collection mostly consisted of sheer groundcover ratings against both photographic and figurative standards across both fallow and in season periods. This results in the singular numerical definition of risk per monitored zone through a colorimetric scale (developed for this project) against the specific groundcover level guidelines. This enabled a simplified approach to assigning consistent groundcover ratings for each monitoring session per crop type and plot/trial treatment or replicate – these records are detailed in tables 6 – 14.

For the purposes of this report this simplified colorimetric scale appears under each monitored plot diagram in a scale that ranges from 8 (zero cover) through to 1 (full cover). There are as previously mentioned two divisions in this scale – the scale used for fallow or non-growing periods where considerations are of stubble loads/consistencies and percentage groundcover and then the scale for the in season crop period ranging once again from emergent crop with little or no associated cover (7) through to above 30 cm high biomass with good residual stubbles and high percentage overall cover (1) as per figure 14. There is as such no designation of biomass weights per ha – it is an indicative scaling system based on erosion risk and the calibration is based on a visual assessment rating against the standards which comprise a mixture of photographic standards (see figures 13 and 14 below) and an indicative guide

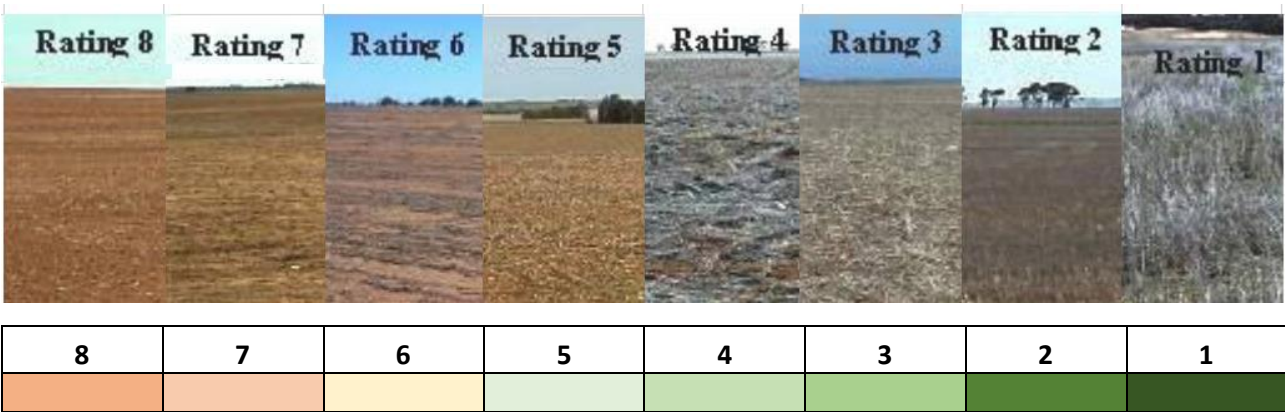


Figure 13: Cover fallow standards used for assessment and colorimetric standard derived



Figure 14: Cover crop ratings used for assessment and colorimetric standard derived

In practice monitored groundcover was considered not only for biomass height relative to the standards but for percentage cover against the guidelines. Additionally crop emergence and crop counts were supplemented with biomass cuts and estimates of biomass in tonnes/ha (see section 4).

Spatial measurement of total chlorophyll at peak biomass was undertaken by the use of drone imaging (Standard and Red Edge NDVI) and together this resulted in the development of two parallel estimates of groundcover across the full year period – a visual monthly eye based

assessment and associated estimates of peak biomass derived through both quadrat cuts and spatially through drone imagery.

3.1 Groundcover monitoring – Pre-sowing - May 2020

Refer table 6 - Prior to sowing the trial in May 2020, an opening site monitoring of residual groundcover was undertaken. A photo record was developed in a V shaped transect across the trial site pre-sowing on May 6 and May 20, 2020. Observations at the site found that there was highly variable residual stubble cover from barley in the 2019 season.



Figure 15: May 6, 2020 – Monitoring transect 1 start



Figure 16: May 6, 2020 – Monitoring transect 1 finish



Figure 17: May 20, 2020 – Monitoring transect 2 start



Figure 18: May 20, 2020 – Monitoring transect 2 finish

The land system at the site has a relief ranging up to approximately 5 metres as a low sand hill system. This combined with the soil type rates the site as category 4 (or high risk) for wind erosion. Slope at the site was found to range between 1.5-3% equating to a water erosion rating of 1 or low. Pre-sowing observations at the site noted some degree of gouging due to wind erosion on highly variable cereal stubble loads. This was evidenced by sand stack up on 2019 crop furrows. The results of site evaluation by transect produced an averaged site rating for combined erosion risk of 4 to 7 (out of a possible scale ranging from 1 or low risk through 8 or extreme risk) across the site. Observed stubble anchorage was good as were residual soil moisture levels (see table 300). High risk days were 14 out of the 24 days post sowing which was approximately 60% of days post sowing. This approach was replicated over the monitoring year period.

3.2 Groundcover post emergence

3.2.1 Monitoring results June 2020

Refer table 7 - Post sowing it was possible to re-define both the impacts of soil amelioration in the deep ripping and spading treatments against general sowing disturbance which varied across the site from minimal to near total residual groundcover loss. The worst rating achieved was an 8 or total loss of groundcover and this combined with the 14 high risk days out of 30 (46% of days in the month) equated to some quite severe drift out which mostly gouged out furrows where looser soil material had aggregated after sowing. In table 7 it can be seen that by and large this tended to

affect the ameliorated sites which against the fallow standard (as emergence was still in progress) produced some maximum loss results of 8 where nil and buffer treatments still produced level 6 results (see table 7).

3.2.2 Monitoring results July 2020

Refer table 8 - By July the risk window had largely closed off the lentils, chickpeas, Faba beans, vetch, field peas and the vetch/canola and field pea canola treatments both of which experienced slow canola emergence. July was a very calm month with only 7 out of 31 days being high risk (22% of days), although one of those days gusted up to 60km/hour. This calmer month provided some respite to young crops with some of the vetchola and peaola plots rapidly moving up to a crop standard of 3 in some of the soil amelioration treatments. The lupins performed the poorest, mostly in the amelioration treatments where they struggled with the alkaline subsoils and very slow establishment. This left all of the amelioration treatments open to further erosion and by the end of July winds had largely refined these and the other treatments that were slow to establish back largely to the substrates that had been brought to the surface.

3.2.3 Monitoring results August 2020

Refer table 9 - August monitoring saw tremendous advancements in the development of the field pea and field pea/canola treatments with some of these treatments attaining a category 2 status, largely a three month turnaround from very high risk conditions in May/June. By this stage most of the soil amelioration treatments were beginning to show the benefits to increased root penetration and biomass production across all of the sites except the lupins. The lentils and chickpeas had gained momentum showing similar improved biomass in the soil ameliorations versus the nil treatments and buffers. To be fair the chickpeas and lentils were at the hilltop and weathered some extra impacts from hilltop drift but by August were of sufficient strength to overcome these issues. High risk days were once again around 14 for the month or 45% of days.

3.2.4 Monitoring results September 2020

Refer table 10 – September was a tremendous month for biomass increase at the site and conditions were relatively calm with only 10 out of 30 days experiencing maximum gusts above 30 km/hour equating to around 33% of days. Filling in of plots in the lentils and chickpeas was a feature of September with plots standardising to level 3 or 4 results and with a reasonably consistent response to soil amelioration treatments.

The lupin soil amelioration treatments finally progressed to a level 7 crop standard which effectively still was a fairly bare low cover scenario but other treatments had at least progressed to level 5. The Faba beans showed a significant additional development capacity in the soil amelioration treatments and this was also mirrored in the vetch, field pea, vetch-canola and field pea-canola treatments.

3.2.5 Monitoring results October 2020

Refer table 11 - October monitoring was largely due to the season in 2020 considered peak biomass with rainfall continuing into the month and with only 10 lesser intensity risk days noted or ~32% of days. By October it was very clear that most if not all soil amelioration treatments had produced tremendous dividends in terms of increased crop biomass and by this stage even the lupins had achieved reasonable levels of biomass and cover.

Overall it was the field pea and field pea/canola treatments that produced the highest amounts of biomass and groundcover in season with plants eclipsing the 80cm height mark and highly intertwined.

It was mostly the deep ripped, spaded and combination treatments that achieved the maximum numerical rating of 1 demonstrating the cumulative benefits of increased root penetration and moisture accessibility.

3.3 Groundcover monitoring post peak biomass

3.3.1 November 2020

Refer table 12 - By November the inevitable regressions in above ground biomass were becoming visible. Once again the lentils and chickpeas were showing almost uniform high rates of regression in the buffer and nil treatments where these plots had slid back to a category 5 groundcover rating. Lupins had pre-existing issues and these were opposite to the rest of the trial in that the soil amelioration treatments had regressed to a level 6 by this point. Faba beans/vetch, field pea and to a lesser degree the mixed field pea/canola and vetch canola plots were all showing noticeable depreciation in the nil and buffer strips with regressions ranging from 5-6. The field pea and field pea/canola treatments retained the highest scoring groundcover biomass option in the amelioration treatments still producing results in the 1-2 range. November was a reasonably hazardous month from a wind intensity perspective with 22 of the 30 days gusting above 30 km/hour equating to risk days being about 73% of days.

3.3.2 December 2020

Whilst no groundcover monitoring was undertaken in December the month was high risk with 29 out of 31 days experiencing maximum gusts above 30 km/hour. Harvest occurred in the period and added to this there was a very intense period between late November and December 7 where winds gusted to ~70 km/hour. This contributed undoubtedly to the detachment of many of the larger biomass crop types such as the field peas. This biomass was largely absent by the January monitoring and the contrast between the November and January monitoring was stark. Overall the month of December featured around 90% of days being high risk greatly depreciating site groundcover.

3.3.3 January 2021

Refer table 13 - Between November and January the predictable major decline in groundcover occurred. Within the lentils and chickpeas there was by this point a uniform level 7 across all plots regardless of treatment and this had led to noticeable drift accumulation on what stubbles remained post-harvest. To be fair the lupins had always had issues throughout the growing season and were most stable in the nil and buffer treatments although treatments 32, 34 and 39 still had level 6 groundcover aspects. The Faba beans had lost much of their biomass across the plots 43 – 50 but this may have been associated with traffic and generalised wind velocities which overtopped at the crest of the lentils/chickpeas before dissipating further downslope. The consistency in the faba plots 51 – 56 tends to support this observation with uniform level 6 coverages being found. The vetch showed very well that soil amelioration and increased biomass had produced a more resilient and longer lasting groundcover with the field pea, vetch-canola, field pea-canola treatments retained high consistent groundcovers mostly within the level 6 domain. From a rainfall perspective there were two decent rainfall events on January 2 and 26 which totalled 20.4 mm. from a wind perspective the month was reasonably gusty and this would have greatly affected the level 7 plots. For the month 24 of 31 days were high risk gusting above 30 km/hour equating to 77% of days.

3.3.4 February 2021

Refer table 14 – February groundcover monitoring concluded the monitoring approach at the site with March monitoring not being possible due to other commitments. At any rate by this stage it was clear which crop types and treatments had the staying power. The chickpeas and lentils despite being attractive crop types economically were completely lost as a groundcover option within the period between November and January where they had largely slid to a category 7 result.

It would be fair to say also that the lupins due to their dislike of the soil amelioration treatments had to be very fair generated enough biomass in plots 32, 37 and 39 to withstand total biomass demise but this residual cover was patchy. Fabas unfortunately had all but disappeared by February most likely due to the effects of wind moving downslope and gouging. Ultimately it was the field peas and vetch and vetch-canola/field pea-canola treatments that held on the longest and mostly within the amelioration treatments. This result validates that risks first monitored in the

May/June period in and around soil working and sowing may be balanced by the reward of longer residual groundcover by comparison to controls. This risk period (refer table 301) suggests that overall for these crop types that the ~1 month risk period where the monthly totals of high pressure days are lesser than later in the season (at least in this project phase) is balanced by the reward of better longer term groundcovers which last to February+ of the following year – achieving minimum level 6 groundcovers – a very positive result. As a month February 2021 was very gusty with around 78% of days being high risk with some periods gusting up to 60 km/hour – a potentially highly erosive period that ultimately greatly affected the ground were ground cover had entirely depreciated.



Figure 19: Field Pea-Canola deep ripped treatment October 2020



Figure 20: Field Pea-Canola deep ripped treatment January 2021



Figure 21: Lentil deep ripped treatment October 2020



Figure 22: Lentil deep ripped treatment January 2021

3.3.5 March 2021

Whilst no groundcover monitoring was undertaken in March the month was lower risk with 14 out of 31 days experiencing maximum gusts above 30 km/hour. This equates to around 45% of days being high risk.

Table 5: May 2020 groundcover monitoring and risk rating – fallow standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded.

FIELD PEA/CANOLA														VETCH/CANOLA													
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
FIELD PEA														VETCH													
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
FABA														LUPIN													
56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
CHICKPEA														LENTILS													
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF

Table 6: June 2020 (Post sowing) groundcover monitoring and risk rating – fallow standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded.

FIELD PEA/CANOLA														VETCH/CANOLA																																			
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85																						
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																						
FIELD PEA														VETCH																																			
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57																						
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																						
FABA														LUPIN																																			
56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29																						
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																						
CHICKPEA														LENTILS																																			
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1																						
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																						
8								7						6						5						4						3						2						1					

Table 7: July 2020 groundcover monitoring and risk rating – crop standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded.

FIELD PEA/CANOLA														VETCH/CANOLA																																		
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85																					
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																					
FIELD PEA														VETCH																																		
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57																					
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																					
FABA														LUPIN																																		
56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29																					
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																					
CHICKPEA														LENTILS																																		
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1																					
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																					
7							6							5							4							3							2							1						

Table 8: August 2020 groundcover monitoring and risk rating – crop standard – fallow standard ‘8- applied to non-emergent lupins - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded.

FIELD PEA/CANOLA														VETCH/CANOLA													
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
FIELD PEA														VETCH													
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
FABA														LUPIN													
56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
CHICKPEA														LENTILS													
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
7														6													
5														4													
3														2													
1																											

Table 9: September 2020 groundcover monitoring and risk rating – crop standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded.

FIELD PEA/CANOLA														VETCH/CANOLA																																																																																			
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85																																																																						
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																																																																						
FIELD PEA														VETCH																																																																																			
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57																																																																						
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Table 10: October 2020 groundcover monitoring and risk rating – crop standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded.

FIELD PEA/CANOLA														VETCH/CANOLA																																		
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85																					
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																					
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BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																					
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BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																					
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Table 11: November 2020 groundcover monitoring and risk rating – fallow standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded.

FIELD PEA/CANOLA														VETCH/CANOLA																																																																																																															
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BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF																																																																																																		
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Table 12: January 2021 groundcover monitoring and risk rating – fallow standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded

FIELD PEA/CANOLA														VETCH/CANOLA													
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
FIELD PEA														VETCH													
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
FABA														LUPIN													
56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
CHICKPEA														LENTILS													
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF
8	7	6	5	4	3	2	1																				

Table 13: February 2021 groundcover monitoring and risk rating – fallow standard - treatment key – BF = Buffer strip, Nil = Nil treatment or control, SP = spaded, DR = deep ripped, DR + S = Deep ripped and spaded

FIELD PEA/CANOLA														VETCH/CANOLA																					
112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85								
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF								
FIELD PEA														VETCH																					
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57								
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF								
FABA														LUPIN																					
56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29								
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF								
CHICKPEA														LENTILS																					
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1								
BF	Nil	SP	DR	DR+S	DR+S	SP	Nil	DR	DR+S	DR	Nil	SP	BF	BF	Nil	SP	DR	DR+S	DR	DR+S	Nil	SP	Nil	DR+S	DR	SP	BF								
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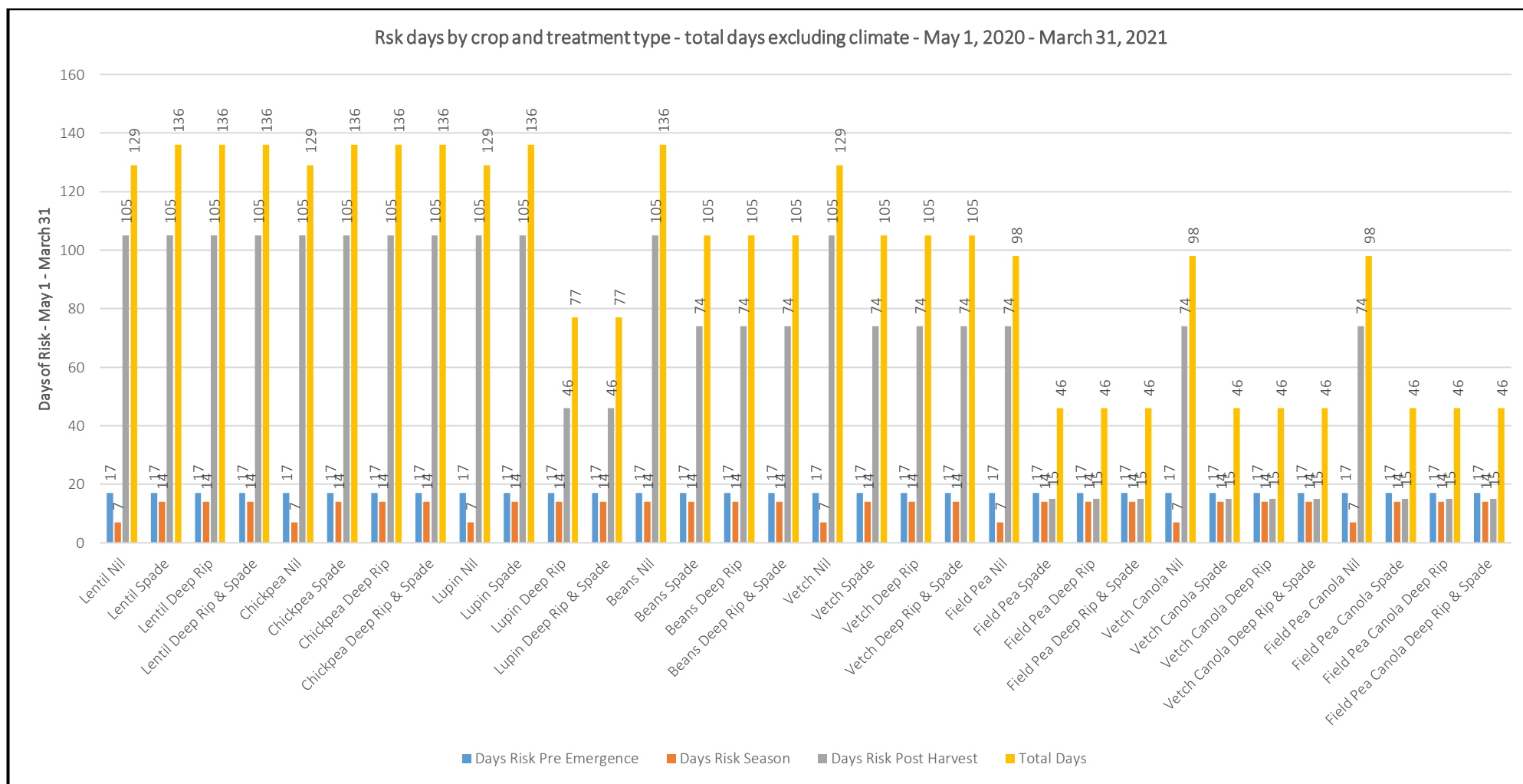


Figure 23: Breakdown of risk periods (total days) by crop type and treatment

4 Biomass yield results

Biomass generation in the trial varied considerably across the season and in response to treatment. In the previous section it is evident that excepting the lupin trial the remaining crop types produced significantly more biomass under the soil amelioration treatments than the nil or buffer treatments. There was a cost price to this additional biomass in the initial de-stabilisation and disturbance of the soil type at a seasonal period where daily wind runs and wind gusts were significant (refer figure 11). This initial risk however became offset later in the season across some crop types as the additional biomass generation extended groundcover well into the early part of 2021 in some but not all crop types.

In Figure 24 the differences in biomass generation can be interpreted through the results by crop type. These figures were collected in early October 2020 at determined peak biomass. The result largely reflects the findings from the monthly groundcover surveys with the field pea-canola topping the result with some 6.45 t/ha of wet biomass and ranges down to the lentil which at best produced some 2.23 t/ha of biomass comparatively.

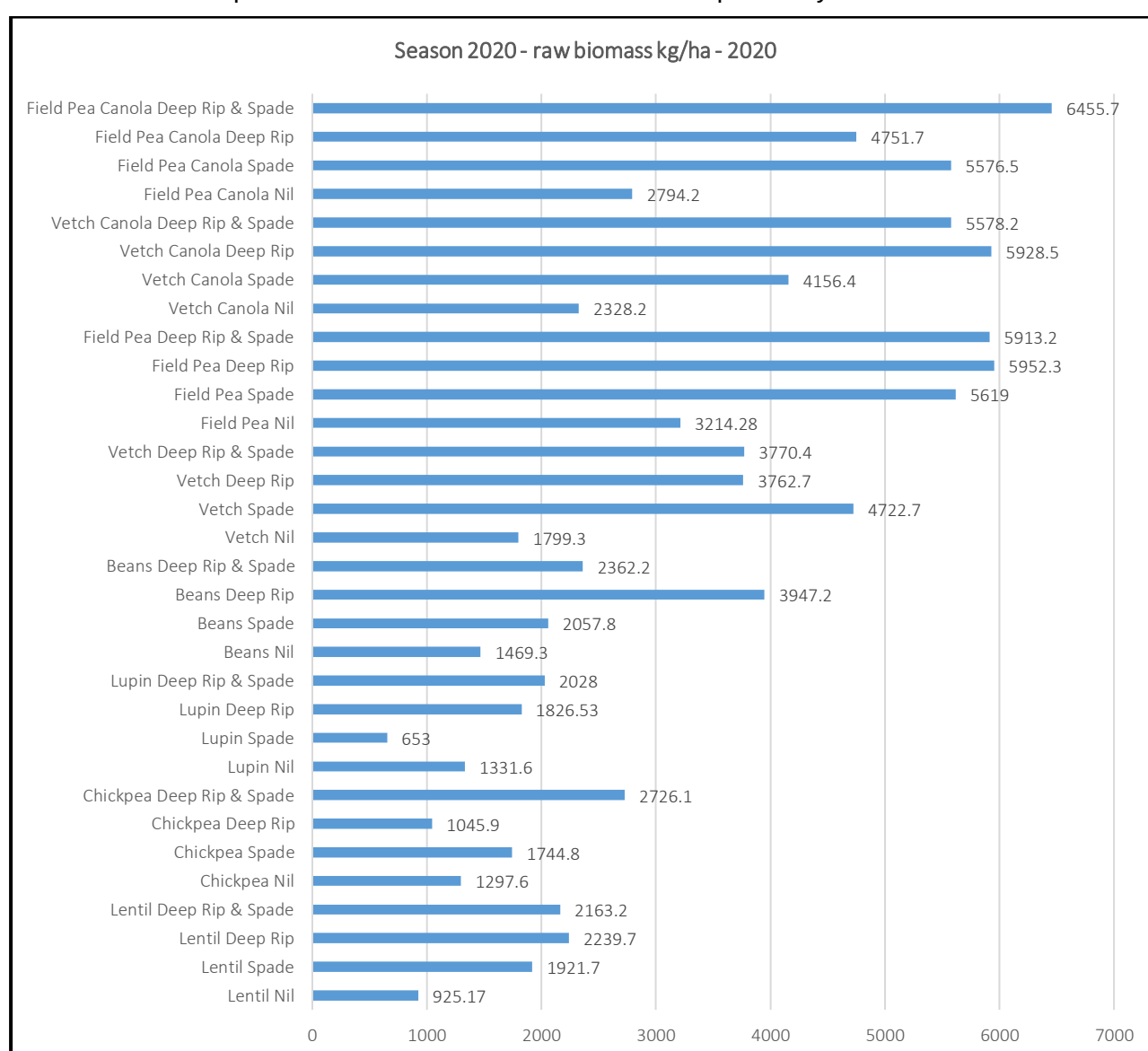


Figure 24: Raw biomass cuts extrapolated to per/ha biomass tonnages – 2020

Viewing this data in isolation however does not provide an adequate perspective of how the biomass formed and how long it protected the soil and land system comparatively over the course of the full annual year rather than just during the seasonal period of annual growth.

The earlier discussion in section 3 has highlighted the classic Mallee dilemma in that seasonal conditions are generally calmer during the annual winter growth cycle as opposed to the out of season period and leading into sowing where there is reduced groundcover and this is readily highlighted in the monthly summaries (tables 6-14) and the climatic records for the 2020/21 period (figures 9-12). These highlight statistically significant higher incidences of higher risk erosive winds outside of the cropping cycle across the two monitored years of the trial.

After having extensively recorded per plot groundcover incidences and total biomass the next basic analysis undertaken was to comparatively analyze the monthly monitoring data as total days of risk against the annual conditions by crop type and treatment. This was not a highly exacting process sheerly due to the fact that edge effects in the plot trials were great and these increased throughout the season in response to climate and traffic. Late in the season wire weed became a significant issue in some places and this has been largely screened out of consideration against the ideal undisturbed plot scenario.

The aggregation of day risk data is shown in figure 23 – this shows simplistic relationships between groundcover ratings and duration by crop type and treatment. Essentially the result shows that in conjunction with the result for total biomass that the field pea-canola and vetch-canola treatments had the least total days overall of all crop types but this was only the case in the ameliorated treatments.

In figure 25 the spatially derived values for Red Edge NDVI (September 2020) can be seen against the vegetation cover fraction values. The result validates the ground based observations undertaken in the monthly monitoring's which are figurative and shows that at peak biomass that excepting lupins most of the monitored responses show that Red Edge NDVI values or were generally greatest in the treatments.

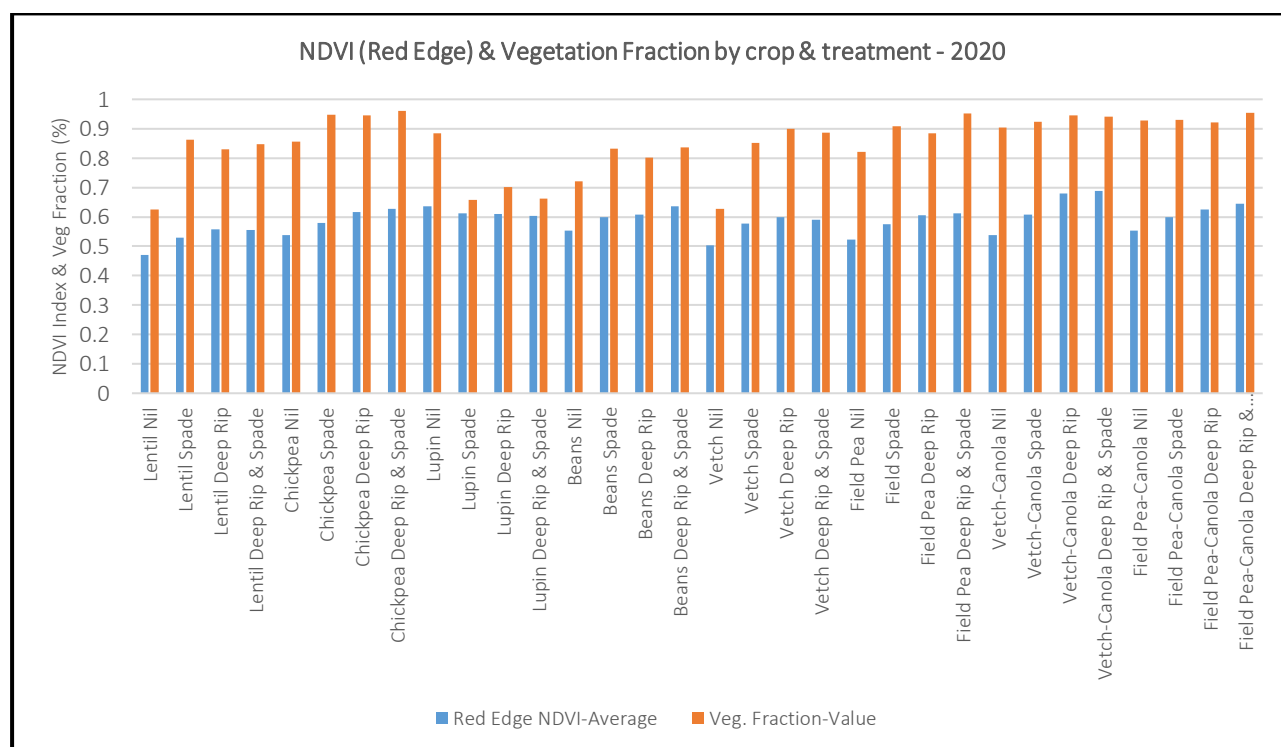


Figure 25: Spatially interpreted red edge NDVI and vegetation fraction values by crop type – 2020 trial

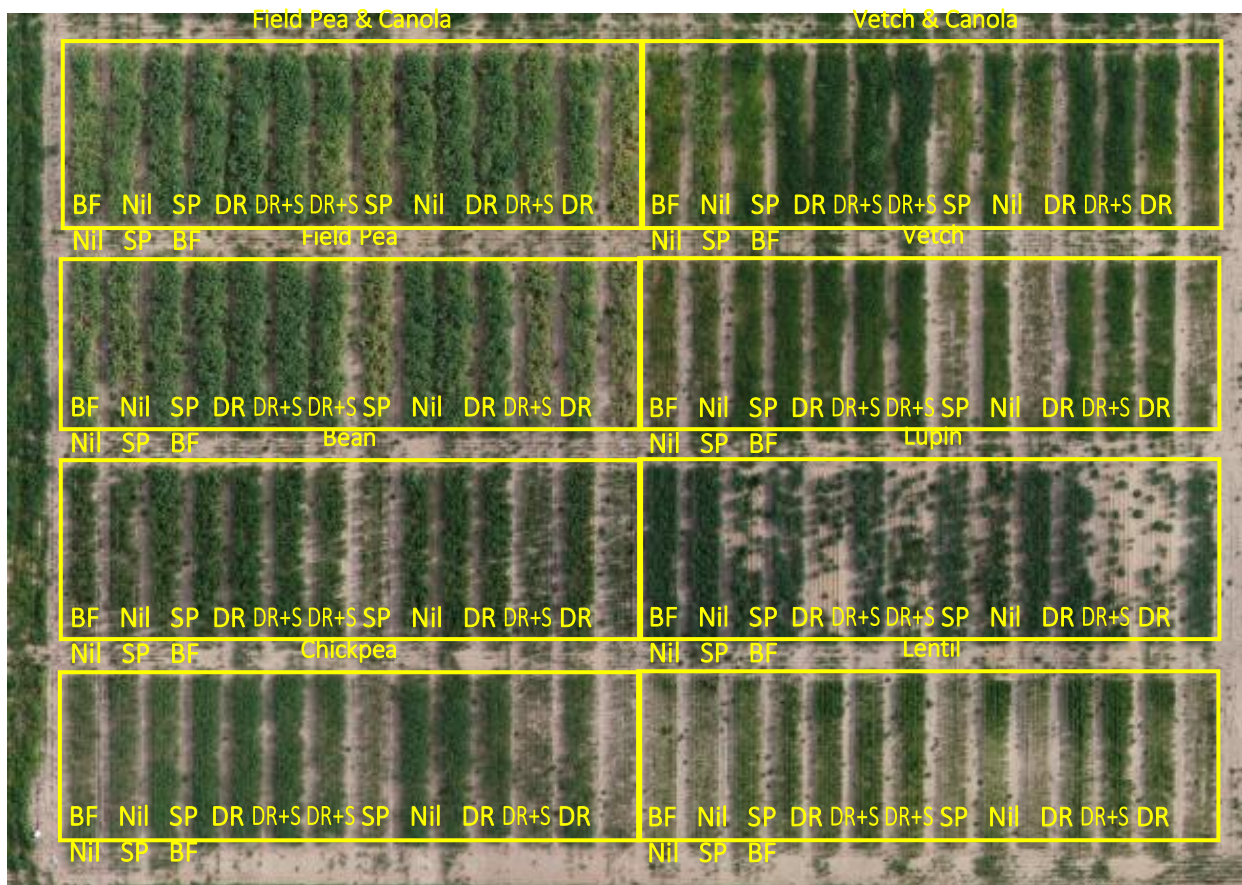


Figure 26: Plot vigour viewed at peak biomass, September 2020

The 'Red-Edge' NDVI index is essentially the NDVI result at a monitored wavelength of +/- 720 nm and as a spectral wavelength it is not as readily absorbed by the plant surface producing a reflectance result that is largely construed as having greater plant canopy penetration. This results in the production of a more ready estimate of overall canopy density. Conventional NDVI which works around the standard visible red light spectrum it is accepted - is as a wavelength much more readily absorbed into the plant surface thereby producing more of a top surface canopy reflectance result which is generally construed of providing more of a better estimate of plant surface density.

The results for vegetation fractional cover are interesting in that as a stand-alone result the interpretation does not of course pick up the large differences in residual groundcover potential that occur post-harvest, i.e. biomass and cover are rated uniformly against the nil treatments and simplistically between crop types – a good example of this is the vegetation fraction cover rates for the chickpea versus the field pea canola and vetch canola results. As such it is essential to consider the previous discussions on residual groundcover potential in conjunction with the biomass and yield summaries to gain a holistic viewpoint. In figure 26 the true colour image of the site at peak biomass matches the graphed results in figure 25 showing the spatial differences in groundcover and groundcover percentages at the time of image sampling.

Arguably the results in Figures 24 and 25 tell a story that success with legumes in this land system are based on generating good consistent cover. There is perhaps not much between some crop types in terms of canopy density but significantly the soil amelioration treatments have contributed greatly to vegetation cover with improved canopy density and this is not only the signal that groundcover potentials are good but also that plant productivities are higher and more productive within some treatments and crop types over others. Once again the vetch-canola and field pea-canola treatments were standouts in this regard.

Essentially the results for biomass and ground stability can be grouped:

Chickpeas and Lentils – treatments did significantly boost total biomass (refer also figure 25) but the nil treatments had a slightly lower overall risk perspective due to the reduced incidence of heightened erosion risk by preserved groundcover. This is not seen as being a reason to not pursue the treatments and is a smaller risk compared to the overall yield benefits that were gained. Overall however the chickpeas and lentils not surprisingly represented the highest overall risk to soil erosion and this was of course largely borne on the back of the light overall canopy of the crop type and the extreme propensity for bio-degradation and detachment of the stubbles post-harvest. Gusty winds into December 2020 assisted this to happen and to be fair most site traffic convened adjacent these plots.

Lupins – the lupins struggled mostly in the treatments due to both soil drift and alkaline sediment incorporation through the deep ripping and spading process. This same sub-soil appeared to also have a higher salinity in field testing and this did not assist the crop type. Overall however the crop type did recover later in the season but from an erosion risk management perspective the result was very poor – essentially the lupins produced the inverse result for the trial, performing best in the nil and buffer strips although some of the deep ripped and combined spaded treatments produced the better late season residual biomass result for the crop type, refer also figure 24. Figure 25 also shows that the lupin deep ripped treatment produced the best vegetative responses across the crop type.

Faba beans - the beans performed best in the ameliorated treatments and overall produced the best biomass and residual groundcover results in the deep ripped and spaded treatments. In figure 23 the minimum total day risk result possible for the maximum biomass and grain yield return was 105 days total risk for the improvement over the nil treatment that generated a higher risk due to chiefly the much earlier dissolution of the bio-mass comparatively. The nature of the bean canopy is impressive in season but is prone to extensive detachment post-harvest and this suggests that a mixed crop type approach to cultivating beans may improve the post-harvest scenario.

Vetch – produced better results in the ameliorated treatments (deep ripped, see figure 25), but overall in terms of longer term residual biomass the result was fairly level for vetch. This probably has much to do with both the root system and canopy of the plant and the resistant nature of the vetch stubbles which are low canopied and tight. Vetch canopies by virtue of their structure tend to compress under traffic rather than detach and this is a major advantage to the crop type in terms of promoting residual cover under challenging conditions. In the final analysis it there was a fairly uniform result for vetch and it was likely that traffic impacted the result. Undoubtedly there were tremendous responses to soil amelioration treatments and that overall risk to drift was actually reduced in the soil treatments over the nil treatments.

Field Pea – There were substantial responses in the soil treatments and these treatments greatly outstripped the nil treatments for biomass yield (see figure 25). The interpreted margin for increased risk over the nil treatment in the growing season amounted to 7 days or essentially an insignificant difference against the benefits of the treatments. The treatments produced both better yields (see section 5) as well as greatly improved biomass which left a lasting groundcover leading into the 2021 season.

Vetch-Canola – Perhaps a bit on par with the plain vetch treatment the Vetch-Canola treatment produced similar longer term residual biomass results but at a higher rate (deep ripped, figure 25) and this also was reflected in grain yield outcomes. It can be seen in figure 23 that from an overall risk perspective that the nil treatment resulted in significantly higher overall risk post-harvest compared to the treatments with respectively minimal opposing risks generated through soil amelioration (figure 23). However regardless of this point the distances involved in this consideration were minimal (i.e. between strips) and overall the longer term biomass result showed more clearly in this crop type the benefits of amelioration.

Field Pea-Canola – responded arguably the best to the amelioration soil treatments over the whole trial producing vastly improved biomass over the nil treatments (deep ripped + spaded, figure 25). The interpreted result for biomass and groundcover stability across the monthly summaries and into the biomass yield record in figure 24 shows the magnitude of change that the soil treatments have produced against the risk profiles in figure 23.

The field pea-canola treatments show a similar picture to the other crop types in that over a whole season risks to soil drift were actually higher in the nil treatments. In the final analysis it may be that traffic and edge effects smudged the overall longer term residual biomass result but it is anticipated that in a broader cropping scenario with good residue management that much better residual biomass levels over the nil treatment are achievable with the added benefits of greatly improved grain yields.

5 Grain yield results

The site was harvested on the 2nd of December and the results have been compiled in Figures 27 and 28. In the course of harvest some significant yield differences were observed in the initial analysis of results. All crop mixes and individual crop types showed a positive yield response to soil amelioration treatments apart from as expected - lupins.

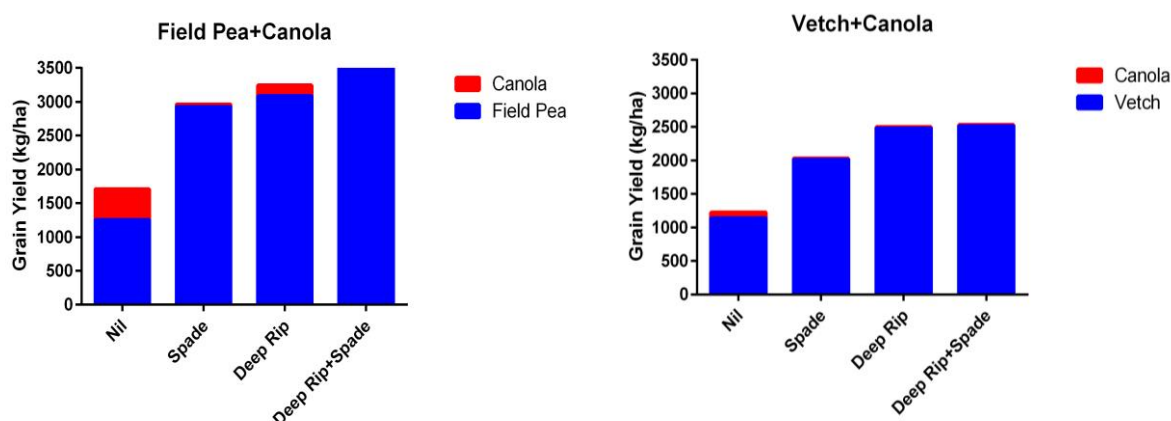


Figure 27: Yield results for mixed crops versus soil amelioration treatments

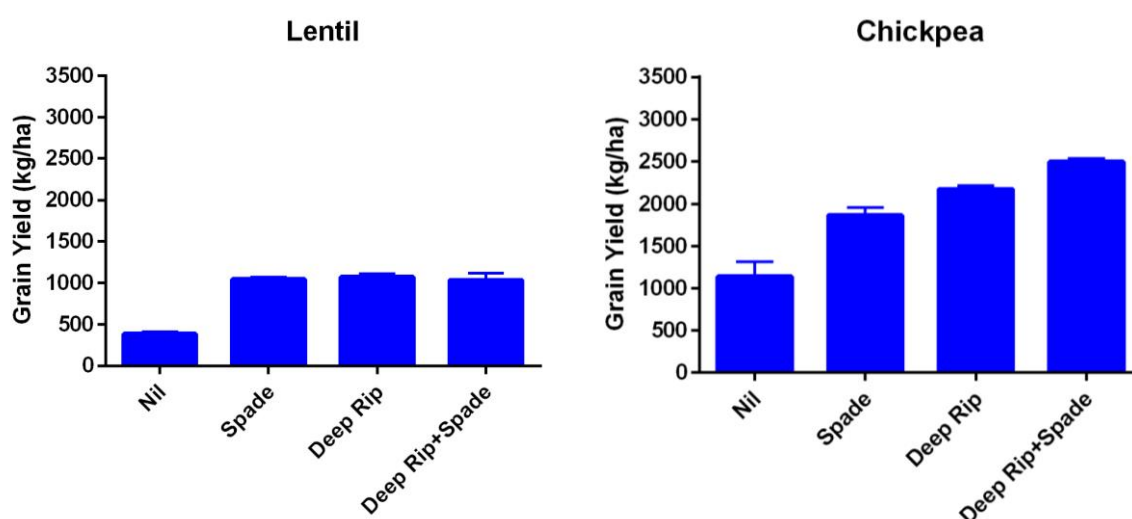


Figure 28: Yield results for lentils and chickpeas versus soil amelioration treatments

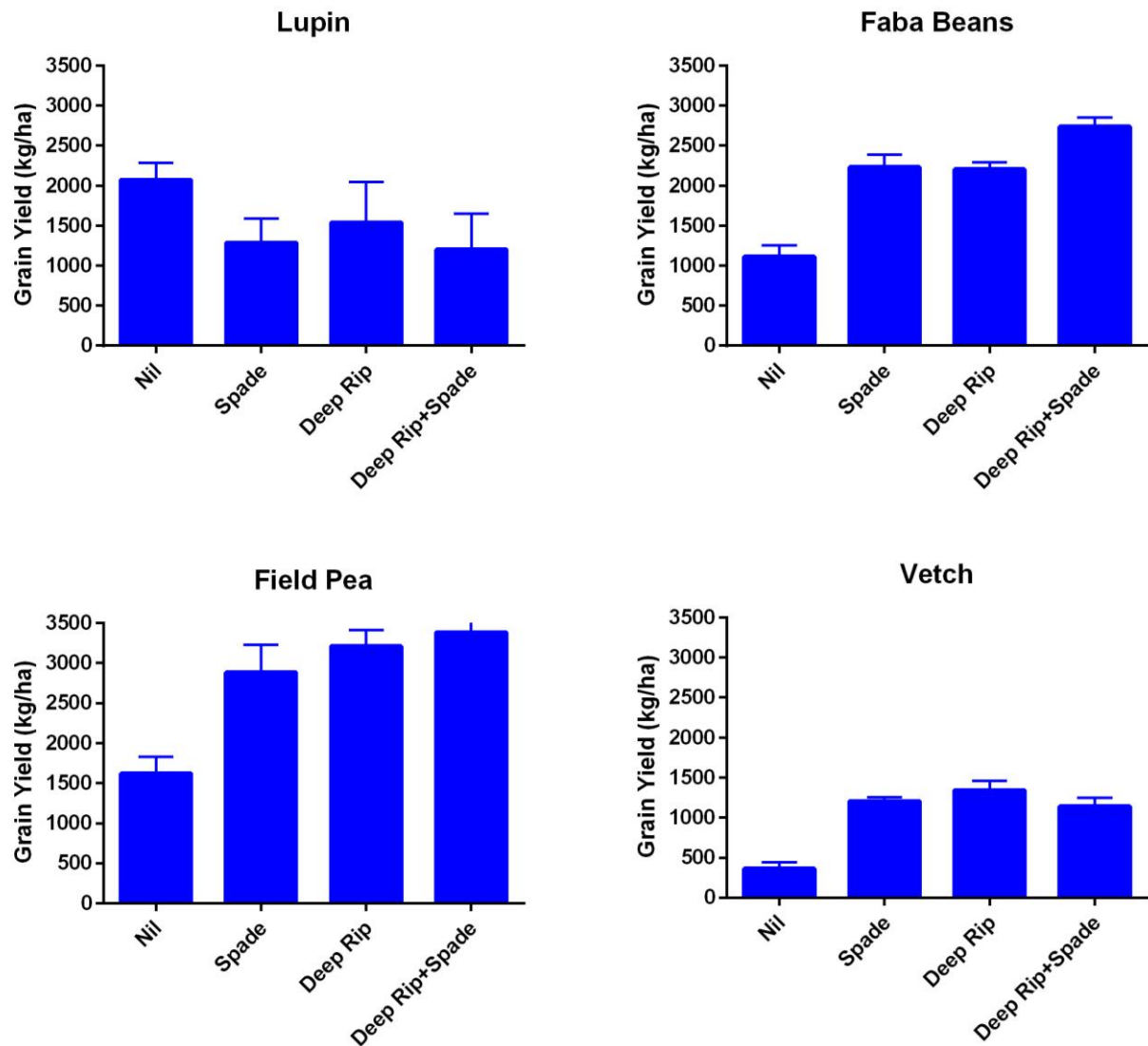


Figure 29: Yield results for lupins, faba, field pea and vetch versus soil amelioration treatments.

The mixed treatments of field pea-canola and vetch-canola were dogged by poor germination rates and this in itself may have been a function of the early drift events that occurred post sowing that relegated sown grain at an undesirable depth – this is a key learning from the 2020 trial in that small grained crops may struggle in inevitable periods of shallow drift in and around sowing and site soil amelioration works.

6 Results & Discussion 2020 Trial

Crop establishment was generally adequate for most crop to reach its yield potential - refer table 15). Windy conditions led to infill of furrows with sand post seeding which resulted in variable and low establishment in lupins and the canola within the companion crop treatments.

Although not statistically significant due to high variability, lupin establishment was reduced by half in soil amelioration treatments. A key consideration beyond soil drift in this scenario was found to be the likely alkalinity of the sub-soils in contrast to the optimal environment for the lupin.

Table 15: Establishment (plants m²) for each crop and treatment (*P value is probability of result not being random*)

Crop	Nil	Spade	Deep Rip	Spade + Deep Rip	P Value
Lentil	111	96	101	100	ns
Chickpea	26	24	25	26	ns
Lupin	19	11	10	9	ns
Faba bean	20	21	16	22	ns
Vetch	44	37	36	35	ns
Field Pea	26	27	31	34	ns
Vetch + Canola					n.s
Vetch	49	44	34	41	
Canola	12	0	12	0	
Field Pea + Canola					0.02
Field Pea	30	29	33	33	
Canola	16	0	5	0	

Soil amelioration by spading and deep ripping resulted in large yield increases for all crops except for lupins. The highest yield increases were observed in vetch which yielded three times more than the control and lentils which yielded 2.5 times more than the control. However, these two crops also had the lowest overall productivity.

Yield was approximately doubled in chickpea, faba bean and field pea.

These three crops were all more productive than the lupin control. There was no significant effect of amelioration treatments on lupin grain yields, although the trend was for a negative effect on grain yield due to the variable emergence. The companion cropping treatment tended to improve grain yield in vetch, however this effect is most likely due to an improvement in soil type in the companion crop trial relative to the monocrop trial.

Further work needs to be done on companion planting in these soil conditions to determine better the relationships that could be stimulated both for grain yield productivity and biomass and residual groundcover potential.

Table 16: Grain yield (kg/ha) for each crop and treatment – (*P value is probability of result not being random*)

Crop	Nil	Spade	Deep Rip	Spade + Deep Rip	P Value
Lentil	384	1045	1070	1032	< 0.0001
Chickpea	1140	1861	2170	2497	< 0.0001
Lupin	2073	1286	1539	1203	n.s
Faba bean	1114	2231	2203	2740	0.001
Vetch	367	1207	1343	1139	0.0003
Field Pea	1619	2882	3212	3383	0.0030
Vetch + Canola					< 0.0001
Vetch	1140	2014	2478	2514	
Canola	87	14	20	16	
Field Pea + Canola					< 0.0001
Field Pea	1255	2925	3087	3584	
Canola	454	38	158	22	

Soil amelioration had a significant positive effect on the level of groundcover provided by lentil, vetch, and field pea (figure 30). Conversely, groundcover levels were lower in spaded and deep ripped plots in lupins because of the variable lupin establishment in these treatments and potentially due to other soil borne factors as previously discussed.

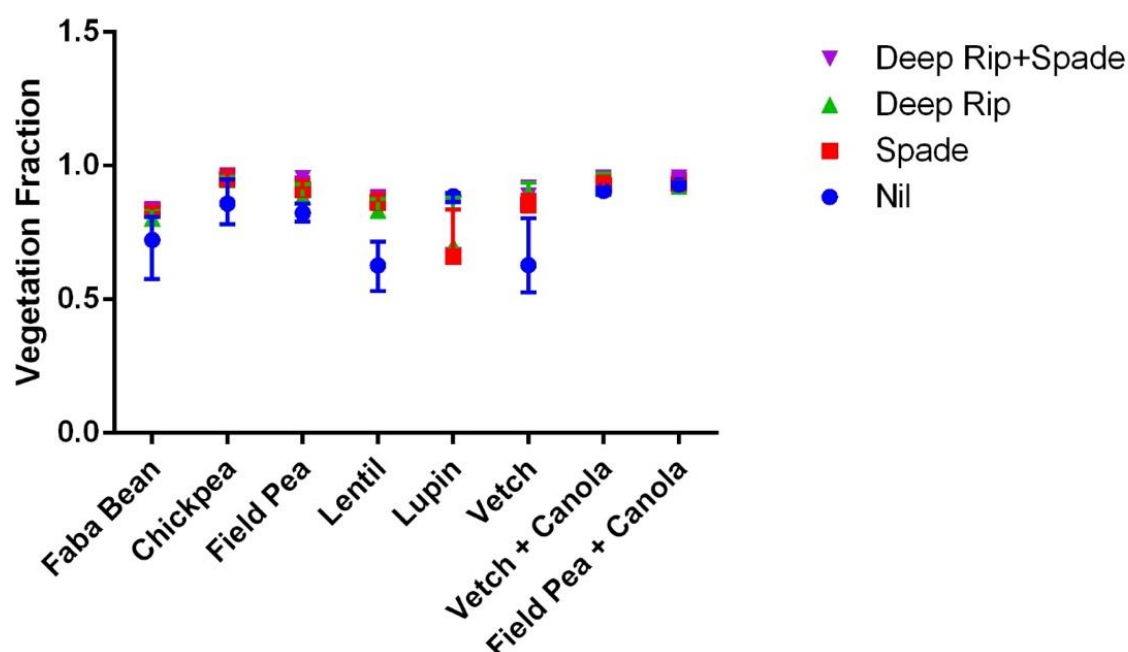


Figure 30: Vegetative groundcover measured in October for each crop and treatment combination.

6.1 Implications for commercial practice

The grain yield benefits from ameliorating sandy soils resulted in significantly greater pulse crop profitability. The gross margin of all pulse crops except for lupins increased by more than \$400/ha because of spading, deep ripping or combinations of the two. This gross margin does not include the cost of the amelioration which is estimated to cost \$100-200/ha with the benefits expected to last several seasons. One feature of the gross margin analysis

was that ameliorated field pea and chickpeas both provided a more profitable option than the un-ameliorated lupins which would be the traditional pulse crop grown on this soil type.

In Figure 31 a basic gross margin analysis is graphed and shows the relationship between soil ameliorated treatments (aggregated) and nil or control treatments. The prices used to enable these estimations were representative of January 2021 prices: Lupin: \$393/t; Lentil: \$672/t; Vetch: \$600/t; Faba Bean; \$370/t; Field Pea: \$350/t; Chickpea: \$610/t. The gross margin does not include the cost of soil amelioration which as previously stated is estimated to cost \$100-\$200/ha depending on the whether singe or combination treatments are implemented.

The question of how long soil amelioration treatments last in field in terms of cumulative longer term promotion of root penetration across a number of rotations is one that could be better quantified. Simplistically the effects can be monitored by a hand held penetrometer from season to season and this could be the best way to monitor the longevity of the effects of soil deep ripping style treatments if realistic transects of monitoring across a land system could be conceivably used as a surrogate indicator for replicate deployments of similar treatments on similar ground.

In conclusion the trial has thus far shown tremendous improvements to biomass and grain productivity in the vulnerable Mallee sandy soil type and it would appear that the risks associated with soil amelioration are vastly outweighed by the benefits to both biomass and grain yield. Farmers wishing to adopt the approaches trialed within this project are encouraged to either contact this project's representative (see back cover of this report) and to consult professional agronomic support and advice before undertaking works.

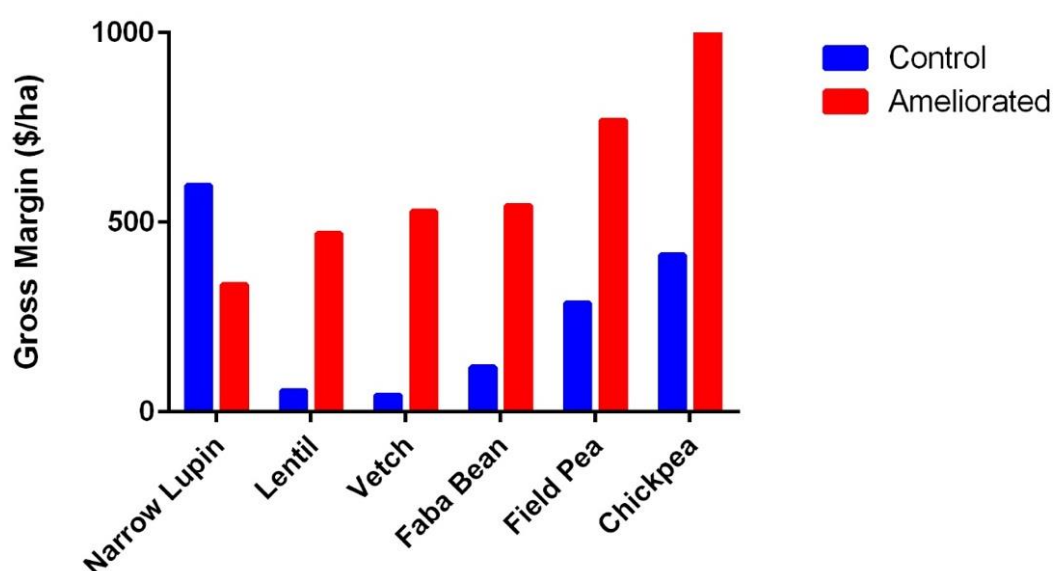
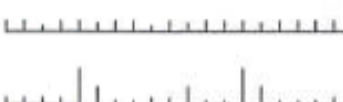
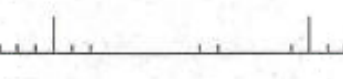


Figure 31: Pulse crop gross margins for the control and the average of the three ameliorated treatments

Appendix 1 – Guidelines for stubble characteristic classifications – DEW (2015)

Rating	Height (wind erosion)	Cover % (water erosion)	
1	Residues 40cm or higher.	75 to 100%	
	Bulk: Very high level of plant matter Anchorage: Majority of cover is anchored and stable, not (easily washed or blown away).		
2	Residues between 10cm and 40cm.	Even coverage of approx. 75 to 100%	
	Bulk: high amount of plant matter, most of which is standing Anchorage: Majority of cover is anchored.		
3	Residue height variable from less than 10cm to 40cm.	More variable cover of approx. 75 to 100%	
	Bulk: moderate to high but more variable across the paddock Anchorage: Cover often slightly flattened and damaged		
4	Residues 2cm-10cm, but of moderate bulk. Residues a mixture of upright and flattened.	50 to 75% cover, residue colour dominates	
	Bulk: Moderate Anchorage: Majority of residues are anchored, although often flattened or damaged.		
5	2cms of relatively even but thin residue cover remain; or, cover variable from sparse 40cm to less than 2cm cover	50 to 75% cover, Residue colour still dominates	
	Bulk: Low, damaged through moderately heavy grazing or traffic by animals and/or machinery. Anchorage: majority of residues are anchored, most residues are damaged.		
6	Height is variable and less than 10cm high to bare.	Soil colour dominates, 25 to 50% cover	
	Bulk: Low amounts of plant material. Anchorage: some residues are anchored; most are damaged through grazing or cultivation.		
7	Mostly bare although some residues can be seen. Grazed or cultivated virtually bare.	Soil colour dominates, 1 to 25% Scattered residues (and/or rocks) remain.	
	Bulk: minimal amount of plant material. Anchorage: Any residues probably unanchored		
8	Nil cover (bare)	0% cover	
	Bulk: Nil Anchorage: Nil		

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