Soil Fertility Trends.

An Analysis of Soil Data from the Murray Mallee 1992-2014

for the NR SAMDB Board

By Chris McDonough, Rural Solutions SA, Loxton

DEC 31ST 2014

RURAL SOLUTIONS SA
PIRSA

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

SOUTH AUSTRALIA

Government of South Australia
Primary Industries and Regions SA

Soil Fertility Trends.
An Analysis of Soil Data from the Murray Mallee, 1992-2014

Information current as of 31 Dec 2014

Disclaimer

All enquiries

Chris McDonough
Primary Industries and Regions SA (PIRSA)
PO Box 411, Loxton SA 5333
T 08 85 959100, F 08 85 959 199, M 0408 085 393
E chris.mcdonough@sa.gov.au

Table of Contents

1. Introduction

Farming systems in the Mallee have undergone a great deal of change over the last 20 years. The areas of most significance include the move toward more intensive or continuous cropping, the reduction in soil cultivation and the increased maintenance of soil cover through chemical weed control and Notill or minimum tillage farming. There has also been a large reduction in livestock numbers, as well as a strong trend toward larger farms and fewer landholders.

As a result of these changes there is far less cultivation equipment, with the main machinery items now being large boomsprays, Notill airseeders and powerful headers capable of full width straw spreading. Intensive cropping has meant that farmers have been fertilizing paddock more often, and with a greater use of nitrogen in particular. However, in this high risk low rainfall environment with high seasonal variability, there is a broad range of farming attitudes, capabilities, opportunities and management, resulting in a range of input levels being applied between farms.

Farmers with livestock are also using more feedlotting or containment feeding, particularly through dry periods when paddock feed is low and erosion risk is high.

With all these changes over this period it is important to be keeping track of key measurable soil parameters to both establish benchmarks through time and to analyze trends to assess whether our soil resource is improving or whether some issues may need addressing. This study analyses soil test results taken across the Mallee over a 6 year period of the 1990’s, and compares these with more recent tests taken from 2009-2014. It also assesses survey results relating to changes in tillage practices that have taken place over this period that have been critical in understanding the sustainability of current Mallee farming systems.

2. Project Brief

- Collate a snapshot of soil fertility across the cropping areas of the SA Mallee to determine overall trends in soil fertility, using existing soil data.
- Determine baseline on soil conditions.
- Interpret the results and trends in regards to soil nutrient levels.
- Develop 4 case studies using long term data from four focus paddocks to include considerations of paddock history, management practices and seasonal conditions.
- Final report with discussions and conclusions.

3. Identified Trends in Soil Fertility

Between 1994 and 1999 the TOPCROP training and monitoring program was run with a total of 15 farmer groups across the Murray Mallee, made up of both Agricultural Bureaux as well as specially formed crop monitoring groups. The local group approach ensured that there was a range of farmers represented, from large farming enterprises to the smaller farmers with very basic equipment.

Each farmer would chose a paddock that would usually be soil tested, monitored and evaluated according to best practice agronomic standards, to help build their knowledge and capacity to improve their farming systems. This was achieved through hands on learning and sharing experiences through interactive group processes. All crop management and monitoring information was recorded and analysed and reported back to the farmers by Rural Solutions SA. This report has collated and analysed this data from between 324 and 347 paddocks (depending on exact parameters measured) in this period and established a baseline of historic data.

This was then compared against 206 soil test results from a variety of farmer trials, surveys, demonstrations amongst local groups and individual consultancies, collected from similar areas as the former TOPCROP groups, but between 2009 and 2014. These results have been colated and analysed to provide a more recent benchmark of key soil parameters, to show trends and to explore the reasons behind changes that have taken place as well as things that have remained the same.

Table 1: Murray Mallee Topcrop and Soil Test Results

Average of Murray Mallee TopCrop soil test results								Total Numbers	
Year	Organic Carbon (%)	Soil P (mg/kg)	Soil K (mg/kg)	Soil pH (H_2O)	Soil pH ($CaCO_2$)	Ave N Applied (kg/ha)	Ave P applied (kg/ha)	No. of Groups	Paddocks tested
1994	0.92	16.4	317	7.7		8.2	9.5	5	36
1995	0.8	15.0	378	7.6		8.9	9.0	6	39
1996	0.6	17.9	337	7.7		8.2	9.6	9	54
1997	0.78	15.2	273	7.8	7.3	15.5	12.8	9	53
1998	0.76	19.3	292	7.7	7.6	16.6	11.9	11	93
1999	0.83	16.3	316	7.7	7.0	20.3	12.0	11	49
Ave 1994-99	0.78	16.7	319	7.7	7.3	13.0	10.8	13	324
Average of Murray Mallee accumulated topsoil test results from various sources								Total Numbers	
Ave 2009-14	0.9	28.5	317.6	7.8	7.1				206

3.1 Baseline of soil conditions

Average soil results from 324 tests from the 1990's (Table 1) show organic carbon (OC) at 0.78%, phosphorus (P) at 16.7ppm, potassium (K) at 319ppm and pH (H_2O) at 7.7.

Current baselines for soil conditions across the Murray Mallee based on the average readings of 206 topsoil tests conducted between 2009 and 2014 are also shown in Table 1. Organic carbon levels averaged 0.9%, Colwell phosphorus levels at 28.5ppm, potassium averaged 317.6ppm, while soil pH (H_2O) had an average reading of 7.8%.

Some of these parameters are more subject to change as a result of management than others, and so each of these are subsequently discussed in more detail along with any trends that have taken place since similar measurements we taken in the 1990's.

3.2 Organic Matter

Organic matter holds more than 95% of a soils nitrogen, 90% of the soils carbon and around 30-50% of a soils phosphorus, making it a vital component of a soils fertility.

Soil organic matter can be deminished in a number of ways, including:

1. Soil erosion. Wind tunnel experiments in the mallee in the 1990's showed the fine dust leaving the paddock in wind erosion events contained 7 times the concentration of organic carbon on class 3 soils when compared to the soils from which they had blown, and up to 10 times the concetration from the class 4 deeps sands, that can least afford to lose any fertility (Leys, Butler et al. 1993, Leys, Butler et al. 1994).

2. Residue removal through burning, harvesting or grazing. Retaining as much residue as possible is the key to sustaining the soil in these environments.

3. Cultivation. The act of agressively pulling steel through the ground burns up soil organic matter.

4. Inadequate fertilisation (particularly N). If farmers are not adequately replacing the nitrogen removal at harvest, through either fertiliser or N fixing rotations, they will tend to run down the organic fraction of their soils.

Surface (0-10cm) organic carbon (OC) is an important soil measurement for indicating organic matter in the soil and it's inherent fertility. Soils with higher OC tend to have a greater ability to mineralise nitrogen and to hold and exchange nutrients.

Mallee soils naturally have raltively low OC levels compared to other areas of SA, and can vary greatly between different soil textures. Mallee sands often range between 0.3-0.8% OC but have been measured at less than 0.1% OC, particularly where they have had a history of severe wind erosion. Loamy topsoils in the mallee generally have levels between 0.8 and 1.2% OC but have been measured at above 1.5%.

Table 1 shows the average organic carbon measurements to have generally been between 0.76 and 0.92% through the 1990's with an average reading of 0.78. OC levels will not change rapidly, and are indeed very hard to change, so it is likely that the lower levels of 1996 may likely be a reflection of more TOPCROP farmers choosing to monitor more sandy problem paddocks that year, as they started to become more familiar with the program and group activities. Table 2 reveals the ranges in OC levels across the two time periods. It can bee seen from these resutls that the majority of soils are placed between 0.4% and 1% OC.

Table 2: Organic carbon range comparisons in periods over the last 20 years

Organic Carbon Range	No. of soil test results in each range	% of soil test results in each range	No. of soil test results in each range	% of Soil test results in each range
(%)	1994-1999		2009-2014	
<0.4	46	14%	29	17%
0.4-0.6	94	28%	27	16%
0.6-0.8	73	22%	31	18%
0.8-1	53	16%	28	16%
1-1.2	28	8%	23	13%
1.2-1.4	18	5%	18	10%
>1.4	23	7%	18	10%
Ave OC levels	0.78		0.9	
No. of tests	335		206	

The average of the 2009-14 OC tests was 0.9%, which is 0.12% higher than the average of 1994-99, and suggests that there has been no decline in mallee organic matter levels with the introdution of new farming systems. It should not necessarily be concluded from this that mallee soils are rapidly increasing in OC as it was not all the original paddocks that were retested. It is more likely a reflection of a slight differences to the numbers of each soil type that were sampled.

However, fact that the average of 324 samples are being compared against the average of 206 recent tests across a full range of districts and soil types gives confidence that Mallee soil organic matter levels are at least being sustained and may well be on the improve.

Some of the early fears of farmers in moving toward more intensive cropping systems was that they would "run the soil down", because "the soil needs a rest". However, it can be shown for these results that with good fertiliser management and full stubble retention, that these systems can be both profitable and sustainable, and by enlarge are not running down the soils organic fraction.

Mallee farmers have made huge improvements to mallee sands, from being their most problematic soils with high erosion, low yields and full of weeds and disease. For many farmers using conservation farming systems these soils have been turned into some of their most consistent and productive soils and with constant maintenance of soil cover (McDonough and Gupta 2010). Huge improvements have been made to these soils fertility through the regular growing and retention of organic matter in crop residues. While the nature of these soils means that it is often very hard to change the levels of organic carbon measured, the increase in biological activity and high turn over of fresh organic matter has greatly increased these soil health, particularly in the midsope sands.

3.3 Phosphorus (P)

The trend in phosphorus levels in the mallee has been clearly increasing over time. Table 1 shows that on average the recent P levels at 28.5ppm are almost double that of the 1990's at 16.7ppm.

There are 2 main drivers that are likely for this dramatic increase. Firstly, the increase in cropping intensity means that paddocks have been fertilised far more regularly with more than adequate levels of phosphorus. Instead of P being applied once every 2 to 3 years to supply the initial crop as well as following pasture production and grazing, phosphorus is now being applied every year on contiunously cropped paddocks, and often at higher levels than in the past.

Secondly, within the 2000-2009 decade there were frequent drought years of very low crop yields. Farmers were regularly supplying 9-12kg/ha P in fertiliser and there appeared to be a trend of increasing P applilcation through the 1990's (see Ave P applied column in Table 1). 1 tonne of wheat will remove about 3kg/ha in the grain. Average yields in low rainfall years were often between 0.5 to 1 t/ha across the district, resulting in P application beng regularly in excess of actual crop requirements. As a general rule of thumb, every 3kg/ha of unused fertiliser P is enough to raise the soil level by 1ppm. Case Studies 1 and 4 (report section 4.1 and 4.4) are clear examples of how excessive P has been applied, resulting in increase soil levels.

Phosphorus levels in the mallee below 10ppm are considered very low, and low between 10-15ppm. Soil P levels of between 15-20ppm are generally fair, but reasonably good at 20-30ppm and excellent above 30ppm. Table 3 tracks the trends in the percentage of paddocks tested within these various ranges. Red colours represent a very low percent and green represents a high percentage of tests in that soil P range. This table reveals a clear trend of soil P levels moving from very low and low levels in the 1990's (on average 55% of tests measuring less than 15ppm) to the recent period (2009-14) showing 73% of soils tested at above 20ppm and 35% above 30ppm.

Again, these results give a clear indication that mallee soil fertility has not declined over the last 20 years, but has infact greatly improved. There is an increasing trend among mallee farmers to move toward P replacement in setting variable fertiliser rates based on the previous years yield maps. This can be a good strategy when P levels are known to be at good levels across the farm and all soil types within paddocks, and this may result in a slowing of the upward trend in soil P levels in the future.

Table 3. Trends in paddock P levels between TOPCROP monitoring period in the 1990's and the last 6 years.

	Percnetage of Paddocks in Phosphorus Level Ranges						Paddocks
Year	< 10ppm	10-15ppm	15-20ppm	20-30ppm	30-40ppm	40+ppm	Tested
1994	11%	47%	22%	11%	6%	3%	36
1995	0%	64%	31%	5%	0%	0%	39
1996	4%	41%	30%	20%	6%	0%	54
1997	32%	28%	19%	13%	4%	4%	53
1998	18%	29%	19%	20%	8%	5%	93
1999	27%	29%	16%	22%	4%	2%	49
Ave 1994-99	15%	40%	23%	15%	4%	2%	324
Ave 2009-14	5%	5%	16%	38%	18%	17%	206

3.4 Potassium (K)

Potassium levels across the mallee are consistently high to very high across the majority of mallee soils averaging close to 320ppm in both time periods of soil testing. Levels ranging form 120-250ppm are generally considered to be adequate, while above 250ppm is considered high.

Deficiency in potassium in South Australia is generally only found on very sandy soils in high rainfall areas. Decline in soil potassium can occur where high yielding hay crops are consistently removed from paddocks without adequate K replacement. While the production of hay has increased in many areas of the southern mallee to help reduce frost risk and control grassy weeds, Table 1 shows that there has been no significnt decline in soil K levels over the last 20 years.

3.5 Soil pH

Soils that are excessively acid or excessively alkaline cause production problems. It is recommended that lime be applied to soils of pH 5.8 (H_2O) to help nuetralise the toxic affects caused by highly acidic soils (such as aluminium toxicity). Highly alkaline soils tend to tie up key nutreints such as phosphorus and have reduced biological activity. pH is a logarithmic scale and is very hard to change in strongly alkaline or high pH soils, whereas low pH or acidic soils can become more acidic relatively quickly, particularly where there is a high production of N fixing pastures or crops.

Table 4 shows that soil pH ranges in the mallee have remained fairly constant over time, which is not supprising given the often calcareous alkaline nature of many Mallee soils. The majority of the mallee soils tested range between 7 and 9 for the last 20 years. There appears to be no significant trend in the small number of of acidic soils increasing in acidity.

Apart from some clay spreading that tends to increase the pH of their generally neutral sands, most farmers adjust their varieties and management to suit their soils pH, rather than try and change their soil pH.

Table 4. Soil pH (H_2O) ranges and comparisons from soil test results

pH Range	No. of soil test results in each range	% of soil test results in each range	No. of soil test results in each range	% of soil test results in each range
	1994-1999		2009-2014	
<6	9	3%	5	2%
6-7	78	22%	51	25%
7-8	113	33%	46	22%
8-9	146	42%	102	50%
9-10	1	0%	2	1%
>10	0	0%	0	0%
Ave pH	7.7		7.8	
No. of tests	347		206	

3.6 Nitrogen (N)

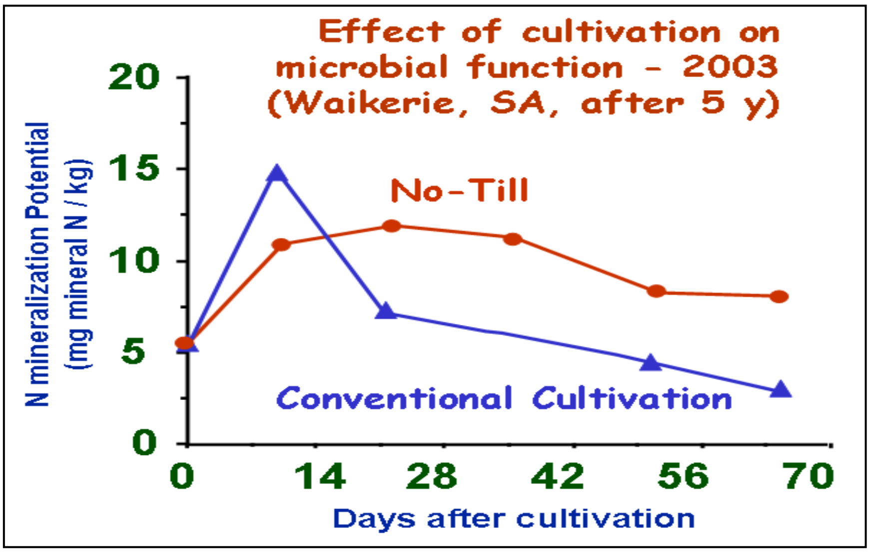
Nitrogen levels in the soil will vary greatly throughout a season, depending on soil texture, rotation, rainfall, temperature and other factors. It is highly mobile, and surface N can quickly be leached, particularly in sandy soil profiles. It is therefore very difficult to make meaningful comparisons between soil tests and different yields. However, a soils ability to naturally mineralize N is generally improved where organic carbon is higher, and there is a higher turnover of organic matter. The indication from organic carbon soil test measurements is that it is not diminishing with modern farming techniques, and this would suggest that the soils natural ability to mineralize N has also not diminished.

Table 1 shows that between 1996 and 1997 there was a clear jump in N application on average from 8.2kg/ha to 15.5kg/ha and continued to increase thereafter. This is most likely due to farmers beginning to realize the importance of N application, particularly as cropping intensified, and their were change from just using MAP or DAP fertilizer only, toward N enriched products such as 19:13, urea and sulphate of ammonia.

Nitrogen is also supplied within rotations through leguminous crops and pastures, and even by bacteria breaking down stubbles in cereal extended cereal phases. The tendency toward intensive cereal rotations in the Mallee has the potential to run down the organic fraction of the soil if inadequate N fertilizer is applied. The use of legumes such as peas, lupins, vetch and chickpeas is currently increasing in the northern Mallee rotations, and this trend is expected to continue.

The move toward intensive Notill farming systems has also changed N dynamics throughout the growing seasons. MSF research (Fig 1.) shows how traditional farming systems tend to produce a flush of N mineralization after cultivation at the start of the season, but then very little more N mineralization thereafter. Notill systems often produce less N up front, but with increased biological activity and organic matter turnover produce more nitrogen throughout the season, and more N overall.

Figure 1. Cultivation effect on soil N availability, after 5 years of tillage system, MSF, Waikerie Core site 2003 (Gupta Vadakattu, CSIRO pers. comm.).



While N management has improved as farming Mallee systems have changed, this needs to be continually monitored. Inadequate N application will tend to be self-regulating to some extent, as grain yields will diminish along with grain quality, generally leading to higher N application or provision in subsequent years. There is also a trend toward variable rate farming leading to farmers targeting N application into the soil areas where it is most needed or are more responsive.

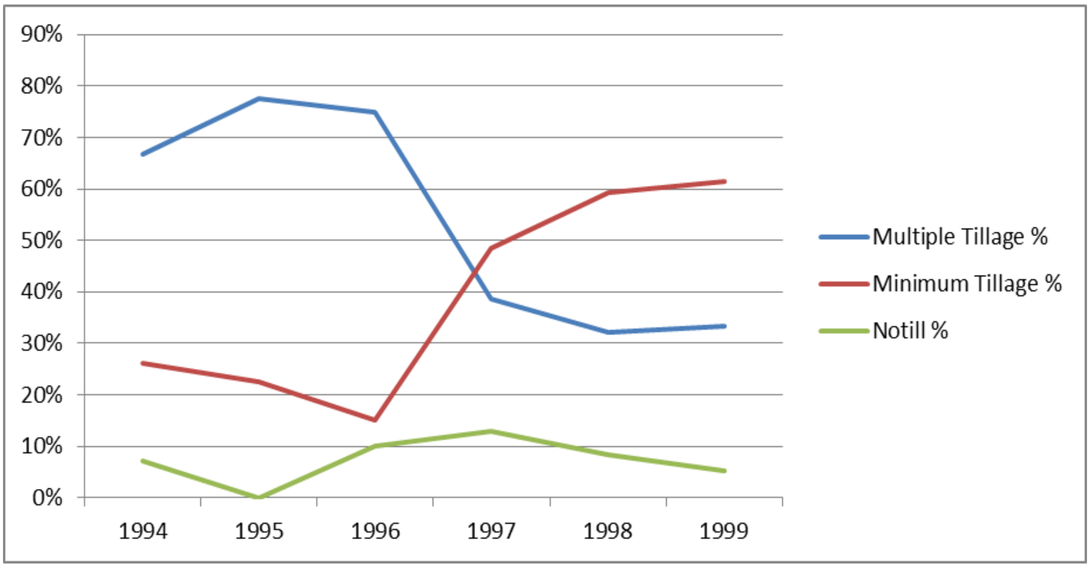
3.7 Tillage practices

Tillage practices have dramatically changed across the Mallee over the last 20 years, resulting in greater soil cover, aggregate stability and microbial activity, and a dramatic decrease in soil erosion.

The trend toward reduced tillage has been clearly demonstrated in two surveys that were conducted throughout Mallee farmers groups (mainly Agricultural Bureaus) in both 1992 and 2006 (full survey results are presented in Appendix 1 & 2). In 1992 the average number of cultivations for sowing cereal into pasture ground in the northern

Mallee was 4.8, and 3.2 cultivations for sowing cereal after cereal. The southern Mallee responses averaged 4.1 passes to sow crop into pasture and 3.1 to sow crop on crop. In 2006 the same questions were asked of the farmer groups, revealing that on average these numbers had reduced to 1.8 passes to sow crop into pasture, and 1.3 passes to sow crop into crop stubble for the northern Mallee. Similarly in the southern Mallee figures had reduced to 1.8 and 1.3 passes respectively, by 2006. This clearly indicates that the vast majority of Mallee farmers had moved from multiple tillage prior to seeding, to either Notill or just one working.

Figure 2. Tillage trends of Mallee Topcrop participants, 1994-99.



Comparisons between surveys also show a dramatic decrease in the number of farmers conducting long fallows and the use of aggressive implements such as disc ploughs. In 1992, 65% of farmers estimated they were sowing into less than 30% soil cover. The majority of this would have been bare ground. By 2006, 65% of farmers estimated they were sowing into at least 30% soil cover. Now most Notill farmers are seeding into standing stubble with close to 100% soil protection.

Figure 3. Trends in Mallee farmers using at least some Notill (Llewellyn and D'Emden 2010).

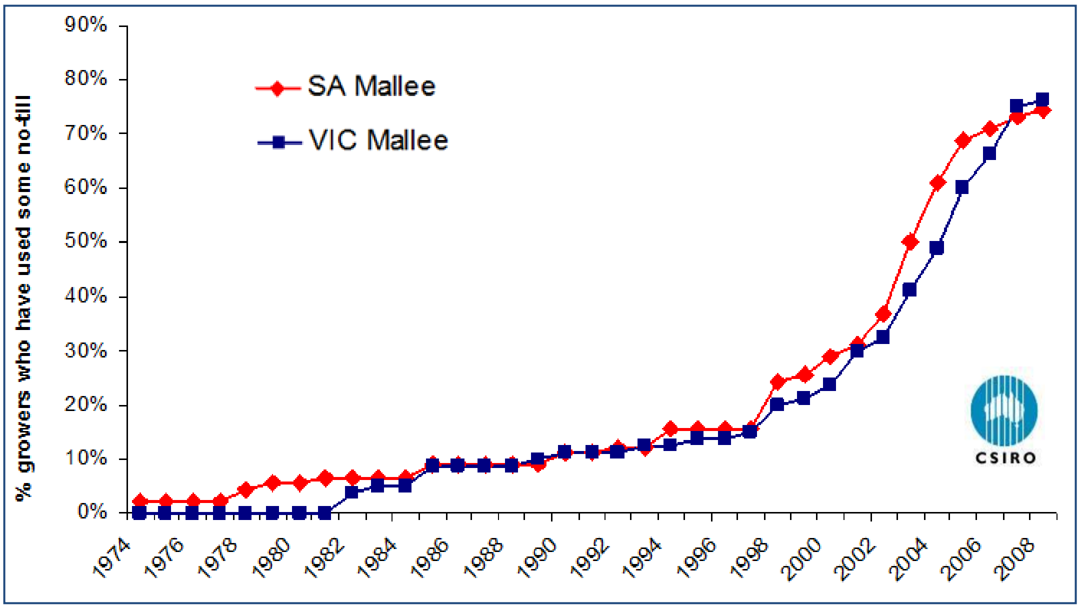
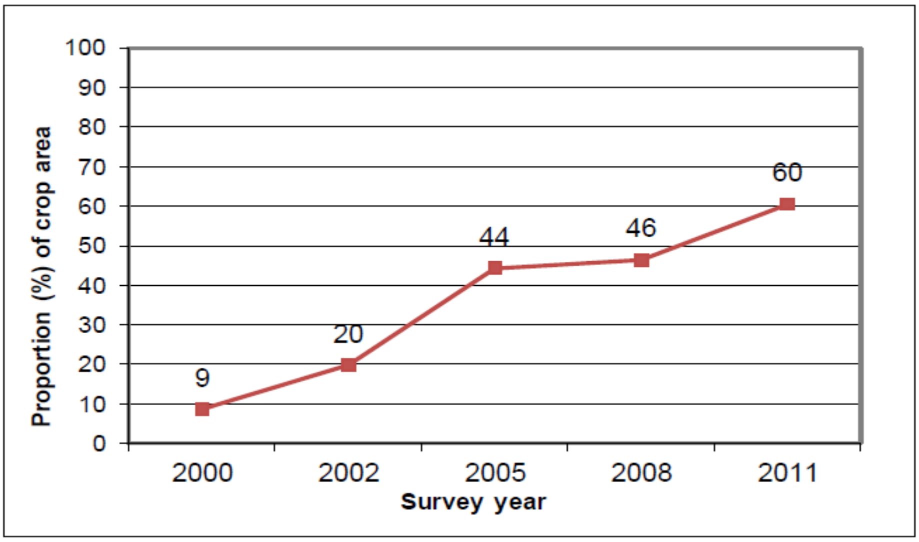


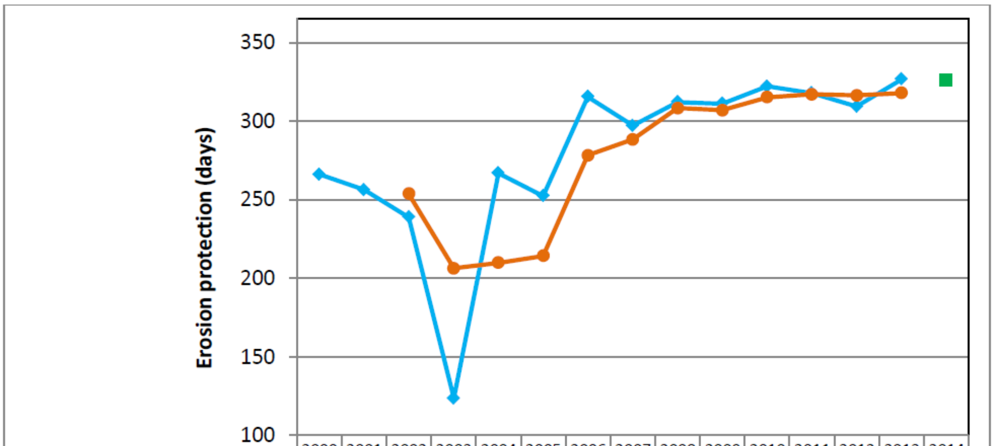
Figure 2 shows a change from multiple to minimal tillage starting in 1996, based on analysis of Topcrop paddocks. Farmers began take the next step and embrace Notill across the Mallee in 1999 (Fig 3), and this greatly increased after the 2002 drought when erosion from cultivated paddocks was widespread and severe (see Fig 3). These changes were strongly influenced by the early results of the Mallee Sustainable Farming trials and farmer group activities that clearly demonstrated the practicality and benefits of Notill farming systems (Roget 2007).

Figure 4. Proportion (%) of crop area in the SAMDB Region sown using no-till (Forward and Young 2013).



The number of Mallee farmers using Notill seeding is likely to now be above 60%, as shown in Figure 4. The trends towards decreased cultivation and increased residue retention, have greatly increased the sustainability of Mallee farming by significantly reducing the loss of valuable topsoil, organic matter and nutrients caused by wind erosion (see Fig 5). It has led to improved soil biological activity and health through the increased growth, retention and turnover of organic matter residues.

Figure 5. Annual and 3 year rolling mean protection of susceptible cropping land from wind erosion (days) in the SAMDB Region from 2000 to 2013 (Forward and Young 2013).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Annual wind erosion	266	256	239	123	267	252	315	297	312	311	322	318	309	327	
3 Yr Rolling wind erosion			254	206	210	214	278	288	308	307	315	317	316	318	
SAMDB Target															326

4. Paddock Case Studies

The following four case studies represent farming paddocks from a range of areas, cropping intensities and farming systems. While each paddock and situation is unique across the Mallee, the histories and results of these four paddocks highlight a number of factors that are present and reveal some explanations as to why they may have occurred.

Farmers were asked to provide paddock histories, including paddock use, rainfall, fertilizer applications, tillage practices and yields from paddocks that have been recently soil tested.

A basic phosphorus budget has been applied based on the fertilizer and application rates, and allowing for 3kg/t P removal for cereals, 4kg/t for pulse crops and 6.5kg/t for canola yield. 1kg/ha was allowed for grazing removal, and 1kg/year was added for tie up in the soil. These are general rules of thumb that can vary with both grain quality and soil type, but should be adequate for giving a reasonable summary.

While N application and removal rates have been included, this is not and attempt at supplying a N budget, as this would require much more information on pasture and pulse growth, legume content, and grain quality, etc. There are many soil and seasonal factors that can greatly vary N mineralization, fixation, leaching and volatilization that can greatly influence N dynamics that are not able to be easily monitored. For instance, organic carbon levels can easily vary from 0.3% on the sands to 1.3% on the heavy flats, which may result in differences in annual N mineralization of 15kg/ha to 60kg/ha in different areas of the same paddock.

The tillage practices recorded tend to reflect the trend from multiple tillage in the late 1990's, toward Notill and stubble retention in recent years, particularly with intensive cropping.

4.1 Case Study 1. Fertility increase with High Crop intensity, Notill.

Table 5. Paddock Management and Fertiliser History of Paddock Case Study 1, Alawoona

Year	Paddock Use	Ann. Rainfall (mm)	GSR Rainfall (mm)	Yield (t/ha)	P Applied (kg/ha)	P Removed or tie up (kg/ha)	N Applied (kg/ha)	N Removed (kg/ha)	Tillage	Residue Retention
2014	Canola		164	0.33	3.3	3.6	38	10	Notill	100%
2013	Wheat	238	200	0.85	3.3	4.1	7	17	Notill	100%
2012	Wheat	204	97	0.7	3.3	3.6	1.5	14	Notill	100%
2011	Wheat	515	135	1.13	6.6	4.9	9.3	22.6	Notill	100%
2010	Canola	471	239	0.9	2.8	7.4	4.4	18	Notill	100%
2009	Barley	239	169	0.8	4.4	3.9	11.6	16	Notill	100%
2008	Wheat	219	145	1.3	7.2	5.4	3.2	26	Notill	100%
2007	Wheat	312	123	0.75	6	3.8	5.4	15	Notill	100%
2006	Pasture	156	102			1.5		0		100%
2005	Barley	322	245	1.5	8	6.0	7.2	30	Notill	100%
2004	Wheat	266	150	0.6	9	3.3	17	12	Notill	100%
2003	Wheat	282	196	1.6	17	6.3	15	32	Notill	100%
2002	Canola	159	97	0	14	1.5	42	0	Min Till	100%
2001	Barley	255	220	1.8	9.1	6.9	19.8	36	Notill	100%
2000	Barley	302	203	3.02	15.4	10.6	7	60.4	Mult Till	50%
1998	Wheat	266	154	1.35	14	5.6	12.6	27	Min Till	75%
1997	Vetch	368	227	0	0	1.5	0	0	Notill	100
				Total	123	80	201	336		
					Difference	44				

Table 5 shows the history of a famers paddock in the Alawoona area that has been intensively cropped since the late 1990's and sown with Notill and full stubble retention over the last 11 years. Much of this loamy paddock has high subsoil constraints (high transient salinity, sodicity and boron) at 50cm, meaning that the roots are less able to penetrate deep to make the most of deep soil stored moisture. Being a reasonably heavy texture means that it maintains good fertility, but can suffer in low rainfall years when much of the limited soil moisture is unavailable to plants (see 2007 and 2012). When it does experience good winter and spring rainfall it can produce exceptionally well, (such as in 2000, when it yielded over 3t/ha).

The most recent soil test from this paddock in 2014 showed that it had a P level of 27ppm, an organic carbon of 0.96%, a potassium level of 518 and a pH (H_2O) of 8.8. A soil test from a neighbouring paddock in 1997 was at 18ppm P.

While this paddock has been intensively cropped, it has been shown to have been fertilised with excess P over the last 17 years. While it is difficult to predict exactly how much P applied gets tied up in the soil every year, it would appear that at least 40kg/ha and maybe up to 55kg/ha of excess P have been supplied. This could be enough to raise the soil P levels by between 13 and 18ppm, which is entirely consistent with the average change in soil P levels from all the soil test results that have been earlier discussed.

While the estimated N removed in grain produced from the paddock has appeared to have exceeded the N fertiliser inputs by about 130kg/ha, the budgeting of nitrogen is far more complex than phosphorus. This is because N can be supplied into the soil by sources other than fertiliser, such as through leguminous crops or pastures and the non-symbiotic N fixing bacteria involved in stubble breakdown with intensive cereal systems. However, given that is has been 16 years since a legume has been grown, and that there has been a large N deficit in 8 of the last 9 years there is a concern that more nitrogen should be supplied in the future. The farmer has been using variable rate and have been placing less fertiliser on the better more fertile ground, and more on the sandier soils.

While early MSF research showed that intensive cereal could be sustained with adequate fertiliser input, more recent studies have shown the value of using break crops, particularly legumes, in rotation. At the Karoonda Core site, putting zero fertiliser on the more fertile heavier soil types did not cause any yield penalty in the first 3-4 years, this treatment has begun to decline in recent years.

Through the drought years of the 2000's many intensive croppers were forced to cut back on the money they were spending on fertiliser, particularly on these soil types. While this paddock has suffered due to some severely dry periods at critical times as well as frosts, there are times in recent years that this paddock has not performed to its potential, which may well have been related to the N supply. It would appear that farmers in this situation will need to consider using more legumes in rotations or increasing their N fertiliser rates to help sustain grain yield and quality, as many are already doing.

The retention of all crop residues on this paddock resulting in the total maintenance of soil cover and high levels of organic matte turnover in the soil would have clearly contributed to the maintenance of soil organic carbon at 0.96%. Overall, this paddock, and many others like it in the Mallee, appear to be being farmed sustainably, but may well benefit from increasing N supply to the crops.

4.2 Case Study 2. High fertility maintained with intensive cropping and Notill.

Table 6. Paddock Management and Fertiliser History of Paddock Case Study 2, Pinnaroo

Year	Paddock Use	Ann. Rainfall (mm)	GSR Rainfall (mm)	Yield (t/ha)	P Applied (kg/ha)	P Removed or tie up (kg/ha)	Fert N Applied (kg/ha)	N Removed (kg/ha)	Tillage	Residue Retention
2014	Barley	304	164	2.8	7	9.9	43.1	56	Notill	100%
2013	Wheat	238	200	2.1	7	7.8	40.8	42	Notill	100%
2012	Wheat	204	97	2.3	7	8.4	40.8	46	Notill	100%
2011	Canola	515	135	1.1	10	8.2	46.7	44	Notill	100%
2010	Oaten Hay	471	239	7	7	16.2	45.4	84	Notill	100%
2009	Barley	239	169	1.4	7	5.7	29.3	28	Notill	100%
2008	Wheat	219	145	1.3	7	5.4	6.3	26	Notill	100%
2007	Barley	312	123	1.5	7	6.0	6.3	30	Notill	100%
2006	Wheat	156	102	1	12	4.5	10.8	20	Notill	100%
2005	Peas	322	245	1.8		8.7			Notill	100%
2004	Barley	266	150	1.3	11.7	5.4	25.2	26	Notill	100%
2003	Wheat	282	196	1.9	9	6.7	8.1	38	Notill	100%
2002	Canola	159	97	0.5	12.1	4.5	57.1	20	Notill	100%
2001	Barley	255	220	2.4	8	8.7	25.6	48	Min Till	50%
2000	Barley	302	203	2.2	10	8.1	27.4	44	Min Till	50%
				Total	122	114	412.9	552		
					Difference	8				

This Southern Mallee paddock has been intensively cropped with 11 cereals, 2 oilseeds, one pulse and one hay crop over the last 15 years, using full stubble retention and Notill seeding for the last 13 years. Table 6 shows that the paddock has yielded very well in the last 5 years and overall the phosphorus input (122kg/ha) has matched the levels of export and tie up (estimated 114kg/ha) very well. With recent soil tests showing excellent average P levels of 30ppm, this analysis suggests that this paddock would have had similar soil P in the late 1990's, and with good management these levels have been maintained.

Soil test results also measured an organic carbon of 1%, potassium of 463mg/kg, sulphur of 6.4mg/kg and a pH of 6.5 ($CaCl_2$) and 7.2(H_2O). Nitrogen application is the highest of any of the Case Study paddocks and has been necessary to support the yield potential of these crops, particularly as it has only had one pulse crop over this period. It should be noted that while there appears to be a N deficit of 140kg/ha between N removal and N application, that the natural soil mineralization of N has not been accounted for in this analysis. A 1% soil organic carbon should normally supply about 40kg/ha N annually, and MSF research has also shown the microbial breakdown of stubbles in intensive cereal rotations can also contribute to extra N fixation.

It would appear that on this evidence, despite the intensity of cropping at this site, the paddock soil is being managed sustainably by these farmers.

4.3 Case Study 3. Fertility low in mainly grazing paddock.

Table 7. Paddock Management and Fertiliser History of Paddock Case Study 3, Bakara

Year	Paddock Use	Ann. Rainfall (mm)	GSR Rainfall (mm)	Yield (t/ha)	P Applied (kg/ha)	P Removed or tie up (kg/ha)	Est. N Applied (kg/ha)	Est. N Removed (kg/ha)	Tillage	Residue Retention
2014	Wheat	351	192	1.5	6.5	6.0	9	30	Min Till	30%
2013	Pasture	222	179			2.0		0		30%
2012	Oats	239	121	1.1	6.6	4.8	3.3	22	Notill	30%
2011	Wheat	422	145	1.2	6.6	8.2	9	24	Min Till	30%
2010	Pasture	473	242			2.0		0		30%
2009	Pasture	249	169			2.0		0		30%
2008	Pasture	217	129			2.0		0		30%
2007	Pasture	307	147			2.0		0		30%
2006	Oats	182	94	0.4	3.9	2.7	5.7	8	Notill	30%
2005	Wheat	341	227	1	11	5.0	5	20	Multiple	30%
2004	Pasture	269	157			2.0		0		30%
2003	Pasture	292	191			2.0		0		30%
2002	Pasture	144	81			2.0		0		30%
2001	Pasture	287	193			2.0		0		30%
2000	Pasture	262	177			2.0		0		30%
					35	47	32	104		
					Difference	-12				

Table 7 shows the history of a paddock near Bakara that has only been cropped and fertilised 5 times in the past 15 years. The paddock was soil tested at numerous sites and soil types across this paddock in recent years, consistently revealing very low P levels of between 8 and 14ppm. Organic carbon levels ranged between 0.35-0.63%. The average potassium reading was 204mg/kg in the top 10cm, while the surface sulphur level was 2.7mg/kg, with a pH of 6.8 ($CaCl_2$) and 7.7(H_2O).

In seasons of above average growing season rainfall in 2005 and 2014 this paddock yielded only 1t/ha and 1.5t/ha which was well below yield potential. This could partly be attributed to low soil P levels.

While this paddock has been used more for grazing and the P amount applied in some years has been adequate in some of those years to account for what was remove in those crops yield, it would appear that not enough P has been supplied to account for P removal and tie up in the pasture years. While there was no soil test information from this paddock in the late 1990's, the paddock history since would be consistent with a slight drop in paddock P levels and the subsequent low soil P measured in recent years.

Low soil cover levels and grazing pressure applied through below average rainfall years with often high winds throughout the 2000 decade contributed to some soil loss on this paddock. This is an example of a paddock that has not been intensively managed, with many years of volunteer pasture and weeds. As a result this paddock has not appeared to have improved in fertility in recent years.

4.4 Case Study 4. Fertility improved through a mixed farming system.

Table 8. Paddock Management and Fertiliser History of Paddock Case Study 4, Loxton

Year	Paddock Use	Ann. Rainfall (mm)	GSR Rainfall (mm)	Yield	P Applied (kg/ha)	P Removed or tie up (kg/ha)	Fert N Applied (kg/ha)	N Removed (kg/ha)	Tillage	Residue Retention
2014	Canola	272	137	Frosted	5.5	1.0	23.5		Notill	60
2013	Wheat	261	209	1.3	5	4.9	16	30	Notill	60
2012	pasture	180	83			2.0				30
2011	Wheat	401	135	1.56	11	5.7	10	36	Notill	60
2010	Wheat	474	248	1.85	11	6.6	10	43	Notill	60
2009	pasture	214	143			2.0				30
2008	Wheat	199	128	1.2	8	4.6	14	28	Notill	60
2007	Oats grazing	277	136		7.7	2.0	3.5		Notill	60
2006	Barley	171	101	1.6	11	5.8	5	37	Min Till	30
2005	pasture	334	234			2.0				30
2004	Rye	254	147	0.95	10	3.9	4.5	22	Min Till	30
2003	Wheat	265	182	1.4	11	5.2	5	32	Min Till	30
2002	pasture	121	71			2.0				30
2001	Barley	250	187	0.9	10	3.7	4.5	21	Min Till	30
2000	Wheat	322	165	1.2	10	4.6	9	28	Min Till	30
				Total	100	56	105	275		
					Difference	44				

This paddock near Loxton has shown a mixed farming system over the last 15 years, with general rotation of 2 years of cereal crop followed by a pasture year for grazing. The farmer has moved from a minimal tillage to a full Notill system in 2007, integrating this with cattle enterprise which involves both paddock grazing and feedlotting practices.

A recent soil test showed a phosphorus level of 21ppm, and an organic carbon of only 0.34% on this sandy loam area of the paddock. The potassium level was 291mg/kg, sulphur at a high 11.8mg with a pH ($CaCl_2$) of 6.6 and pH (H_2O) of 7.1.

Table 8 shows that this paddock had 100kg/ha P applied over the previous 15 years, and it is estimated that approximately 56/kg/ha have been removed or tied up in the soil. This suggests that the surplus P applied would have help raise the P in the soil to a level considered to be adequate, and farm more robust to supply crops in a range to seasons and soil types, than what it had previously been. Soil tests form the 1990's from 2 paddocks on the same farm measured P at 11ppm, and if this paddock was at a similar level, much of the excess P applied would be accounted for in its rise to 21ppm.

This paddock has not had a strong history of N application, as the farmer has relied on the natural mineralization and N fixation of pastures to support the needs of the cereal crop. The farmer has also sown vetch for grazing in other paddocks. This is certainly a good strategy provided that the pasture has a high legume content and good growth and could lead to an N contribution in excess of 60kg/ha in this 250mm average annual rainfall environment.

However, where pastures are poor quality or growth is poor in dry years, then N production can be significantly reduced. In years of high summer rainfall events, much of the N produced can be leached beyond the rootzone, particularly on deep sands or on heavier soils that have high chemical constraints to root growth within 40cm of the surface. The second cereal in rotation will generally require increased N application to reach yield potential.

The organic carbon levels measured on this and other paddocks has been reasonably low at 0.3-0.5%, even on the loamier soils. This means that the soil can only naturally mineralize low levels of nitrogen each year. These low levels are not at all likely to be due to the current farming systems which are characterized by Notill farming, residue retention, good pasture growth and the maintenance of soil residues. Rather they may be due to historic farming practices of high cultivation levels in long fallows resulting in regular erosion events and the loss of valuable fertile topsoil. It may also be due to the natural formation of these soils in this area.

It is generally hard to build up organic carbon levels in Mallee soils as measured in soil tests, even with maximum stubble retention. However, MSF research has shown that conservation farming that grows and returns high levels of residues to the soil, greatly increases the organic matter turnover that greatly increases microbial fertility into these soils, even on sandy soils where organic carbon levels are low (McDonough and Gupta 2010).

5. Conclusions

Comparing soil result from the 1990's with those of 2009-14 show that on average there has been a substantial increase in soil P levels across the Mallee region with an average of 28.5ppm across 206 paddock soil tests. Organic carbon levels have not decreased, and possibly improved, indicating an average soil test level of 0.9%, while other parameters such as potassium and pH levels have essentially stayed the same.

Despite increases in cropping intensity and decreases in the areas dedicated to livestock and pastures, there is no indication that Mallee soils are in decline. The evidence of increased fertiliser application, stubble and residue retention, reduced tillage and wind erosion through the application of conservation practices suggest that the majority of Mallee farmers are farming sustainably and improving microbial activity and soil health.

While there will always be diversity in farming practices across the region for a multiple of reasons, this study reveals that number of paddocks having higher levels of fertility, organic matter turnover and soil protection is increasing.

Appendices

Appendix 1. 1992 Murraylands Agricultural Bureaux Soil Management Survey Summary

Chris McDonough, Land Management Officer, PI(SA) Murray Bridge

for the "Sustainable Land Management for the Murray Mallee Project"

Funded by the Natural Resources Management Strategy.

Introduction:

The Sustainable Land Management for the Murray Mallee Project aims to promote farming systems, which have both sound soil management as well as good financial returns. Many farmers have been modifying their farm management over recent years, due to financial pressures, root diseases and new varieties and technologies. It is therefore important to establish which farming practices are presently used across the Murray Mallee, as both a guide for future extension and a baseline from which to measure change.

This document contains results from a survey which was conducted between February to April 1993 through the Agricultural Bureaux of the SA Murray Mallee. Results have been collated on a Bureau by Bureau basis, but have been grouped into the Northern and Southern Mallee summaries. The Northern Mallee is characterised by lower and less reliable rainfall, which limits crop options and leads to different management techniques. The Southern Mallee has higher rainfall, and many areas are suitable for growing grain legumes.

Methods:

A single sided A4 survey form was devised, asking questions on six main areas related to sustainable land management in the Murray Mallee. The information sought related to farmers rotations, tillage operations, stubble handling methods, maintenance of soil cover, pasture weed control and basic record keeping and financial management.

For questions 1 and 2 of the survey, the farmers were asked for information relating to their most productive cropping land only, since they may use a variety of rotations on different parts of the farm. The survey was filled out individually during Bureau meetings. An example of a survey form is attached as Appendix 1.

The Northern Mallee Agricultural Bureaux surveyed were Lowbank, Loxton, Browns Well, Paringa and Wunkar. The Southern Mallee Agricultural Bureaux surveyed were Borrika, Karoonda, Ettrick, Southern Mallee, Geranium and Netherton.

Results:

There were 63 responses from the Northern Mallee Agricultural Bureaux, and 75 responses from the Southern Mallee Agricultural Bureaux. This gave a total of 138 responses which is approximately 15% of the farmers in the region.

1. Rotation

Rotation information is not easily summarised as many rotation variations were recorded. The individual rotations are more meaningful when assessed on a Bureau by Bureau basis.

In the Northern Mallee, there were between 6 and 10 different rotations listed for the most productive cropping land from each Bureau. 60% of the farmers surveyed were growing at least one pasture for every cereal crop, while 34% were growing more cereals than pasture in their rotation. 6% recorded no set rotation. 59% listed fallowing as a part of these rotations, while only 2% were growing grain legumes.

In the Southern Mallee, there were between 5 and 14 different rotations listed for the farmers most productive cropping land from each Bureau. 64% of the farmers surveyed were growing at least one pasture for every cereal crop, while 32% were growing more cereals than pasture in their rotation. 4% recorded no set rotation. 21% were growing grain legumes, 18% were continuous cropping and 1% were green manuring.

2. Tillage

Cultivation levels are generally high across the Mallee. The vast majority of farmers are sowing cereals into pasture ground, and this is where the most tillage is occurring. In the Northern Mallee, 70% of farmers fallowed with the average length of 8.3 months. In the Southern Mallee, 15% of farmers said they fallowed with the average length of 7.2 months. 55% of these farmers opened their fallows with disc ploughs.

<u>Table 1.</u> Summary of cultivation levels on farmers most productive cropping land for 1992 crops (including sowing and harrowing), Northern Mallee.

CROP	% of Total Farmers	% of farmers using each number of workings to sow crops							Ave. no. work-ings
		1	2	3	4	5	6	7+	
Cereal after cereal	43	15	19	30		19	7	11	3.2
Cereal after gr. legume	8		40	60					2.6
Grain legume after cer.	5	33	66						1.7
Cereal after pasture	87	4	5	7	18	29	25	11	4.8

<u>Table 2.</u> The proportion different implements used to open fallows by those 70% of farmers recording fallowing in the Northern Mallee.

Implement	%
Disc plough	27
Cultivator	25
Chisel plough	25
Blade plough	23

<u>Table 3.</u> Summary of Cultivation levels on farmers most productive cropping land for 1992 crops (including sowing and harrowing), Southern Mallee.

CROP	% of Total Farm-ers	% of farmers using each number of workings to sow crops							Ave. no. work-ings
		1	2	3	4	5	6	7+	
Cereal after cereal	44		27	48	15	6	3		3.1
Cereal after gr. legume	29	5	41	36	18				2.7
Grain legume after cer.	25	37	26	26	11				2.1
Cereal after pasture	89		18	18	49	25	4		4.1

Table 4. **The proportion different implements used to open fallows by those 15% of farmers recording fallowing in the Southern Mallee.**

Implement	%
Disc plough	55
Cultivator	18
Blade plough	27

3. Stubble Handling Methods

A variety of stubble handling methods are used across the Mallee, with the majority of farmers grazing and working their stubbles in some way. However, it should be noted that many of those that recorded grazing stubbles may be following with pasture and not another crop.

Table 5. **The stubble handling method used by farmers in the Northern Mallee, shown as percentages of total farmers surveyed.**

STUBBLE HANDLING METHOD	PERCENTAGE OF FARMERS
Grazing	84*
Trash cultivators	37
Working	33
Trash seeders	32
Straw spreader	16
Burning	14
Prickle chains	13
Slashing	8
Rolling	8
Harrowing	6
Straw choppers	2
Baling straw	2

Table 6. **The stubble handling method used by farmers in the Southern Mallee, shown as percentages of total farmers surveyed.**

STUBBLE HANDLING METHOD	PERCENTAGE OF FARMERS
Grazing	91*
Working	33
Burning	32
Slashing	27
Straw spreader	24
Trash cultivators	20
Trash seeders	16
Baling straw	11
Harrowing	7
Disc	7
Rolling	5
Straw chopper	1
Prickle chains	1

4. Soil Cover

The majority of farmers surveyed are sowing crops into less than 30% soil cover, while a small percentage are able to sow into high cover levels.

Table 7. **Estimated vegetative cover levels into which crops were sown, Northern Mallee.**

COVER LEVELS	% of FARMERS
0-30%	62
30-60%	30
60-100%	8

Table 8. **Estimated vegetative cover levels into which crops were sown, Southern Mallee.**

COVER LEVELS	% of FARMERS
0-30%	68
30-60%	27
60-100%	4

5. Weed control methods used in pasture years.

Spray topping is by far the most used chemical weed control method in pastures by farmers in the Mallee. Spray grazing and selective grass removal has been used less frequently, while chemical fallowing has been used least of all, particularly in the Southern Mallee.

Table 9. The use of various weed control methods in pastures, Northern Mallee.

WEED CONTROL METHOD IN PASTURE	PERCENTAGE OF FARMERS		
	REGULARLY	SOMETIMES	NEVER
Selective grass removal	5	37	59
Spray grazing	14	26	59
Spray topping	27	39	33
Chemical fallow	6	32	61

Table 10. The use of various weed control methods in pastures, Southern Mallee.

WEED CONTROL METHOD IN PASTURE	PERCENTAGE OF FARMERS		
	REGULARLY	SOMETIMES	NEVER
Selective grass removal	8	38	54
Spray grazing	11	36	53
Spray topping	55	29	17
Chemical fallow	0	14	86

6. Management and Records

Greater than 70% of the farmers surveyed soil test at least some of the time. Medic pastures have been sown in the past by most farmers in the Mallee, although often at very low rates. Over 50% regularly do cash flow budgets and most keep paddock records sometimes. However, few farmers work out their gross margins obtained from individual paddocks.

Table 11. Farm management activities in the Northern Mallee.

FARM MANAGEMENT ACTIVITY	PERCENTAGE OF FARMERS		
	REGULARLY	SOMETIMES	NEVER
Soil testing	5	60	35
Sowing medic pastures	33	48	19
Cash flow budgets	54	22	24
Keep paddock records	41	32	27
Paddock Gross Margins	11	22	66

Table 12. Farm management activities in the Southern Mallee.

FARM MANAGEMENT ACTIVITY	PERCENTAGE OF FARMERS		
	REGULARLY	SOMETIMES	NEVER
Soil testing	15	67	19
Sowing medic pastures	15	56	29
Cash flow budgets	56	23	21
Keep paddock records	48	36	16
Paddock Gross Margins	13	27	60

Table 13. The various rates of medics sown, shown as a percentage of those farmers that actually recorded sowing pastures in the Mallee.

SOWING RATES (kg/ha)	1-2	3-4	5-6	7-10	11+
Northern Mallee (% of farmers)	66	16	12	8	0
Southern Mallee (% of farmers)	28	17	33	19	3

Discussion:

Rotation.

The wide range of rotations used across the Murray Mallee suggests that many farmers have been experimenting with and modifying their systems and generally cropping more intensively than in the past when more traditional systems were favoured.

Financial pressures have caused farmers to crop more intensively in an effort to increase their overall financial returns. Other changes have been brought about because cereal root diseases are a major threat to productivity in the Mallee, and disease resistant varieties are being grown prior to wheat or malting barley. Changing markets and new varieties, particularly grain legumes have also resulted in changes to rotations in the Mallee.

Increasing cropping areas may require a greater investment in capital equipment. Machinery replacement, depreciation, alternatives and appropriate capitalisation levels are all vital aspects that this project needs to cover in assessing the financial sustainability of farming systems.

Most farmers have at least one pasture or grain legume for every year of crop in their rotation on their most productive cropping land. Approximately one third of farmers surveyed had more cropping years than years of pasture. To remain sustainable, according to the Right Rotations "Crop Rotation Sustainability Index" these farmers need to pay more attention to reducing tillage, maintaining residues or growing good quality pastures.

However, it is evident from Tables 1 and 3, that many farmers are using high levels of cultivation in their rotations, particularly when sowing cereals. Cover level results (Tables 7 and 8) would suggest that the majority of farmers do not retain significant residue levels prior to sowing. Questions on pastures (Tables 9,10 and 13) reveal that few farmers, particularly in the Northern Mallee are sowing sufficient rates of medics, or using grass selective herbicides, to produce good quality pastures.

Tillage. (see **Tables 1-4**)

Cultivation and tillage practices affect sustainability by their impact on soil erodability, soil cover, soil structure and organic matter. While tillage is an important tool in paddock preparation and controlling weeds and root diseases, excessive cultivation has contributed to land degradation, particularly through wind erosion.

There is a very high reliance on cultivation for weed control and paddock preparation in the Northern Mallee. While 34% of farmers sowing cereals on cereals were either direct drilling or sowing after one working, another 37% used 5 workings or more. 65% percent of farmers sowing cereals into pasture ground also used 5 workings or more. Many of these workings could be attributed to fallowing practices.

While 70% of the farmers practised fallowing, 48% of these opened them with low inversion implements, ie chisel or blade ploughs, which maintain higher levels of surface cover than other methods. While their was no record of farmers opening their fallows with chemicals instead of cultivation, 38% later recorded that they at least sometimes use chemical fallows, with 6% regularly. (However, it was also noted by the District Plant Protection Agronomist that many farmers idea of a chemical fallow is more like a spray topping at heavier rates and not a true chemical fallow.)

Generally this high level of cultivation means that adequate cover levels could not be maintained, leaving a large amount of land prone to wind erosion. Wind tunnel studies in the Mallee suggest that on class III land a level of 45-55% cover is needed to protect the soil. This emphasises the need to promote conservation farming techniques in the area. There is also scope for the greater adoption of chemical applications to open fallows and reduce the number of cultivations.

The Northern Mallee is generally unsuitable for growing grain legumes. Only a small percentage of farmers are presently using grain legumes in rotation. With erosion potential being higher with grain legumes, the low average working levels of 1.7 for sowing grain legumes into cereal stubbles ensures that higher levels of cover are maintained. The average number of workings for sowing cereals following grain legumes was 2.6.

In the Southern Mallee there is also a high reliance on cultivation for weed control and paddock preparation with the average number of workings to sow cereals into pasture being 4.1. This is slightly less than in the Northern Mallee which may be explained by the greater use of spray topping for weed control, and a lower number of farmers fallowing (15%). Even so, this level of cultivation could be a concern for maintaining adequate cover levels to protect the soil and the crops from wind erosion, particularly on sandier soil types.

Areas in the Southern Mallee are suitable for growing grain legumes, with 29% of farmers recording using grain legumes prior to cereals. It is important that minimum tillage is used with grain legumes as they do not provide as persistent soil cover as cereals. This is reflected in the low average working levels of 2.1 for sowing grain legumes into cereals, and 2.7 for cereals following grain legumes.

However, there has been concern that some farmers in the Southern Mallee have been using traditional cereal sowing techniques to sow grain legumes. 54% of farmers used 3-4 workings to sow cereals after grain legumes, while 37% used 3-4 workings when sowing grain legumes after cereals, which means a greater potential for soil degradation. The importance of minimum tillage and stubble retention is increased for those farmers continuous cropping since the ground is being cultivated and crops harvested each year, without a pasture year to replenish the soil resource.

3. Stubble Handling Methods (see **Tables 5-6**)

From the rotation results, it clear that fewer people in the Northern Mallee are sowing into stubbles, and being a lower rainfall area, the stubbles would not be as heavy as the Southern Mallee. However, it appears that most farmers are grazing stubbles and working them up, many with trash cultivators. The large use of trash seeders would mainly be disc drills used to trash feed into stubbles.

A range of stubble handling methods are used, including a number of prickle chains. Since 62% of farmers are sowing into low levels of soil cover (Table 7) it is possible that many crops sown on sandy soils have insufficient cover levels to protect against wind erosion.

In the Southern Mallee, where rotations are generally more intensive and crops produce heavier stubbles, there is a larger use of burning, slashing and straw spreaders. While burning may be necessary occasionally to reduce snail populations, it is generally discouraged due to the loss of nutrients and organic matter, and the reduction in soil cover.

Again, grazing and working stubbles are the most used methods of stubble handling in the Southern Mallee.

4. Soil Cover (see **Tables 7-8**)

Increased soil cover will lead to a decrease in soil loss and maintenance of soil fertility. Soil cover is the most critical factor in wind erosion control in the Mallee. Wind tunnel studies have shown that it is the soil fines which are most readily lost from the paddock during wind erosion events. These fines are enriched with around four times the nutrient concentration of the paddock soil and this loss can be a significant cost to the farming business over time.

Many farmers would prefer to retain and sow into more stubble, but do not have the equipment or the experience in using various stubble handling techniques to do so. Sowing into stubble can cause machinery blockages, poor seed placement, poor seed/soil contact and increase root disease problems. Stubble handling machinery can be very expensive, although many farmer are using cheaper modifications and innovations to help overcome these problems.

While it is good to see that about a third of farmers estimate they are maintaining reasonable soil cover levels in both the Northern and Southern Mallee, there is obviously the possibility for a great deal more stubble retention in the future. It is particularly important to maintain soil cover when growing grain legumes, as has previously been discussed.

5. Weed control methods used in pasture years. (see **Tables 9-10**)

There has been a concern over the general decline in pastures over recent years in the Mallee. There are a number of management strategies which both can improve pastures and/or prepare the ground for cereal crops following. Better pastures and root disease control would greatly improve the profitability and sustainability of farming in the Mallee.

Selective grass removal in June/July is used in pasture to reduce cereal root disease hosts, as well as the competition for the medic pasture. Although the cost of herbicide is considered expensive the losses in cereal crops attributed to root diseases have also been costly. Another reason why this is not used more regularly is that most of the pastures are grass dominant with very poor legume content. Spraying out grasses may leave much of the paddock bare and prone to erosion or allow other broadleaf weeds to dominate.

With the low rainfall and high seasonal variably it is difficult to get good pastures established, particularly in the Northern Mallee. With sheep commodity prices being low at the present time, many farmers are unwilling to spend money on improving their pastures. However, some farmers (5-8%) are regularly using selective grass removal, and 37% of the farmers surveyed in the Mallee sometimes do. There may be scope to encourage more farmers to experiment with selective grass removal, in conjunction with other pasture management improvements.

Spray grazing is an excellent method for controlling some broadleaf weeds in pastures, while providing good stock feed and using low chemical rates. Tables 9 and 10 reveal that the majority of farmers have not yet used spray grazing, which has great scope to be used more widely and increase the quality of medic pastures.

Spray topping is an important method using low chemical rates to help control weeds for the following crop. The fact that only 27% of the farmers use it regularly in the Northern Mallee is a reflection of large reliance on cultivation to control weeds, particularly in fallowing. The condition of boomspray units would also prevent many farmers effectively spraying large areas of pasture. Spray topping is used far more regularly in the Southern Mallee.

Chemical fallowing is not widely used in the Northern Mallee, yet spraying has the potential to replace many cultivations. Although initially expensive, this method cuts down on soil disturbance and can retain more surface cover, and has been more widely used by farmers in the Victorian Mallee. It may be necessary to do more work on the economics of this practise in the Northern Mallee. Chemical fallowing may not be as important in the Southern Mallee, as there is less fallowing done in general, and more continuous cropping.

6. Management and Records (see **Tables 11-13**)

Soil testing is an important tool for understanding the soil resource to make more informed management decisions and can also help farmers to monitor their systems over time.

In the Northern Mallee 65% of the farmers surveyed have soil tested in the past, with only 5% regularly, and 35% never soil testing. While 81% of farmers surveyed in the Southern Mallee have soil tested, only 15% use this important management tool on a regular basis. The actual cost of testing is very small compared to total spent on fertilisers for each paddock. Better informed management decisions have the potential to make or save large amounts of money, and better maintain soil fertility. Soil testing therefore needs to be more widely promoted across the Mallee.

Sound medic pastures are an important part of a good farming system. Many of the volunteer pastures in the Mallee contain minimal improved pasture, and therefore may have great potential for increases production. There has been a growing awareness as to the importance of establishing good medic stands in recent years. However, unreliable rainfall leading to poor establishment, particularly in the Northern Mallee, as well as the initial costs have always been considered as major problems.

81% of the Northern Mallee farmers surveyed sow medic pastures at least sometimes. 66% of these are sowing at rates of 2kg/ha or less. Rates of 5-10kg are recommended for pasture renovation. Of the 71% that sow medic pastures in the Southern Mallee, 56% use a rate 5kg/ha or greater. A number of demonstration paddocks have recently been set up across the Mallee, showing appropriate species and pasture management techniques in each area, to promote greater pasture establishment.

Cash flow budgets are a fairly basic summary of farm financial details. 55% of the farmers surveyed across the Mallee regularly do them. However, the large percentage of farmers that do not regularly work out their cash flow suggests that there are large deficiencies in financial planning and book keeping skills. This may affect their ability to loan money, and make appropriate purchases of agricultural products and capital items.

Record keeping is vitally important for sound management and decision making, and in Northern Mallee 73% of farmers at least sometimes keep paddock records, with 84% in the Southern Mallee. More importantly, 41% in the Northern Mallee, and 48% in the Southern Mallee regularly keep them.

Paddock gross margins help farmers understand what has been spent on each paddock and for what return. While a high percentage keep paddock records at least sometime, 66% in the Northern Mallee and 60% in the Southern Mallee have never worked out paddock gross margins. Again this is another area of financial management in which an improvement could be made.

Record keeping, financial management and planning is one of the most important areas which needs to be addressed in the farming community. Farmers must be making more critical and informed assessments of all their operations and paddocks to best plan for the future.

1992 Murraylands Ag. Bureaux Soil Management Survey

The Department Primary Industries, Murray Bridge. (Formerly Dept. Agriculture)

Name of Bureau:	

1. Your rotation on your most productive cropping land (if possible):

2. What were the average number of workings to sow crops last season on your most productive cropping land in the following situations (including sowing and harrowings):

Cereal sown following cereal			
Cereal following grain legume			
Grain legume following cereal			
Cereal following pasture			
If long fallowed, what did you open it with:		months?	

3. What stubble handling methods do you use:

Grazing			Trash seeders	
Slashing			Straw choppers	
Rolling			Straw spreaders	
Working			Baling straw	
Burning			Other	
Trash Cultivators				

4. What would you estimate the last years soil cover levels prior to sowing:

0-30%		30-60%		greater than 60%	

5. Have you used herbicide control methods in pastures for any of these purposes:

	Regularly	Sometimes	Never
Selective grass removal			
Spray grazing			
Spray topping			
Chemical Fallow			

6.	Regularly	Sometimes	Never	
Do you soil test				
Do you sow medic pastures				Rate:
Do you do cash flow budgets				
Do you keep paddock records				
Do you do paddock gross margins				

Appendix 2. **Results from the 2006 Murraylands Soil Management Follow-up Survey by Chris McDonough, Farming Systems Consultant, Rural Solutions SA, Loxton.**

1. Farm Location

	Response Percent	Response Count
Lowbank	9.8%	8
Loxton	11.0%	9
Paringa	3.7%	3
Browns Well	18.3%	15
Nildottie	0.0%	0
Wanbi/Copeville	15.9%	13
Karoonda	4.9%	4
Southern Mallee	**26.8%**	22
Geranium	0.0%	0
Netherton	0.0%	0
Coomandook	0.0%	0
Ettrick	0.0%	0
Cambrai	6.1%	5
Wunkar	3.7%	3
	answered question	**82**

2. Typical Crop Sequence (on most productive land)

	Response Percent	Response Count
Continuous Cereal	10.3%	8
Opportunity Crop Intensive	**33.3%**	26
Crop /Crop /Pulse	2.6%	2
Other Intensive	2.6%	2
Crop /Pasture	16.7%	13
Crop /Crop /Pasture	18.0%	14
Crop /Pasture /Fallow	2.6%	2
Crop /Pasture /Pasture	2.6%	2
Other Mixed	11.5%	9
	answered question	**78**
	skipped question	**4**

3. What were the average number of workings to sow crops last season on your most productive cropping land in the following situations (incl. sowing and harrowings):									
	1	2	3	4	5	6	7+	Rating Average	Response Count
Cereal after Cereal	**74.6% (53)**	15.5% (11)	8.5% (6)	1.4% (1)	0.0% (0)	0.0% (0)	0.0% (0)	1.37	71
Cereal after Pulse	**86.1% (31)**	11.1% (4)	2.8% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	1.17	36
Pulse after Cereal	**85.3% (29)**	11.8% (4)	2.9% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	1.18	34
Cereal after Pasture	35.4% (23)	**44.6% (29)**	15.4% (10)	4.6% (3)	0.0% (0)	0.0% (0)	0.0% (0)	1.89	65
								answered question	**82**
								skipped question	**0**

4. If long fallowed, what did you open it with, and how many months was fallow for?		
	Response Percent	Response Count
Disc Plough	22.2%	4
Cultivator	**38.9%**	**7**
Chisel Plough	5.6%	1
Blade Plough	16.7%	3
Herbicide	16.7%	3
How many months	view	17
	answered question	**18**
	skipped question	**64**

5. What stubble handling methods do you use?		
	Response Percent	Response Count
Grazing	**79.3%**	65
Slashing	3.7%	3
Rolling	3.7%	3
Working	15.9%	13
Burning	11.0%	9
Trash Cultivator	12.2%	10
Trash Seeders	14.6%	12
Straw Choppers	37.8%	31
Straw Spreader	58.5%	48
Baling Straw	7.3%	6
Prickle Chain	8.5%	7
Harrowing	0.0%	0
Sowing into Standing Stubble	72.0%	59
Other	7.3%	6
	answered question	**82**
	skipped question	**0**

6. What would you estimate the last years soil cover levels prior to sowing?		
	Response Percent	Response Count
0-30%	35.1%	27
30-60%	**46.8%**	36
>60%	18.2%	14
	answered question	**77**
	skipped question	**5**

7. Have you used herbicide control methods in pastures for any of these purposes?				
	Regularly	Sometimes	Never	Response Count
Selective Grass Removal	41.0% (25)	**52.5% (32)**	6.6% (4)	61
Spray Grazing	28.8% (17)	**62.7% (37)**	8.5% (5)	59
Spray Topping	**60.0% (42)**	31.4% (22)	8.6% (6)	70
Chemical Fallow	**42.6% (29)**	36.8% (25)	20.6% (14)	68
			answered question	**79**
			skipped question	**3**

8. Farm Management Activities				
	Regularly	Sometimes	Never	Response Count
Do you soil test	17.5% (14)	**76.3% (61)**	6.3% (5)	80
Do you sow medic pastures	4.0% (3)	38.7% (29)	**57.3% (43)**	75
Do you do cash flow budgets	**65.4% (51)**	25.6% (20)	9.0% (7)	78
Do you keep paddock records	**81.5% (66)**	16.0% (13)	2.5% (2)	81
Do you do paddock gross margins	36.4% (28)	**49.4% (38)**	14.3% (11)	77
		If Sowing medics, what rate (kg/ha)?	view	14
			answered question	**82**
			skipped question	**0**

2006 Murraylands Soil Management Survey

Chris McDonough, Rural Solutions SA, Loxton

Following is a repeat of the "Murraylands Ag. Bureaux Soil Management Survey" Chris McDonough conducted in 1992. It would be appreciated if you could take a brief few moments to re-fill out this survey, so that we can get a direct comparison of management practices.

Farm Location:	

1. Your rotation (or typical sequence) on your most productive cropping land:

2. What were the average number of workings to sow crops last season on your most productive cropping land in the following situations (incl. sowing and harrowings):

Cereal sown following cereal			
Cereal following grain legume			
Grain legume following cereal			
Cereal following pasture			
If long fallowed, what did you open it with:		months?	

3. What stubble handling methods do you use:

Grazing		Trash seeders	
Slashing		Straw choppers	
Rolling		Straw spreaders	
Working		Baling straw	
Burning		Sowing into standing stubble	
Trash Cultivators		Other	

4. What would you estimate the last years soil cover levels prior to sowing:

0-30%		30-60%		greater than 60%	

5. Have you used herbicide control methods in pastures for any of these purposes:

	Regularly	Sometimes	Never
Selective grass removal			
Spray grazing			
Spray topping			
Chemical Fallow			

6.	Regularly	Sometimes	Never	
Do you soil test				
Do you sow medic pastures				Rate:
Do you do cash flow budgets				
Do you keep paddock records				
Do you do paddock gross margins				

6. References

Forward, G. and M. Young (2013). Progress Report for reporting on achievment of soil erosion protection target: SA Murray Darling Basin Region Natural Resources Management Board.

Leys, J., P. Butler and C. McDonough (1993). Wind Erosion Research at Borrika in the South Australian Murray Mallee. Sydney, Department of Conservation and Land Management NSW.

Leys, J., P. Butler and C. McDonough (1994). Wind Erosion Research at Pinnaroo in the South Australian Murray Mallee. Sydney, Department of Conservation and Land Managment NSW

Llewellyn, R. S. and F. D'Emden (2010). Adoption of no-till cropping practices in Australian grain growing regions, Australian Government, Grains Research and Development Corporation.

McDonough, C. and V. Gupta (2010). Success with Sandy Soils. M. S. F. Inc., Farmtalk 37, http://msfp.org.au/wp-content/uploads/2013/06/Farmtalk-no37-Success-with-Sandy-Soils.pdf.

Roget, D. (2007). Intensify Cropping, Improve your Profitability. M. S. F. Inc., Farmtalk 2, http://msfp.org.au/wp-content/uploads/2013/06/Farmtalk-no2-Intensify-your-cropping-Revised-2007.pdf.