CONSERVATION CROP FARMING: A FARM MANAGEMENT PERSPECTIVE

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1. –INTRODUCTION

1.1. INTRODUCTION TO THE PROJECT

This aim of the research is to investigate conservation cropping from a farm management perspective. This means looking at conservation cropping as a practice and an innovation, in the context of technical, economic, financial, risk and beyond the farm gate aspects of the operation of crop farm businesses.

2. –A TECHNICAL LITERATURE REVIEW

2.1. INTRODUCTION

In this chapter technical background material that underlies decisions by crop farmers to adopt or reject conservation cropping methods is given. The introduction of conservation tillage systems can be viewed as a major recent development in the quest to improve soil and water conservation (Carter, 1994). Conservation cropping in its various guises of minimum tillage, reduced tillage, direct drilling, no-till and zero-till has increased throughout the cropping zones of South Eastern Australia over the last two decades. Crop farmers who have adopted the various forms of conservation cropping have done so with the hope and aim that they, and their business, will benefit in some way. Most of the literature about the subject has focused on the science of conservation cropping practices. While this is inevitable with any new farming technology, the whole farm situation and the decision making processes of farmers adopting new techniques is important and warrants investigation. There can be no universal prescription for the adoption of changed tillage practices, or any farming innovation, on any farm or in any location. Invariably technical, economic, financial, risk and beyond the farm factors specific to each whole farm situation affect the adoption and the implementation of tillage practices that have the potential to conserve and improve soil and other resources. In this case the technology of conservation cropping, and thus the adoption process, is somewhat different to many other new agricultural technologies. With conservation cropping farmers are adopting a farming system, rather than a single new technique – thus in terms of adoption and implementation it is a complex technology not a simple technology. Adoption of conservation cropping will have consequences for the whole of the farming business, not just the cropping enterprise. In general terms, the aim of this study is to investigate the constraints, and the potential of conservation cropping in the context of the operation of whole crop farm businesses, including looking at how adoption of conservation cropping practices has affected, or could affect, profitability and management of cropping farm businesses in the cropping zone of south-eastern Australia.

A necessary part of this study is a review of past and present farming systems. Examining business structure and change requires understanding of the whole system and the environment in which it operates. In the case of conservation cropping, the volumes of scientific literature that exist on the subject warrant reviewing and the operations of crop farmers who have experience with conservation cropping systems in a range of cropping environments warrant scrutiny – and not only as it happened in south eastern Australia but in Western Australia and North America as well. Understanding farming systems is fundamental to assessing the impact of conservation cropping technology in the wide range of environments that exist in the southern cropping zone. In short, changing practices have different effects in different environments.

2.2. OVERVIEW - A BRIEF HISTORY OF CONSERVATION TILLAGE

To properly evaluate the potential of conservation cropping methods a changed perspective from agricultural researchers and farmers is often needed. The thinking and methods fostered by generations of tillage-based farming are different in many ways, some major, some subtle, from the thinking and methods involved with conservation cropping. The quote in the box, text qouted from (Phillips, 1973) is pertinent, even given the distinctly American perspective that it brings.

"The plow is as American as the 4th of July. Famous farmers such as Thomas Jefferson and Daniel Webster perfected it and today's politicians still speak of realigning national priorities from "swords to plowshares". The sword has reduced in importance but the plow is still a cornerstone of American history. For two centuries it has been a symbol of the nations priorities."

"Centuries elapsed between the use of wooden tillage tools and Thomas Jefferson's development and testing of maths formulae to describe the mouldboard plough. Newbold's patent in 1796 of a cast iron plough was followed by manufacture in the 1830's after Daniel Webster's design. A number of years passed before the ploughs were accepted. Farmers of the time thought they increased weed growth and poisoned the soil. They may have been near the truth. For 125 years the methods were developed and the country was equipped with a vast array of tillage implements. The lack of understanding of tillage saw the establishment of many research centres around the world. In 1951 K.C. Barrows, J.H. Davidson and C.D. Fitzgerald of the Dow chemical company reported the successful development of chemicals in seedbed preparation. In 1952 and 1953 wheat, oats, flax, soybeans and corn were produced with no-till methods. G.E. McKibbon, Illinois, was perhaps the first to scientifically look at corn growth in the new system. R.J. Speight of North Carolina may have been the first to grow double-cropped soybeans into wheat stubble. Thus, for all the centuries of agricultural development the process had come full circle. From little or no tillage with fingers and sharpened sticks to the excesses of the plough back to the use of little tillage again the old methods have become new again."

"It may seem futile to try to copy a system that the Indians and pilgrams used when they arrived in the new world. The system is not without it's problems however. It does demand extensive management ability. However coming generations will find it hard to work out why their forefathers found it necessary to turn, stir, sift and comb every acre of the soil every year. They may also find it hard to believe that the sky turned black or that rivers ran black with wind and water erosion."

> *"Total elimination of the plough is unlikely and inadvisable but indiscriminate stirring of the soil risks the most vital natural resource that we have: the soil. Many still feel that the decision is economic to plough – it may be but in most cases the number of operations could be reduced with no ill-effects."*

The early insight offered by Phillips is relevant in modern times as poor cropping management in both the US and Australia continue to pose risks to resource quality and business sustainability. Consequently the tillage debates continue.

Australian farming has evolved rapidly over the last two centuries. How to best farm Australia's generally shallow, infertile, low organic matter, structurally poor soils, while subject to an extremely variable climate, has been the subject of a tradition of agricultural research extending back to the late nineteenth century. Change is the norm in Australian agriculture, and adoption of conservation farming on a wide scale would not alter the need for constant adaptation in farming. In farming in Australia new ideas must continually supercede the old if farmers are to be able to continue to increase the supply of agricultural products at competitive lower costs.

Simultaneously, conservation cropping as a management practice, and technology, is not straight-forward to define. A range of methods exist that can be classed as being conservation farming methods. As not all conservation cropping methods suit particular farming environments, characterised as they are by varying physical, biological and socio-economic characteristics, it is useful to consider these definitions in a regional manner. Interactions of soil and climate tend to be dominant influences on production systems (Carter, 1994) and on the resultant effect of farming on the environment. Farmers use a mixture of tools and methods that may fit somewhere along the continuum of practices known as conservation cropping.

As demonstrated by *Table 1*, various definitions of conservation farming systems have evolved in recent times. These are to some extent arbitrary terms, and are to be used as a general guide in this report.

Table 1 Terminology used for conservation farming

SOWING PRACTICE	**TERMINOLOGY BY REGION**				
No prior cultivation	***WA***	***NSW***	***Vic***	***SA***	***Qld***
No inter-row disturbance	Zero –Till (disc seeding) No-Till (knife points)	Direct drill (narrow points) but increasingly termed no-till with worldwide adoption.			Zero till, direct drill
Full inter-row disturbance	Direct drill	Direct drill (full disturbance)			Zero till (wide points)
Prior cultivations					
1	Conventional	Minimum tillage			Minimum tillage
2	Conventional	Minimum tillage		Reduced tillage	
3		Reduced tillage		Conventional	
4+	Conventional				

Source: (GRDC, 1998)

The importance of the definition of the terms in *Table 1* has to be stressed because the practical effectiveness of alternative cropping systems can be misunderstood or misrepresented, simply by poor understanding of what operations are involved with different cropping systems. The detail of the practices, the environment and the particular whole farm sustem define the method. Experiences in Western Australia reinforce this view. Direct drilling, as defined in south-eastern Australia, is looked upon in a different light to no-till. Direct drilling means complete soil disturbance in WA. No-till, knife points that disturb the soil to depth but not width, and wider row spacings for improved chemical control and stubble retention, have very different effects on crop agronomy and thus success of the system to that of direct drilling methods. In this report the Western Australian definitions of tillage systems are used. Reduced tillage is defined as one pass prior to seeding with full soil disturbance; direct drilling is one pass seeding with full soil disturbance; no-tilling uses narrow point seeders with less than full soil disturbance, while zero-till involves the use of disc seeders that barely disturb the soil (Crabtree, 1997).

2.2.1. CROPPING IN SOUTH-EASTERN AUSTRALIA

Until relatively recent times two crop production systems predominated in the Southern Australian wheat belt. The first, generally seen in the higher rainfall environments of NSW, Vic, WA and SA involves a rotation of annual legume pasture *(Trifolium subterraneum or Medicago spp.)* in combination with crop. The length of the crop and pasture phases vary according to relative profitability, but traditionally involve three or more years of pasture followed by several cereal, grain legume or oilseed crops. This system changed in the 1980s where the area put into crop increased at the expense of pasture.

The second system, mainly seen in drier areas, involves extended periods of fallow to conserve moisture and control weeds. This usually takes the form of pasture/wheat/fallow rotation. The introduction of grain legumes has allowed lengths of rotations to expand, depending on the relative profitability of grain and livestock.

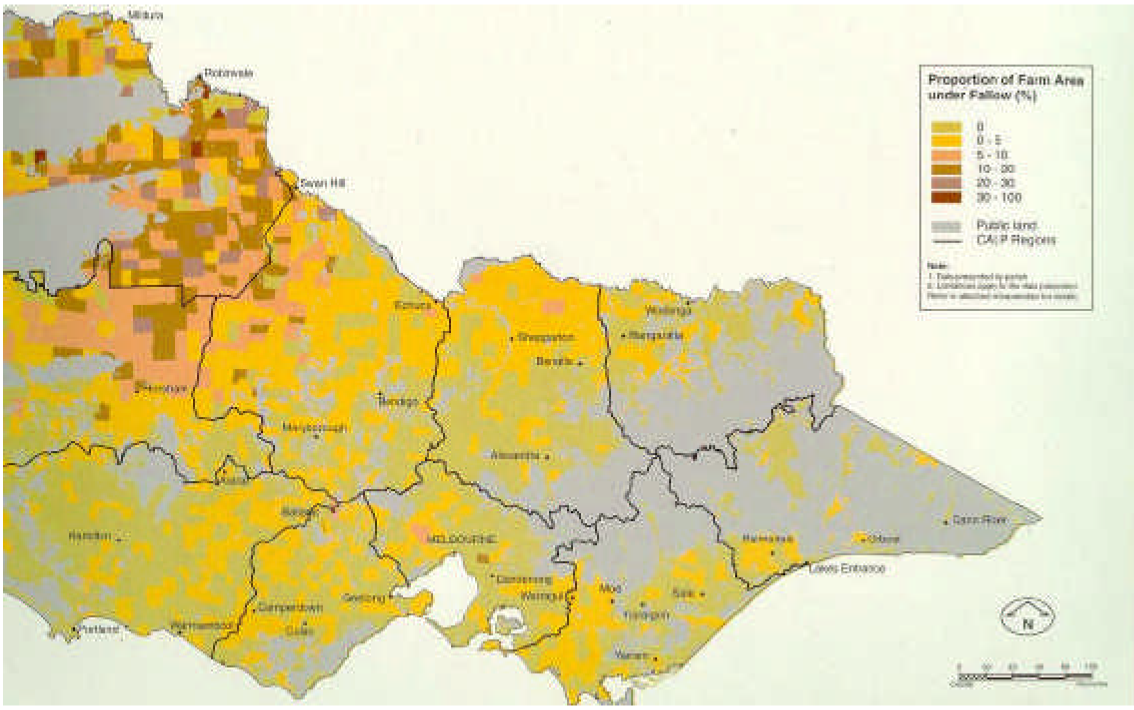


Figure 1– Proportion of farm area under fallow in the Victoria (DNRE, 1997).

Nowaday's crop farming systems, particularly in higher rainfall environments, are much more flexible than that of even twenty years ago. A third cropping system has now become a widespread option - continuous cropping. Continuous cropping was practised in the early days of cropping in Australia, reappeared as an option in the 1970s, and has increased in large areas of Western Australia, the Victorian Wimmera, Northern New South Wales and Southern Queensland. In all of these areas, cropping is more profitable than livestock production. The economic need for farmers to intensify their cropping operations saw the need for techniques of cultivation, such as minimum tillage, that would allow this to happen without damaging soil structure and long term profitability. It is likely, as claimed by Poole (1987) that increasing cropping intensity has been the primary catalyst for change in cropping methods, not concerns for conservation. Even so, deep appreciation of the need to 'farm' soil resources and not 'mine' the soil goes back several thousand years. A noticable change over the last twenty or so years in Australia, has been crop farmers increasingly replacing earlier cultivations with chemicals to control weeds, in order to retain surface residues that protect fragile soils from erosion and general structure decline.

2.2.2. RESIDUE RETENTION

In general, grain production still relies on a clean seedbed free of residue to establish the crop. This means that stubbles and residue from the previous crop or pasture are either ploughed in or burnt. In 1983, only five percent of southern Australian crops were grown using stubble retention techniques (Poole, 1987). The main reason for this was the poor stubble handling ability of the combine drill, although other management aspects such as increased disease, weed and insect loads have also had an impact. However the intensification of cropping lead to increased interest in stubble retention methods. Making these systems work in the southern Australian climate, where breakdown of stubble is slow over the dry summer period, remains a major challenge. Good establishment of crop seedlings is difficult without specialised equipment.

Stubble retention is a regional issue. In areas where yield potential is high, large quantities of cereal stubble residues can occur and these are difficult to sow crops into. Stubble retention is less of a problem in drier areas with limited trash loads. In either case, the use of machinery that will allow trash flow is needed. Best results for soil and water conservation are achieved when the straw is left above ground. Grazing of the stubble is also a benefit, and an integral part of the whole farming system for many producers in the mixed farming zone.

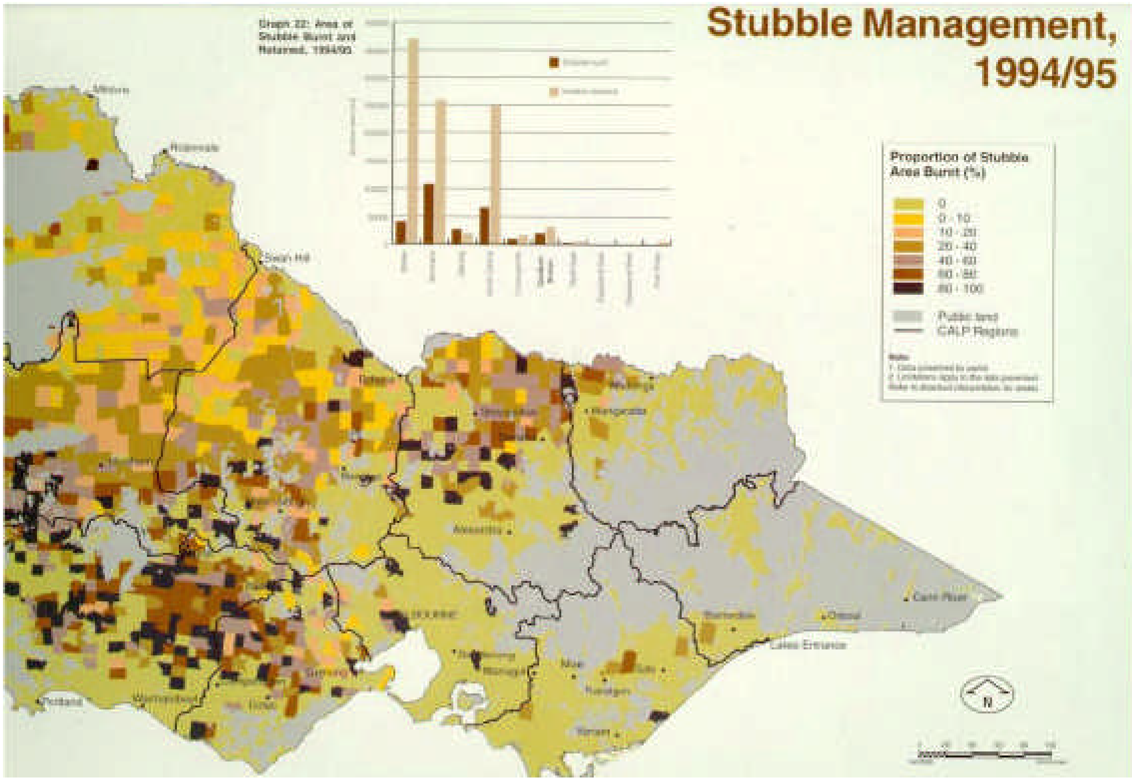


Figure 2 - Use of stubble burning in Victoria (DNRE, 1997).

2.2.3. MACHINERY

Recent times have seen significant advances in machinery technology to cater for the needs of conservation cropping. In the past most farms were equipped with a reasonable size tractor and an array of cultivation machinery such scarifiers, disc ploughs, offset disc ploughs, chisel ploughs, harrows and combines for sowing. Most farmers did not own a boom spray pre-1970. The introduction of herbicides began changing the machines that worked the landscape. These include:

- The introduction of high horsepower, four-wheel drive tractors,
- Wider cultivating and sowing equipment,
- Air seeders and chisel ploughs to improve stubble handling ability when sowing,
- Introduction of fertiliser banding below the seed,
- Enhanced boom spray technology.

These factors have combined to make crop preparation, sowing, treatment and harvest activities more timely and more intensive. Like all intensification, both costs and returns are increased. For instance, the specialised nature of the machines can result in higher costs of machinery services. At the same time the introduction of larger capacity machines in combination with herbicides allows producers to no longer require machinery previously used for secondary cultivation.

The effect of these changes on the cropping practices of today will be seen in greater detail in the case studies and further analysis in chapters three and five.

2.3. PROCESSES UNDERLYING PLANT AND SOIL RESPONSES

2.3.1. YIELD IMPACTS OF DIFFERENT TILLAGE AND STUBBLE TREATMENTS

The evolution of conservation cropping systems continue to alter the way in which Australian farmers establish crops and manage production. A recent, most comprehensive, review of long term tillage and stubble trials in Australia (Kirkegaard, 1995) aimed to examine regional interactions and the effect of time on crop yield in differing soils and climates. The results are summarised below in Table 2.

Table 2 -Summary of Australian long term tillage trials. Nb. Yield differences expressed as reduced tillage yield minus conventional yield. (ie. positive figure = reduced tillage yield was greater than conventionally cultivated crop.)

Site	Soil	Year	Crop sequence	Stubble treatment	Tillage comparison	Yield difference(t/ha) *Mean difference	Range	Reference
				Southern N.S.W. and Victoria				
Wagga Wagga	Red earth	1967-73	WW	Burn	DDC v CC	+0.01	-0.88 to +0.59	Rowell et al (1977)

Wagga Wagga	Red earth	1969-75	WW	Burn	DDC v CC	-0.48	-1.15 to +0.05	Poole (1987)
Wagga Wagga	Red earth	1969-75	WW	Burn	DD v CC	+0.29	-0.02 to +0.87	Pratley (1995)
Wagga Wagga	Red earth	1979-90	LW	Burn	DD v CC	+0.26	0 to +0.57	Heenan et al (1994)
Wagga Wagga	Red earth	1979-90	LW	Retain	DD v CC	+0.31	0.01 to +0.77	Heenan et al (1994)
Wagga Wagga	Red earth	1980-83	WW	Burn	DDC v CC	+0.06	-0.11 to +0.18	Cornish and Lymbery (1987)
Lockhart	Red Brown Earth	1981-83	WW	Burn	DDC v CC	0	-0.22 to –0.11	Mason and Fischer (1986)
Yanco	Red Brown Earth	1981-83	WW	Burn	DDC v CC	-0.29	-0.74 to +0.11	Fischer et al (1988)
Harden	Red Earth	1990-94	OWLWCW	Burn	DDN v C1	+0.08	-0.53 to +0.66	Kirkegaard et al (1994)
Harden	Red Earth	1990-94	OWLWCW	Retain	DDN v C1	-0.15	-1.00 to +0.63	Kirkegaard et al (1994)
Rutherglen	Red Brown Earth	1977-83	WW	Burn	DDS v CC	-0.14	-1.10 to +0.23	Ellington (unpub data)
Rutherglen	Red Brown Earth	1977-83	WL	Burn	DDS v CC	-0.01	-0.15 to +0.25	Ellington (unpub data)
Rutherglen	Red Brown Earth	1981-88 and 1989-92	WW LW	Burn	DDS v CC	+0.17	-0.03 to +0.32	Steed et al (1995 unpub data)
Walpeup	Sandy loam	1985-89	WW	Burn	DDC v CC	-0.11	-0.35 to +0.02	Incerti et al (1993)
Regional mean						**0.01**		
					Western Australia			
Merriden	Red Brown Earth	1977-92	WW	Burn	DDC v CC	+0.03	-0.61 to +0.20	Jarvis et al (1986 unpub data)
Merriden	Red Brown Earth	1982-93	WW	Burn	DDC v CC	+0.26	-0.07 to +0.66	Jarvis (unpub data)
Merriden	Red Brown Earth	1982-93	WW	Retain	DDC v CC	+0.20	-0.02 to +0.67	Jarvis (unpub data)
Wongan Hills	Earthy sand	1977-86	WW	Burn	DDC v CC	-0.25	-0.66 to +0.04	Jarvis et al (unpub data)
Wongan Hills	Grey loam	1979-89	PaW	-	DDC v CC	-0.52	-1.33 to –0.22	Jarvis et al (unpub data)
Esperance	Fine sand	1979-87	PaW	-	DDC v CC	-0.05	-1.39 to +1.12	Jarvis et al (unpub data)
Beverley	Sandy loam	1977-83	WW	Burn	DDC v CC	-0.01	-0.32 to +0.37	Jarvis et al (unpub data)
Regional mean						**-0.03**		
					South Australia			
Avon	Sandy loam	1979-84	WW	Retain	DDC v CC	-0.16	-0.70 to +0.34	Roget (1995 unpub. Data)
Avon	Sandy loam	1979-84	PW	Retain	DDC v CC	-0.22	-1.27 to +0.07	Roget (1995 unpub. Data)
Kapunda	Red Brown Earth	1984- 94	WW	Retain	DDC v CC	-0.07	-0.40 to +0.30	Roget (1995 unpub. Data)
Kapunda	Red Brown Earth	1984- 94	LW	Retain	DDC v CC	-0.27	-1.70 to +0.22	Roget and Rovira (1995 unpub. Data)
Regional mean						**-0.02**		
					Northern NSW and Queensland			
Hermitage	Blach Earth	1969-87	WW	Burn	DD v CC	+0.10	-0.24 to +0.63	Marley and Littler (1989)
Hermitage	Blach Earth	1969-87	WW	Retain	DD v CC	+0.08	-0.42 to +0.81	Marley and Littler (1989)
Billa Billa	Sodic duplex	1984-93	WW	Remove	DD v RT	-0.11	-0.73 to +0.58	Radford et al (1992)
Billa Billa	Sodic duplex	1984-93	WW	Retain	DD v RT	+0.16	-0.20 to +0.66	Radford et al (1992)
Warra	Black Earth	1987-93	WW	Retain	DD vCC	+0.37	0 to + 0.80	Dalal et al (1994)
Biloela	Alluvial clay	1987-92	WW(unfer)	Retain	DD v RT	-0.15	-0.46 to +0.06	Radford et al (1995)

Biloela	Alluvial clay	1987-92	WW (fert)	Retain	DD v RT	+0.33	-0.12 to +0.75	Radford et al (1995)
Breeza	Blach Earth	1983-87	WW	Retain	DD v CC	+0.03	-0.33 to +0.78	Felton et al (1993)
Croppa Creek	Grey clay	1983-90	WW	Retain	DD v CC	-0.23	-1.21 to +0.28	Felton et al (1993)
Winton	Brown solodic	1983-90	WW	Retain	DD v CC	+0.01	-0.32 to +0.60	Felton et al (1993)
Regional mean						**0.06**		

Source: (Kirkegaard, 1995)

In this analysis, no statistically significant or readily discernable yield-tillage interaction was observed in southern Australia. Twenty-one of the 36 experiments analysed had increased average yields with some relatively consistent benefits in summer rainfall areas. Reasons for differences in tillage treatments were attributed to poor seedling and root growth and weed ingression.

A similar summary of stubble management experiments is outlined below in Table 3.

Table 3 - Summary of long term stubble treatment experiments (Kirkegaard, 1995).

Site	Soil	Year	Crop sequence	Tillage	Stubble comparison	Yield difference(t/ha) *Mean difference	Range	Reference
				Southern N.S.W. and North East Victoria				
Wagga Wagga	Red earth	1979-90	LW	DDC	SR v SB	-0.31	-1.08 to +0.24	Heenan et al (1994)
Wagga Wagga	Red earth	1979-90	LW	CC	SR v SB	-0.35	-1.70 to +0.35	Heenan et al (1994)
Lockhart	Red Brown Earth	1981-83	WW	DDN	SR v SB	-0.21	-0.36 to +0.03	Mason and Fischer (1986)
Yanco	Red Brown Earth	1981-83	WW	DDN	SR v SB	-0.29	-0.70 to -0.40	Fischer et al (1988)
Harden	Red Earth	1990-94	OWLWCW	DDN	SR v SB	-0.45	-0.80 to -0.24	Kirkegaard et al (1994)
Harden	Red Earth	1990-94	OWLWCW	CC	SR v SB	-0.22	-0.74 to +0.30	Kirkegaard et al (1994)
Rutherglen	Red Brown Earth	1981-92	WW	DDS	SR v SB	-0.12	-0.65 to +0.90	Steed et al (1995 unpub data)
Rutherglen	Red Brown Earth	1984-92	LW	DDS	SR v SB	-0.10	-0.53 to +0.48	Steed et al (1995 unpub data)
Rutherglen	Red Brown Earth	1985-93	LW	DDS	SR v SB	+0.03	-0.72 to +1.60	Steed et al (1995 unpub data)
Rutherglen	Red Brown Earth	1987-94	LW	DDS	SR v SB	+0.11	-0.34 to +0.45	Steed et al (1995 unpub data)
Regional mean						**-0.31**		
				Western Australia				
Merriden	Red Brown Earth	1982-93	WW	DDC	SR v SB	-0.01	-0.40 to +0.14	Jarvis (unpub data)
Merriden	Red Brown Earth	1982-93	WW	CC	SR v SB	+0.04	-0.42 to +0.14	Jarvis (unpub data)
Merriden	Yellow Earth	1979-94	WW	CC1	SR v SB	-0.05	-0.19 to +0.26	Jarvis (1991)
Wongan Hills	Earthy sand	1979-94	WW	CC1	SR v SB	-0.32	-0.75 to –0.08	Jarvis (1991)
Regional mean						**-0.09**		
				South Australia				
Tarlee	Red Brown Earth	1978-87	WW	CC	SR v SB	-0.14	-0.86 to +0.74	Schultz (1995 unpub. Data)
Tarlee	Red Brown Earth	1978-87	LW	CC	SR v SB	+0.10	-0.58 to +0.54	Schultz (1995 unpub. Data)
					Northern NSW and Queensland			
Hermitage	Blach Earth	1969-87	WW	DD	SR v SB	+0.02	-0.51 to +0.81	Marley and Littler (1989)
Hermitage	Blach Earth	1969-87	WW	CC	SR v SB	-0.04	-0.32 to +0.52	Marley and Littler (1989)
Billa Billa	Sodic duplex	1984-93	WW	DD	SR v SB	+0.23	-0.94 to +1.08	Radford et al (1992)
Billa Billa	Sodic duplex	1984-93	WW	CC	SR v SB	-0.03	-0.42 to + 0.30	Dalal et al (1994)
Breeza	Blach Earth	1983-89	WW	CC	SR v SB	-0.49	-1.04 to +0.08	Felton et al (1993)
Croppa Creek	Grey clay	1983-90	WW	CC	SR v SB	-0.31	-1.12 to +0.01	Felton et al (1993)
Winton	Brown solodic	1983-90	WW	CC	SR v SB	-0.40	-0.96 to +0.11	Felton et al (1993)
Regional mean						**-0.14**		

Source: (Kirkegaard, 1995)

The effect of stubble retention on wheat yield was found to be negative more often than not. Seventeen of the twenty-three sites had negative yield responses to stubble. These responses appeared to be related to rainfall. Increasing amounts of rainfall generally reduced stubble-retained yields, but the trend was not statistically consistent over all experiments. This trend was thought to be because of increased levels of leaf and root disease and reduced early growth; factors encouraged by favourable moisture regimes. A detailed review of effects of stubble retention and conservation tillage practices on soil and crop production factors ensues.

2.4. EFFECTS OF CONSERVATION CROPPING ON SOIL PHYSICAL PROPERTIES

The effect of conservation tillage on various soil properties and associated crop production holds the key to continued adoption. Increased organic matter and, by default, increased carbon and nitrogen, and generally improved soil health and structure, should theoretically lead to higher long-term yields. The summary of long-term experiments indicates that these expected advantages have not been observed on a consistent basis.

2.4.1. IMPACT OF TILLAGE AND STUBBLE MANAGEMENT ON SOIL STRUCTURE

The physical structure of a soil is determined by a suite of complex physio-chemical interactions affecting aggregate forming ability, aggregate arrangement and, to a large extent, the productive potential of the soil. Chemically, structure of the soil is dominated by the reactive colloidal surfaces of the clays and the organic matter that they harbour (Hamblin, 1987), sometimes termed the backbone around which soil structure is built (Carter, 1994). Tillage has the ability to change these factors in not only the upper surface of the soil, but in subsoil layers, with direct effects on plant growth via the alteration of water retention, plasticity and soil strength.

Many Australian soils have been altered by the use of tillage, leading to excessive compaction and poor soil structure. Seventy five percent of Australian surface soils have organic carbon contents of less than one percent (Malinda, 1995), leading to weak structure. These factors have been significant in the adoption of conservation tillage techniques in many areas. On the other hand, there are soils that require tillage to prevent excessive compaction and poor structure that reduces water infiltration and restricts plant growth: and is caused by natural processes and vehicular traffic. High silt and fine sand contents of soils, or a predominance of non-expanding clay minerals, limit the ability of some soils to restore structure by shrinking and swelling cycles (Carter, 1994). Such soils may require tillage, even in undisturbed states as demonstrated by the high soil strength and low porosity measured in sandy soils of Western Australia after numerous years of pasture and only one year of cropping (Hamblin, 1979). Western Australian sands generally respond positively to tillage (Crabtree, 1998), with the need for tillage determined by aggregate stability, shrinkage and compactability indices. In other cases however the need for tillage will be related to soil management rather than the soil alone. This has been the case in many compacted soils, where deep ripping benefits the soil structure. Similarly, various land classifications that aim to determine soil suitability to direct drilling have been developed (Stengel, 1984) (Cannell, 1978).

Solid particles and their colloidal behavior have been a focus of soil research because of their influence on pore structure. Pore structure is crucial to the storage and flow of water, nutrients and gases to the plant. Tillage alters pore structure, and hence the soil's general properties. In technical terms, there are three factors determining pore structure and hence water infiltrating ability of the soil. These are total porosity, pore size distribution and pore continuity. Total porosity is defined as

$$1 - (p_d / p_p)$$

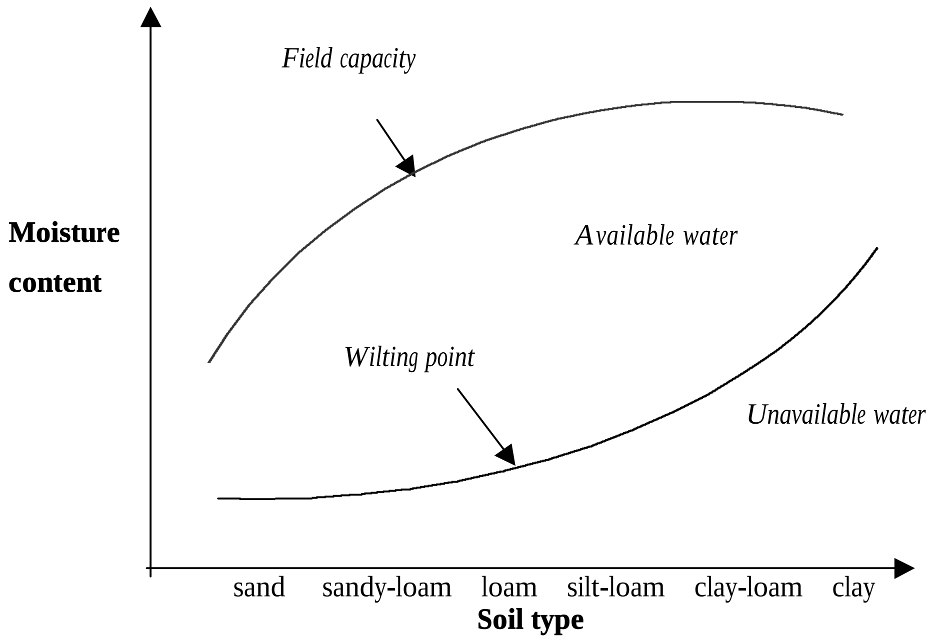
where p_d is bulk density (weight/volume) and p_p is particle density in the soil. Changes in bulk density have far greater bearing on porosity than particle density as this does not change markedly over time. Hence the porosity increases when bulk density decreases such as when the soil is broken up by tillage, frost or when clays swell when wet. Conversely, porosity decreases when bulk density of the soil is increased such as the case when soil is compressed by traffic or clay shrinkage.

Estimates of porosity allow approximations to be made of soil water storage capacity. Pore space is filled with either gas or liquid. When soils contain less than 10% gas space, as is the case when soils are waterlogged, plant growth is not possible. Additionally, roots encounter mechanical resistance to growth when bulk density is greater than 1.7 t/m^3 or 1.3 t/m^3 in loam and clay respectively. Bulk density, due to its effect on porosity and soil strength, is a useful measure of soil structure, although measurement of swelling clays present difficulties.

Pore distribution, in turn, allows measurement of a soil's water-holding ability. The ability to use and store water effectively is vital in Australian wheatgrowing environments. Smaller pores require greater suction to extract water due to the higher surface tension to volume ratio and hence have greater water storage and holding ability. Thus, water-holding ability is primarily a characteristic related to soil texture. The corollary of finer textured soil's higher water storage ability is the fact that water is not given up as freely as a loam or sand due to the increased soil surface area

Source: (Hamblin, *1987)*

Figure 3 below estimates the water storage capacity, also referred to as field capacity, of a range of different soils and how this relates to their water holding ability (Pratley, 1994). Water-holding ability, also referred to as wilting point, is the moisture content below which the plant cannot extract water, hence wilting and eventually dying. Moisture content between wilting point and field capacity indicates water available to the plant during growth.



Source: (Hamblin, 1987)

Figure 3 - Soil-water relationships on different soil types

Hence, loamy soils have the most capacity to supply available water to the plant. This has been continually demonstrated in irrigation research. Thus irrigation schedules are dependent on soil type as well as environment. Sands need to be watered more regularly than loams because of their poor water holding ability. It also explains why sandier soils can use light showers more effectively than heavier soils (Pratley, 1994). Reduced tillage also increases soil water storage (Cavanagh, 1991).

Table 4 - Plant available water in different soil types.

Soil type	Water available to plants (mm/m depth)
Sand	50
Fine sand	75
Sandy loam	110
Fine sandy loam	144
Loam	170
Silt loam	178
Light clay loam	178
Clay loam	170
Heavy clay loam	152
Clay	144

Source: (Hamblin, 1987)

Flow of water through the soil (porosity) depends on the transmissiveness of soil. Tillage can significantly alter transmissiveness; theoretically allowing greater storage of water and transmission through the profile due to the increased presence of continuous vertical pores. Pore size also has a large bearing on soil transmissiveness. Pore types present also have a large bearing on levels of plant available moisture as seen in Table 5 below (Hamblin, 1987).

Table 5 – Pore diameter, origin and effect on soil-water properties.

Average pore diameter (μm)	Origin	Significance
0.003	Separation distance between clay platelets	Smallest pores; contain structural or bound water
0.1	Spaces between clay domains or packages	Equivalent to permanent wilting point (-1.5Mpa)
1-2	Pores within stable micro aggregates	"Storage" pores capable of penetration by hyphae and bacteria
5-10	Pores within stable micro aggregates	Size of root hairs and higher order lateral roots
30	Pores between single grain, close packed sand or between micro aggregates	Field capacity (-10kPa) i.e. retaining water against gravity for 24 hours
100-1000	Created by roots and macro fauna, pressure and tension cracks	Transmission pores for rapid transport of water
10000-100000	Primary shrinkage cracks in clay soils, fracture planes from tillage, fissures	Transmission pores for very rapid draining of water from clay soil surfaces

Source: (Hamblin, 1987)

To fulfill the needs of agricultural uses soils need a balance of all pore types. Smaller pores are needed for storage of water but a lack of larger transmission pores will increase the wilting point and create lower water availability. Conversely, too many large pores will provide insufficient soil surface tension to hold water in the profile, as is the case with coarser sands. The result is that clay soils may be able to hold up to three times the water of sandier soils but half of this water maybe held by suction at close to, or beyond the limit of, plant availability, which is generally defined as being 1.5Mpa (= 15 bar). These soils will also have low infiltration rates, measured by hydraulic conductivity, that may result in runoff of water and reductions in overall storage. The most useful soil will have a combination of the two characteristics in almost equal proportions to allow adequate infiltration rates, sufficient storage ability and transmission to the plant. Reduced numbers of pores of more than 10 μm will also decrease the formation of root hairs, which are vital to the uptake of nutrients in the soil (Cresswell, 1992).

Tillage and stubble retention can significantly alter the distribution of pores in a soil. Zero-tilled soils generally allow greater water storage and higher transmission rates than ploughed soils.

This effect increases over time as macrofaunal populations increase and fungal growth creates pores in the soil. Work in the Wimmera and Mallee on long term experiments saw that conservation tillage significantly altered the soil's infiltrative ability. On the grey clay of the Wimmera hydraulic conductivity was increased eight fold, while on the Mallee's sandy loam infiltration was doubled, despite the fact that bulk density was significantly higher on the zero till soils at both locations (Bisset, 1996). Water-holding and yield were only affected on the heavy Wimmera clay however. On the red-brown earths of southern NSW infiltration rate dramatically increased when stubble was retained and 28mm of rain fell in 40 minutes.

Table 6 – Rainfall infiltration under different soil treatments.

Paddock treatment	Rainfall runoff (% incident rainfall)	Soil loss (kg/ha)
Chemically fallowed lucerne pasture	71	1250
Direct drill in previous year with stubble burnt	58	1150
Direct drill in previous year stubble retained	3	25
Direct drill disturbance and stubble burnt	46	950

Source: (Roberts, 1999)

2.4.2. STRUCTURAL STABILITY

Development of aggregates in topsoils is a dynamic process that is linked to plant growth and decay, as to well as microbial and faunal activity (Hamblin, 1987). Much of the research that has been done in Australia has been focussed on the red-brown earths. Cultivation alters the rate of microbial respiration, decreasing levels of organic matter and macrofaunal activity. Exposure of bare soil to rain and traffic causes slaking, dispersion and lower permeability; thereby making it more difficult for seedlings to emerge. The stability of aggregates is reduced when the soil is repeatedly cultivated, especially when wet. This effect is reduced when organic matter levels in the soil are high. Distribution of organic matter is also important, with an even distribution holding pores together and increasing permeability of soil.

It is well established that on many soils direct drilling and stubble retention improve soil structure (Chan, 1992) (Carter, 1992). Improved soil structure leads to improvements in water storage capacity and reduced waterlogging, compared to the performance of the soil under conventional cultivation and/or stubble burnt treatments. Friability of the soil is also greatly improved by direct drilling and stubble retention (Macks, 1996). This is related to a range of other soil characteristics.

Soil aggregation is a complex phenomenon to analyse, but a number of key elements exist. While the amount of macro-aggregation is related to the total amount of organic matter in the soil, the extra stability of pasture soils is related to the presence of aromatic bonding materials, microbial polysaccharides, decomposing fine root matter and hyphal micro-aggregates. Much of the fine root network that creates stable micro-aggregates in pasture are ruptured and subsequently oxidised by cultivation, causing large clods, surface crusts, poor germination and reduced emergence (Hamblin, 1987). The soil structure can, however, be restored to a large extent by increasing organic matter. Most red brown earths are either sodic or saline and are calcic at depth, requiring gypsum to improve cation balance, which in turn reduces dispersion and surface sealing. Stable aggregation contributes to reduced slaking and dispersion. Soils that are naturally sodic have a much greater predisposition to dispersion as measured by exchangeable sodium percentage (ESP). Exchangable sodium percentage becomes critical on Australian soils when it is greater than six percent. This is seldom a problem in US soils as exchangeable magnesium is not usually prevalent. The critical ESP value in many US soils is fifteen percent. Eight percent ESP is generally needed on soils classed as vertisols (Sarmah, 1996). This has obvious implications for both production and soil conservation on Australian soils where cultivated soils are generally prone to dispersion. Tillage and cropping intensities in Australian cropping reflect these basic characteristics of the soils crop farmers have to manage.

The extent of breakdown of soil organic matter, and trends in the organic matter component of soils is likely to be indicative of broader trends in soil health. Cultivation in general reduces the amount of organic matter in the soil compared to direct drilling (Heenan, 1995) (Hamblin, 1980) (Carter, 1992) but differences are often small (Fettell, 1995). Conservation cropping methods aim to maintain or even increase levels of organic matter, to promote stability of soil structure and maintain productivity of the soil.

2.4.3. SOIL EROSION

Water erosion occurs when the soil's capacity to absorb rain is less than rates of precipitation. Then ponding occurs, followed by surface water movement, which can remove soil particles. The infiltration capacity of a soil depends on the rate at which water is transmitted down the soil profile, as measured by hydraulic conductivity (K). Conductivity is notoriously difficult to measure but perhaps the best estimate involves measuring the 'time to ponding' given certain rates of rainfall. This is dependent on the presence of a crusted layer however. It has been shown that dry, uncrusted soil can absorb rainfall at up to four orders of magnitude greater than that of dispersed, crusted soil (0.02 mm/hr vs 36 mm/hr) (Poole, 1987). In practical terms this means that a slaked surface could only absorb the moisture from a fine mist and not from a significant downpour. This has obvious implications for erosion and waterlogging susceptibilities of different land management systems. Rates of soil erosion, infiltration, hydraulic conductivity and runoff are all improved by direct drilling and stubble retention (Malinda, 1995) (Carter, 1992). Evidence from many long-term experiments support this conlusion (Cavanagh, 1991).

2.4.4. SOIL STRENGTH AND COMPACTION

The strength of the soil depends on the cohesive and frictional properties of the material, as measured by the maximum shear strength that a load can exert as measured by the Mohr-Coulomb equation:

$$\tau = c + \delta \tan \Phi$$

where τ = shear stress, c is the cohesive force between particles, δ is the stress normal to the shear plane and Φ is the angle of internal friction. Cohesion increases with clay content due to the greater surface area. Friction increases with the number of interlocking particles. Sand, for example, has a low clay content, but considerable frictional strength due to the cementation of particles as the soil dries. Conversely, intra-aggregate bonding and electrochemical repulsion reduce the angle of internal friction so that the soil shears at lower imposed forces. This can occur with the addition of lime and organic matter (Hamblin, 1987) (Macks, 1996).

When the soil is compressed there is a reduction in pore volume as particles reorientate themselves toward each other. Tractor tyres, for example, can produce pressures of 0.2 MPa, horses and cattle 0.3 MPa and sheep 0.1 MPa. Roots, although they can produce pressures of up to 1 MPa, can be impeded and deformed by pressures as low as 0.05 MPa. Increasing shear strength has been seen to reduce root growth rates (Hadas, 1997) (Hamblin, 1979) and consequently dry matter production in a range of environments (Chan, 1996) (Chan, 1992). Zero till response in sandy soils is particularly important in Western Australia where much of all cropping occurs on sandy soils. Zero tillage was seen to increase both soil strength and promote water retention (Hamblin, 1979); a result of reduced root growth. Over time these roots compensated, altering water use patterns. Hamblin (1979) found that triple disc drills used in the zero till treatment resulted in high soil strengths being maintained, due to the lack of tillage. This is consitent with the observation that in general the use of disc drills on Australia's hard setting soils has not been successful. High soil strength affects rooting depth, which is vital to plant development. Variation in rooting depth will be a product of soil type and tillage treatment (Tennant, 1976). As well, stubble retention has the ability to limit soil strength and the effectiveness of disc drills (Crabtree, 1998).

Table 7 – Effect of soil type on root depth.

	Root Depth (cm)		
Soil	1969	1970	1971
Deep sand	140	169	165
Sandy loam	158	173	168
Grey clay	26	31	28
Sand over clay	61	73	70

Source: (Tennant, 1976)

Compaction is evidenced by the sheared zones distributed over a pear shaped area resulting from the arching of the soil outward from the centre of the impaction zone. Hence, reducing load or distributing it over a greater area, by the use of tracks, can reduce the level of compaction (Chamen, 1992). Irrespective of management however, cultivation is likely to cause soil structural damage due to implement load requirements. Without load, wheelslip will occur, which is similarly damaging for the soil due to soil shearing forces. Susceptibility to compaction increases with the level of soil water content but this is the most practical time in which to cultivate. Compaction can be reduced by using tramlines (controlled traffic), reducing the number of operations and by maintaining reasonable organic matter levels (Chamen, 1992). Swell and shrink cycles associated with high clay content and freeze-thawing will offset compaction.

Higher levels of organic matter contribute to lower bulk density while maintaining water content for longer periods of time. Both factors reduce draught requirements. Cultivation was shown to decrease the porosity of six Queensland soils by an average of twenty percent from their original level after ten years of cultivation and cropping (Dalal, 1986). Different crops have also been seen to have significant effects on soil strength and aggregation (Chan, 1996). Lupin based rotations reduce the shear strength of the soil compared to a range of other crops.

Table 8 – Effect of different crops on soil strength.

Crop	Soil Strength	Bulk Density
Canola	13.5	1.21
Barley	30.5	1.53
Lupin	12.3	1.13
Field pea	19.1	1.47

Source: (Chan, 1996)

Lower soil strengths were also seen to increase porosity, friability, microbial activity and structural stability of the soil. The use of these different crops to modify soil structure will become increasingly important as crop farmers place greater emphasis on rotational and longer term profitability rather than short term management (Chan, 1996). Deep-rooted legumes are generally regarded as being superior to grasses in their 'biological drilling' ability because of larger, more penetrative roots (Cresswell, 1992). This has yield benefits for the following crop in that it can generally extract greater amounts of moisture and nutrient at depth compared to those of cereal based rotations.

2.4.5. STUBBLE MANAGEMENT

As early as the 1920s it was recognised that stubble retention had a role in reducing wind erosion in southern Australian environments. Possible effects on water erosion in summer rainfall environments were realised in the 1940s following North American developments as a consequence of erosion during the ‘dust bowls’ era of the 1930s (Felton, 1987). In Australia crop residues have traditionally been burnt or heavily grazed as the first step in seedbed preparation. This tradition, and other factors such as poor stubble handling ability of combine drills and increased disease and pest incidence, have conspired to restrict large-scale adoption of residue retention until the last ten to fifteen years. In 1983 only five percent of stubbles were retained. Increasing cropping intensity has seen a need to tackle the issue however.

The defining characteristic of scientific information on stubble retention is the lack of definitive answers. A number of factors, varying with climate, management and soil, influence the stubble decision. Lack of summer rainfall in southern Australia limits residue breakdown and inhibits early growth, while also causing sowing problems. Soil incorporation may hasten breakdown but cultivation has deleterious effects on soil structure (Heenan, 1995).

To summarise, there are a number of claimed advantages and disadvantages surrounding the use of stubble retention.

Advantages:

- Reduction in wind and water erosion,
- Surface protection from raindrop damage and sealing,
- Improved water infiltration,
- Reduced soil evaporation and hence, improved moisture retention,
- Improved, or maintained levels of organic matter,
- Increased number and diversity of soil fauna,
- Improved soil structure,
- Grazing of stubble providing summer feed,
- Use of allelopathy to reduce weed burden in some situations.

Disadvantages

- Machinery blockages,
- Nitrogen tie up,

- Insect and disease problems,
- Lowered soil temperature and reduced plant establishment (Thomas, 1995),
- Weed protection from herbicides,
- Interference with soil incorporated herbicides,
- Phytotoxic effects on seedlings,
- Reduced pasture re-establishment.

Many machinery problems with stubble retention are being overcome with the sustained refinement of airseeders and drills. Modifications to harvesting equipment such as chaff choppers and spreaders have also improved the effectiveness stubble retention methods.

With few exceptions, stubble retention and reduced tillage improves moisture retention efficiency in fallow situations (O'Leary, 1997) (Cantero-Martinez, 1995) (Felton, 1987) (Incerti, 1993) and others. Efficiency of fallowing depends on rainfall infiltration and evaporation, both of which are influenced by stubble retention. It is being recognised increasingly by researchers and farmers alike that fallowing is a relatively inefficient way of storing water in the soil.

Table 9 – The effect of stubble retention and reduced tillage on fallowing efficiency (stored soil water/incident rainfall in fallow period).

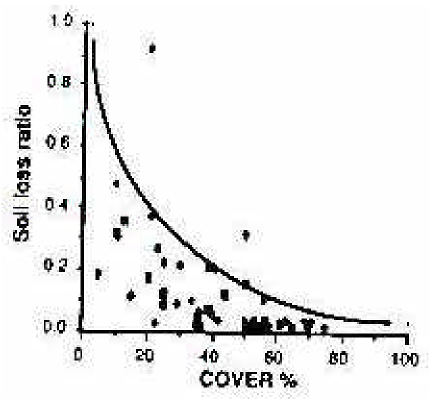
Bare fallow/cultivated	Stubble retained/zero tillage	Location	Reference
16%	21%	Southern Queensland	(Freebairn, 1993)
21%	29%	Northern NSW	(Felton, 1987)
17.7%	24.6%	Darling Downs, Qld	(Marley, 1989)
14%	25.3%	Darling Downs, Qld	(Marley, 1990)
26%	34%	Dooen, Vic	(Cantero-Martinez, 1995)
16%	60%	Kansas, USA	(Peterson, 1996)

Evaporation is not greatly influenced in southern Australian environments as heavy stubble loads (10-15 t/ha) or continually wet soils are needed for significant effects to be seen (Heenan, 1997), especially on non-vertisolic soils (Cooke, 1985). Reductions in runoff and improved infiltration are more likely to influence water economy, while at the same time drastically reducing erosion (Freebairn, 1993) (Roberts, 1999). Stubble lowers the impact of the raindrop at the surface, reducing soil particle detachment, disruption of aggregates; hence maintaining soil porosity. A one in five year storm of 32 millimetres in 40 minutes at Junee in southern NSW saw 58 percent of rainfall run off a direct drilled/stubble burnt treatment, as opposed to three percent water runoff from a direct drilled/stubble retained treatment (Roberts, 1999). Similar reductions in soil loss were observed when stubble was retained. Ground cover of 80-90 percent (4 t/ha) is needed to maximise infiltration (Malinda, 1996). Standing stubble under a zero till regime has higher infiltration rates than stubble mulched soils (Freebairn, 1993).

Stubble retention maintains moisture levels for longer periods after rainfall, allowing earlier sowing, increased yield potential and reduced production risk (Chan, 1996). Stubble residues as low as two tonnes per hectare have been seen to extend sowing time by two to six days. Retention inhibits early crop growth, which can alter patterns of water use (Kirkegaard, et al., 1994). The impact over the cropping program of a farm may still be positive however, as greater areas can be established at optimal sowing periods. The effects of stubble retention on early growth are discussed in following sections.

Research has shown that prospective benefits from stubble retention improved water economy have rarely resulted in observable improvements in crop yields (Chan, 1996). In drier years, these conservation tillage measures resulted in better yields but in higher rainfall years nitrogen became restrictive, reducing yield (Thomas, 1995). Postulated reasons include: lower soil temperature, altered water relations, reduced nutrient availability and uptake, reduced root growth, increased incidence of foliar and root disease, allelopathic effects from residue and increases in inhibitory microorganisms and phytotoxins (Kirkegaard, et al., 1994). The effects of altered residue and tillage management are markedly different to that experienced in North America, where higher cropping intensity is acheivable (Peterson, 1996) and more profitable (Dhuyvetter, 1996) than traditional practices in Australia, because of significant climatic and other environmental differences.

The susceptibility of soil to erosion is directly related to land management practice, existing soil water content and summer rainfall incidence (Freebairn, 1993), and hence decreasing latitude. Soil erosion is asymptotically related to soil cover.



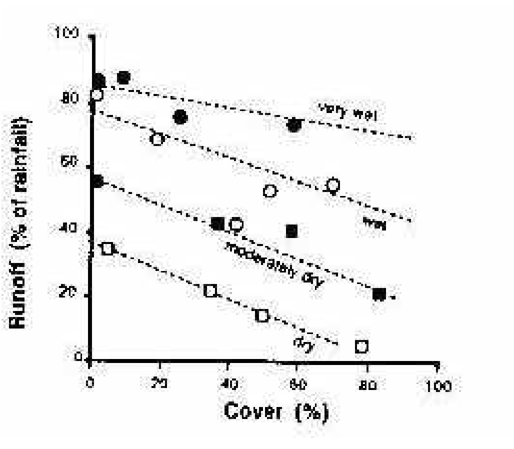


Figure 5 and Figure 6 - The effect of surface cover and soil water contenct on soil loss and rainfall runoff (Freebairn, 1993)

Table 10 – Effect of management on relative soil loss.

Practice	Relative soil loss (%)
Wheat-long fallow, stubble burnt	100
Annual wheat, stubble burnt	40
Annual wheat, stubble incorporated	14
Permanent pasture	1

In southern climates the impact of erosion on soil health is not as important due to the lower incidence of high intensity erosion events but the implications of management practice on other soil properties such as infiltration, soil strength and surface sealing can influence crop growth (Roberts, 1999).

2.4.6. FALLOWING

Fallowing, tillage and residue management are intricately related. Mechanical fallowing is still widely practised in the south-east Australian wheatbelt, particularly in marginal areas where water conservation is vital to subsequent crop growth (Latta, 1998), and is considered 'conventional' crop preparation.

Whilst the potentially beneficial effects of conservative tillage practices have been outlined in numerous studies that indicate improved soil structure and hydraulic properties (Packer, 1983) (Chan, 1988) (Burch, 1986) and increased soil water storage (Fischer, 1987) (Schultz, 1972) and many others, the effect of conservation cropping on soil water accumulation during fallowing, and on subsequent crop yields, have been questionable in the southern wheatbelt (Fischer, 1987). Yield and moisture benefits of fallowing in areas receiving more than 300mm of growing season rainfall, are likely to be insignificant (Kohn, 1966). Significant yield penalties have been seen on the grey and brown clays of the Wimmera (O'Leary, 1989) however without the use of fallowing. Yield advantages in clay soils are a result of high water-holding ability. In sandier soils, yield responses to winter fallowing are likely to be due to greater nitrogen mineralisation as water is stored at depth (Incerti, 1993). Medium textured soils respond to both factors. Weed control on fallows is vital to water accumulation. Even low weed populations can rapidly deplete soil water levels (Tuohey, 1972).

Fallowing experiments on duplex North Central Victorian soils compared chemical and mechanical fallowing in winter (eight months), spring (six months) and autumn (two months). Mechanical fallowing resulted in higher (0.26t/ha) average yields than chemical fallowing, as did winter fallowing compared to spring (0.46 t/ha) and autumn (0.56 t/ha) fallowing respectively. Yield was positively correlated to soil nitrate levels at sowing time, but was not related to soil water content (Cooke, 1985). This finding suggest that soil biological or physical factors may be at play. The yield advantage of winter fallowing over spring (0.86 t/ha) and autumn (1.13 t/ha) fallowing was greater on Wimmera grey clays (Tuohey, 1972). French (1978) reported that the average yield advantage of winter fallowing in South Australian soils was 0.35t/ha. Yield advantages are greater the earlier the fallow is established (O'Leary, 1989) but this has to be weighed against lost production and risks of soil erosion (Cooke, 1985).

If fallowing is to occur, the main agronomic question becomes ‘How best to do it?’. Similar or improved water conservation is seen in herbicidal long fallows compared to mechanical long fallows (Schultz, 1972) (Cooke, 1985) (Fischer, 1987) (O'Leary, 1997). The effect of tillage on nitrogen accumulation, has been both postive (Robson, 1987) and negative to nuetral (Reeves, 1974) (Mason, 1986) (Heenan, 1992) (Stein, 1987) (O'Leary, 1989) (O'Leary, 1997) (Kohn, 1966) (Rowell, 1977) (Thomas, 1995) (Marley, 1989). Mineral nitrogen levels are dependant upon stubble management. Stubble retention generally reduces nitrogen levels at sowing due to nitrogen immobilisation (Marley, 1990). Physical disruption of the soil is not needed to produce satisfactory mineralisation rates but higher yields were seen in the cultivated soils of these experiments (Touhey, 1972). After many years of research the mechanism for greater nitrogen and yield efficiency in cultivated crops is still not precisely known. Unlocking the potential of the water-saving ability of conservation cropping techniques in dry areas, where benefits are most likely (Crabtree, 1999) and use of mechanical fallowing is still commonplace will be a critical factor in determining the form, and probability of crop farming systems in the future.

The role of fallowing and improvements in water use efficiency from conservation cropping methods has been much less dramatic than the North America experience. Results from fourteen-month fallow efficiency followed by winter wheat at Akron, Colorado is shown in Table 11.

Table 11 – Changes in fallowing efficiency over time.

Practice	Fallowing efficiency
Dust mulching 1916-30	19%
Conventional tillage; shallow disk and rod weeder 1931-45	24%
Improved conventional tillage; begin stubble mulching 1946-1960	27%
Stubble mulch; begin minimum tillage with herbicides 1961-75	33%
No-till 1976 to present	40%

Source: (Peterson, 1996)

The continental climate and subsequent lower evaporative demand have allowed these improvements in efficiency of water use in the U.S. to occur, a stimulus not present in most of the Australian wheatbelt. As yet, the demonstrated marginal benefits of improved moisture retention available through conservation cropping methods have not been seen to outweigh the marginal cost of its use in many south-eastern Australian marginal cropping zones. It appears that this will remain so until the substitution of chemicals for mechanical fallowing has clear short and long-term economic benefits.

2.4.7. CONTROLLED TRAFFIC

Controlled traffic methods have gained rapid acceptance overseas but adoption has been slow in Australia's lower intensity agricultural environment. Controlled traffic aims to reduce soil compaction and has been defined as any crop production system in which the crop zone and the traffic lanes are distinctly and permanently separated (Taylor, 1983). This increases compaction in wheel tracks, improving trafficability and operation timeliness, while reducing compaction on other parts of the paddock and improving yield.

Ninety percent of soil compaction is incurred in the first equipment pass (Johnson, 1997). Increased economies of scale and use of high horsepower, heavy machinery has increased axle loads and compaction risk in many areas. In a no-till system of seeding and harvesting around forty two percent of the ground will be covered in one season (Tullberg, 1997). Add spraying, especially in more intensive production areas, and most of the paddock area will be covered over the season's course. Controlled traffic can reduce this trafficked area to ten percent (Johnson, 1997). Efficiency improvements follow from reduced operational overlap, while thirty to fifty percent lower implement draft forces reduce fuel costs (Tullberg, 1997). European work saw draught forces for primary and secondary tillage respectively 37-70 percent and 45 percent higher in conventional cultivation treatments compared to zero till (Chamen, 1992) (Dickson, 1996), translating into 49 percent and 46 percent more power required for primary and secondary tillage operations (Dickson, 1996). Overall energy requirements for crop establishment were reduced by 70 percent under zero traffic and cereal yields were increased. Nitrogen fertiliser recovery was also seen to increase in one experiment from 54 percent to 74 percent (Vermeulen, 1992). As pressure on the soil from tractors and implements is eliminated or reduced, soil strength and energy required for cultivation is also reduced while total pore space and hence water storage is increased (Chamen, 1992).

Table 12 – Effects of cropping system on yield in various studies.

Location	Soil	Crop	Zero traffic	Reduced	Conventional	Author
Edinburgh, Scotland	Clay loam	Winter Barley	4.70	4.13	4.08	(Dickson, 1996)
		Spring Barley	5.89	5.11	4.93	
		Rape	3.1	2.24	2.48	
		Potatoes	32.92	31.36	31.18	
NW Holland	Clay loam	Wheat	8.8	9.2	9.1	(Vermeulen, 1992)
		Sugar beet	12	11.8	11.3	
		Onion	51.3	49.1	46.5	
		Potato	64.3	60.4	58.8	
England	Clay loam	Winter wheat	6.77 (gantry)		5.72	(Chamen, 1992)
Minnesota, USA	Clay loam	Spring Wheat	3.7	1975 wet	2.69	(Voorhees, 1985)
			1.45	1976 dry	2.22	
			2.73	1977 wet	2.52	
Scotland		Winter barley	100%		106%	(Chamen, 1992)
Germany		Winter barley	100%		98%	
England		Winter wheat	100%		93%	
England		Winter wheat	100%		121%	
Germany		Sugar beet	100%		112%	
Scotland		Potatoes	100%		118%	
			Zero Traffic – Direct Drill	**Zero Traffic – Cultivation**	**Reduced Traffic - Cultivation**	
Millaroo, Qld.	Cracking clay	Soybean	1.3	1.2	Not planted	(Braunack, 1995)
		Maize	10.9	11.1	9.0	
		Soybean	2.6	2.5	2.2	
		Maize	8.3	7.5	6.8	

Controlled traffic aims to reduce energy used as a result of the tractor and implements compacting soil for traction and the subsequent decompaction by cultivation. The development of thrust by the tractor is inefficient due to the need for soil deformation and compaction to resist tyre forces (Tullberg, 1997). This compacted soil is then 'uncompacted' by cultivation, and the resulting draft forces in the wheeltrack are generally twice that of the other tynes. Around 25 percent of engine tractor power is used to deform soil downwards and backwards (Tullberg, 1997). Tillage mostly occurs after rain. Soil may be dry in the surface layers, where wheels will 'powder' the soil and reduce porosity. Deformation in moist lower layers will still occur however. Poorer soil structure results and the development of 'plough pans'; areas of higher density soil, has the potential to reduce root growth and water infiltration. Damage is affected by tyre width, implement width, tyre pressure and axle load.

Potential efficiency gains are best demonstrated by a practical example. A broadacre four wheel drive tractor of 160kW (215hP) delivered 120kW to the axles, of which 90kW was transmitted to the implement. Moving at 7.2km/hr and weighing 13 tonnes on dual tyres spaced at 1.8m, the tractor was pulling a 9m chisel plough requiring 45kN (5kN/m) with a mass of 5 tonnes. Draft in non-compacted soil is only 3.3kN/m, or 33kN for the implement. If traffic effects were eliminated then only two thirds as much power would be required to do the same job (30 vs 45kN).

This would equate to a drawbar power of 60kW rather than 90kW. One third of the implement power input is used reloosening wheeltracks (Tullberg, 1997) but 30kW has already been absorbed producing conditions for traction, so the total power used in making and loosening the wheeltracks is 60kW. Around half of the tractor energy is wasted compared to the controlled traffic situation. A tractor of half the size could do the same job and the effects on the soil would be lessened significantly.

Reduced porosity is the hidden impact of tillage, resutling in rainfall runoff (Tullberg, 1997). The impact of changed management is seen in Table 13.

Table 13 – Effect of tillage on rainfall runoff and crop yield.

Traffic system	Runoff (mm)		Crop yield (t/ha)		
	Conventional tillage	Zero tillage	Wheat 1994	Sorghum 1995	Maize 1996
Conventional	322	282	1.23	5.25	6.48
Controlled	266	166	1.5	5.51	7.45

Source: (Tullberg, 1997)

Rainfall over the two years runoff was measured totalled 1354mm. Around one quarter of rainfall ran off the land in the conventional tillage and traffic system. All measurements between conventional and controlled traffic were significantly different ($p<0.01$).

Adoption of the method has obvious problems in terms of machinery conversion, but the move to controlled traffic systems by northern Australian graingrowers and adoption of tracked tractors, indicate that the deleterious effects of compaction are being recognised in some areas.

Research in the US has found little difference in crop development or root growth on soils with greater than 40 percent clay and/or a predominance of 2:1 clay minerals (Gerik, 1987) (Unger, 1996). Bulk density, soil strength and porosity were not altered by tillage treatment, although soil under traffic lanes was adversely affected. The high swell-shrink capacity of vertisols repair much of the damage caused by cultivation, where five wet and dry cycles doubled the water infiltration rates of wheel tracks (Sarmah, 1996). Bed forming on formerly trafficked areas has seen cotton yield decreases of fifty percent (Sarmah, 1996) but the potential for repair is high considering that eighty percent of Australia's cotton is grown on vertisols.

Controlled traffic is more effective on structurally susceptible soils like red-brown earths but efficiency gains through increased timeliness and use of double cropping were still possible on high clay content Australian soils (Braunack, 1995). Improved field efficiencies and timings will improve farm productivity even when no discernable soil benefits are seen.

The use of global positioning systems (GPS) has provided impetus for the adoption of controlled traffic systems. Property and individual paddock size in northern NSW and southern Queensland justify the cost of GPS-marked controlled runs. The uptake of no-till farming in the area has demonstrated benefits of reduced cultivation. The use of controlled traffic is seen as a natural progression. Set up costs involving marking of runs are $2.50 per hectare, while guidance systems to increase machinery efficiency cost $10,000 to $50,000 depending on the degree of sophistication.

2.5. CONSERVATION CROPPING AND THE CHEMICAL PROPERTIES

2.5.1. SOIL ORGANIC MATTER AND ORGANIC CARBON

Maintenance of soil physical and chemical fertility is highly dependent on organic matter (OM). Organic matter is the major natural source of inorganic nutrient and microbial energy; serves as ion exchange material; it is a chelating agent to hold water and nutrients in available form; and promotes soil aggregation, root development, water infiltration and improved water use efficiency (Rasmussen, 1991). Additionally organic matter can decrease soil bulk density and increase macro and micronutrient cycling (Dalal, 1986). Cultivation and residue management, in turn, can have large influences on these factors, with organic matter contents of surface soils increasing as the degree of cultivation decreases (Locke, 1997) (Haines, 1990) (Blevins, 1983) (Carter, 1992).

Legume crops and pastures are used to maintain soil organic matter levels in south-eastern Australia. Intensive cropping regimes have the potential to rapidly reduce organic matter levels (Hamblin, 1987) (Dalal, 1986) (Heenan, 1997). Conservation tillage concentrates and maintains organic matter at the surface (Campbell, 1996) but in semi-arid areas like much of southern Australia change is slow to occur due to naturally lower organic matter levels and different crop growth patterns.

Organic matter levels are intracately related to soil organic carbon (OC) content (OM = OC*1.724). Soil organic matter levels vary from less than one percent in coarse textured sands to more than five percent on fertile prairie grasslands. The level of organic matter is influenced, in order of importance, by climate, vegetation, topography, parent material and age (Rasmussen, 1991). High rainfall environments produce greater biomass, increased rates of weathering and higher clay contents, which all promote higher levels of organic matter. In general, higher organic matter content is favoured by:

- Grassland soils compared to forest soils;
- Increasing precipitation and lower temperature;
- Fine textured soils;

- Naturally moist and poorly drained conditions and;
- Soils in lowland positions.

In temperate semi-arid regions, such as the majority of Australia's wheat producing areas, the organic fraction of the soil is vital due to its unusually large impact on water conservation, nutrient availabilty and stabilisation of yield (Rasmussen, 1991). Virgin organic matter levels are usually high due to low residue removal and oxidative rates, high root and crown matter production of native grasses and negligible erosion. Once cultivated the amount of organic matter begins to drop exponentially, declining rapidly in the first ten to twenty years and then more slowly until reaching a new equilibrium in fifty to sixty years. New equilibrium levels will be highly dependent upon farming practices such as rotation, tillage and residue removal. Restoring the organic fraction of the soil takes many years, explaining the stubble retention's lack of impact in some Australian experiments. In Queensland, organic carbon decreased by 33 percent in six cropped soils compared to uncropped soils (Dalal, 1986), with concomitant drops in mineralisable nitrogen (51%), total nitrogen (34%), organic phosphorous (29%) and increased exchangable sodium (35%). In double-cropped tropical soils the effects of tillage become apparent more readily with organic matter levels almost halving compared to untilled soil over the course of fifty years (Oleschko, 1996). The use of stubble burning and cultivation reduced organic carbon levels by thirty-one percent compared to stubble retention and direct drilling after ten years of continuous wheat-lupin rotation in southern NSW (Chan, 1992).

A range of management effects have an impact on organic matter levels. Increasing fallowing frequency increases the rate of soil organic matter loss. Decreases of fifty percent were seen in Canadian soils after thirty-seven years (Rasmussen, 1991). At thirteen of fourteen sites in America's Mid West fallow-grain rotations lost more organic matter, and thus nitrogen, than continuous small grain rotations (Rasmussen, 1991). Similar results were seen on the Canadian prairies, where increasing fallowing frequency from thrity-three to fifty percent increased organic matter loss by twenty-one and twenty-eight percent respectively compared to annually cropped soils (Doormar, 1980). Reduced retention of residues, higher erosion rates and increased cultivation, which leads to oxidation of organic matter, were quoted as the main reasons for there being detrimental effects of fallowing.

Altering crop type and tillage can affect the rate of loss of organic matter. Row crops generally increase losses compared to small grains due to reduced surface protection and increased tillage weed control. North American work saw spring ploughing significantly reduce organic matter losses compared to post-harvest, autumn cultivation (Unger, 1982). Following from this, conservation tillage significantly increased organic matter levels in surface (5-15 centimetre) soils

(Rasmussen, 1991). Non-inversion of surface residue and reduced oxidation and erosion contributed to these gains, but in lower soil layers conservation tillage had little effect on soil carbon and nitrogen levels. A summary of eighteen conservation tillage experiments saw average annual increases in organic nitrogen and carbon of 2.2 and 1.7 percent per annum. (Rasmussen, 1991). Over time this may have significant effects on soil nutrition and agronomic behaviour as the surface layer modifies crop and soil performance greatly, particularly by way of its effect on the soil's microbial component.

Nitrogen is inherently deficient in many of the world's agricultural areas, including native grasslands in semiarid regions, limiting production. Supplying nitrogen increases productive potential creating opportunities for higher levels of residue retention, which in turn impact on organic matter levels (Grace, 1998) (Fettell, 1995). In addition, applied nitrogen rarely leaches below the root zone on calcareous soils despite nitrogen recovery by crops rarely exceeding fifty percent (Rasmussen, 1991). Many of Australia's cropping soils are calcerous in nature, reducing leaching losses but the use of ammonium based fertilisers and legume-based pastures acidify the soil, reducing production in subsequent crops.

Residue is vital in setting new organic matter equilibrium levels in the soil, with effects being highly related to the amount, rather than the type, of residue in the soil (Larson, 1972). In one study, one-third of originally buried crop residue carbon remained after one year, the remainder evolved as carbon dioxide. One-third (eleven percent) was associated with the microbial biomass. This increased in the following years and after ten years, twelve percent of labeled carbon remained in the soil (Jenkinson, 1965). In general, twenty percent of added carbon is stabilised in the organic fraction with organic matter turnover averaging two to five percent per year. (Rasmussen, 1991).

Organic carbon and nitrogen levels have been seen to increase linearly with the amount of residue added in a number of experiments summarised in (Rasmussen, 1991). A range of studies showed that fourteen to twenty-one percent of added residue was incorporated into soil organic matter. High rates of carbon addition (Rasmussen, 1991) are still needed to maintain existing organic carbon levels however. Additions of this magnitude may not be compatible with many cropping situations however. Higher levels of retention are needed when rainfall is higher and cropping intensity lower. A quantity of 4.6 t/ha/yr of residue was needed to maintain organic carbon levels in a wheat fallow rotation in a 550 mm rainfall zone, compared to 1.9t/ha/yr in 240 mm, annual cropping situation. In a humid climate, continuous corn situation 6t/ha was estimated to be required. Continual applications are required however or organic matter will decline to original levels, indicating that most carbon is incorporated into labile carbon pools. Few semi-arid environments have productivity levels that permit substantial residue removal without accelerating organic matter depletion (Rasmussen, 1991).

2.5.2. STUBBLE BURNING

Stubble burning has varying effects on organic matter levels. Short-term studies saw minor impacts (Rasmussen, 1980) but more recent work has seen accelerated organic matter losses and reduced microbial activity (Beiderbeck, 1980) (Heenan, 1995). Burning volatilises fifty to seventy percent of residual carbon, as does microbial breakdown, but carbon remaining after stubble burning is biologically inactive, hence altering soil organic matter quality rather than quantity. This, in turn affects the buffering capacity of the soil. Retained stubbles have higher proportions of weak carboxylic acid groups, which increase the risk of aluminium toxicity. Carbon structure is altered by burning, aiding aluminium ion retention and hence, reducing toxicity risk. This possibly explains higher yields obtained when stubble is burnt on acid soils. (Slattery, 1998).

The rate of organic carbon loss is affected by management and climate. Long-term experimentation at Wagga in southern NSW elucidated the impact of management.

Table 14 – Rate of organic carbon decline in surface ten centimetres.

Treatment	Annual rate of decline in organic carbon (kg/ha/yr)
Stubble retained/Direct drilled	44
Stubble burned/Direct drilled	115
Stubble retained/Conventional cultivation	179
Stubble burned/Conventional cultivation	250

Source: (Heenan, 1997)

Green manuring is less effective than residue retention in maintaining organic matter levels. Vegetation is incorporated into the soil before maturation when carbon content is lower, subsequently limiting impacts on organic matter (Rasmussen, 1991). The primary function of green manuring is to sequester atmospheric nitrogen before incorporation into the soil.

2.5.3. MICROBIAL ACTIVITY

Soil organic matter exerts a positive influence on soil microbial biomass, which mediates the process of organic matter turnover, nutrient cycling and soil aggregation (Locke, 1997). Dramatic decreases in biomass occur when a virgin soil is cultivated and management practices are changed in cropping systems. Native grasslands contain twice the amount of root biomass as agricultural soils, maintaining organic matter and microbial biomass levels twice as large as those of cultivated soils. Quantities of microbial biomass are specifically related to the amount of degradable carbon in the soil and management. In two studies, over a range of soil types, 2.3 percent of soil organic carbon existed as microbial biomass in cereal monoculture compared to 2.9 percent when in rotation (Rasmussen, 1991), highlighting the beneficial effect of rotation. Macroclimatic conditions, like precipitation and evaporation, also influence the size of the microbial component; particularly in drier environments. The effects of changed management practice are evident more quickly in microbial biomass than in other factors (Gupta, 1994). Diversity of microbial activity, as well as size, also indicate system health and responsiveness to disease and other factors (Mele, 1998). Considerable increases in microbial activity are seen when stubble is retained, increasing rates of organic matter breakdown and subsequent nutrient supply to the crop. This does not necessarily increase yield as only three to five percent of carbon in stubble returns to the soil organic carbon pool (Haines, 1990) (Fettell, 1995) (Heenan, 1997); the balance being respired into the atmosphere by the microbial component as carbon dioxide. Hence long-term alterations to soil structure are slow to occur in Meditteranean environments (Lopez-Bellido, 1997) (Carter, 1992) (Hamblin, 1980). In general, changes to total organic matter in semi-arid environments will only be seen after twenty to thirty years (Rasmussen, 1991). However, effects in the surface layers will be apparent over a period of four to five years. Coarse and fine textured soils are likely to show greater changes than medium textured soils (Campbell, 1996).

2.5.4. NITROGEN

Stubble contains about 0.5 percent nitrogen. Retention can improve soil nitrogen levels, however in the short-term deficiencies can result due to the microbial biomass' need to maintain a carbon to nitrogen ratio of around ten. Addition of stubble, which has a carbon to nitrogen ratio of around sixty, to the soil requires the use of nitrogen from the soil to maintain a relatively constant carbon to nitrogen ratio. The high demand for nitrogen when breaking down stubble can cause significant benefits or problems depending upon rotation. Deficiency of nitrogen as cereal stubble breaks down will enhance nitrogen fixation in legumes. Alternatively, early cereal growth can be reduced but this will also be affected by tillage methods. Reduced tillage at sowing will also reduce the flush of nitrogen resulting from mineralisation.

Stubble and tillage management can play large roles in short-term soil nutritional change (Haines, 1990) (Carter, 1992) (Fettell, 1995). In conjuction with nitrogen application potentially significant changes have been seen (Chan, 1992) (Fettell, 1995) (White, 1990). A suite of management practices, rather than reliance on one practice such as stubble retention, are needed to alter long-term soil health. Reduced tillage, less exploitive rotations, residue retention and adequate fertilisation will all aid improved soil conditions. The use of nitrogen fertiliser is particularly important, as high levels of production return more residue to the soil for incorporation and increase cash flows. Also crops preferentially use applied inorganic nitrogen (Armstrong, 1996).

2.5.5. SOIL PH

Soil pH is generally not significantly affected by stubble and tillage treatment (Carter, 1992) (Fettell, 1995) however higher rates of nitrogen application can result in lower pH levels. pH in the top five centimetres of soil was seen to be 0.4-0.5 units lower when ammonium nitrate was applied annually (Fettell, 1995). The impact at depth is much less (Chan, 1992). This is consistent with much of the other work (White, 1990) (Heenan, 1997) but tillage and stubble burning has significantly reduced surface pH in some work (Chan, 1992). Low pH retards organic matter decomposition, which conversely maintains relatively stable organic carbon levels in the soil. Hence the ability to increase organic matter levels is greater in strongly acidic soils than soils that are relatively neutral. However, the supply of nutrient to the crop may be slower. Soil acidity in Victoria highlights the relationship between high rainfall and lower pH levels.

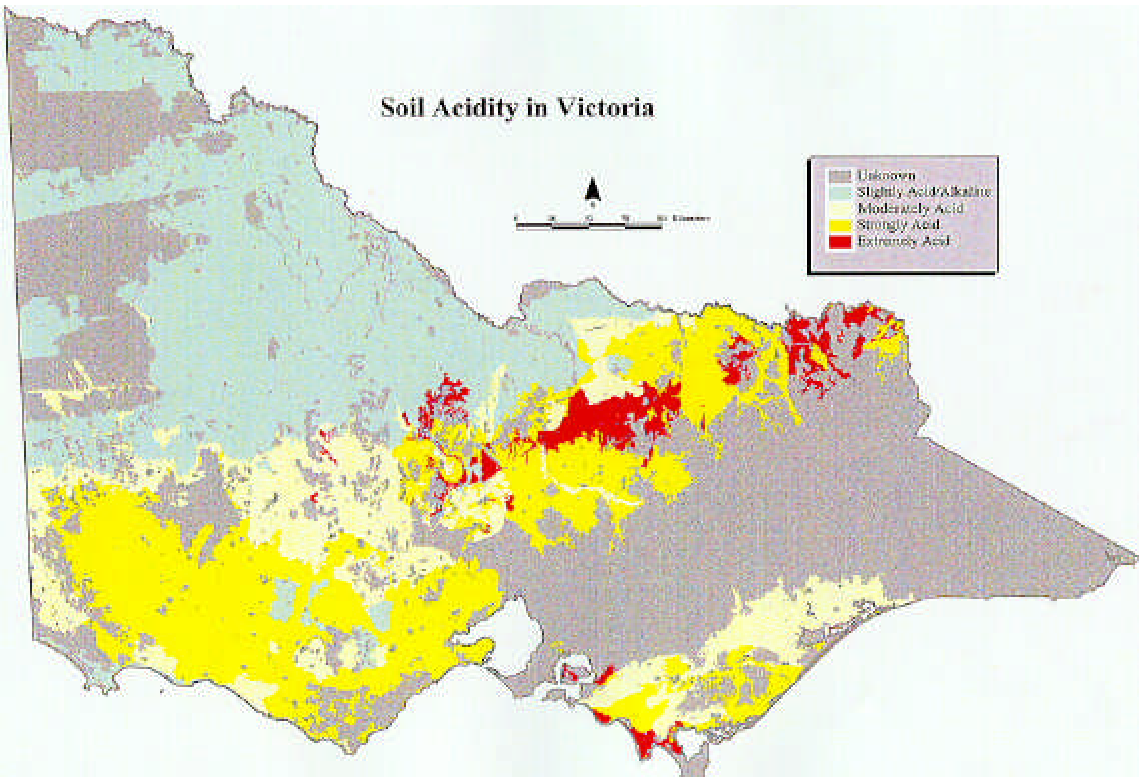


Figure 7 – Extent of acidity in Victoria (DNRE, 1997).

Acidification is increased by rotations including legumes and high levels of nitrogen application. Continuous wheat and legume monoculture at Rutherglen saw significant differences in soil pH over time (Slattery, 1998). Original 0-10cm pH_{CaCl} of 5.95 was reduced to 4.43 in lupins and 5.04 in wheat after fifteen years. Nitrate leaching leaves hydrogen ions at the surface, reducing pH. The amount of lime needed to neutralise pH reductions was calculated to be 380 kilograms per hectare in a wheat-lupin rotation; a rate higher than seen in other work. Higher intensity cropping rotations require increased nitrogen inputs and consequently, lime application.

2.6. CONSERVATION CROPPING AND ITS BIOLOGICAL IMPACTS

Microbiological factors and their significant effects on soil structure, nutrient availability and general crop growth have recently become better understood, but remain a research priority because of the many unknown impacts. The top ten centimetres of fertile soil can contain as much as two tonnes per hectare of micro-organisms including fungi, bacteria, algae, nematodes and protozoa, but total amounts vary considerably with sampling time (Mele, 1993). Micro-organisms can improve productivity and soil structure by facilitating the formation of stable soil aggregates, hence influencing soil porosity (Carter, 1992). Stabilising agents such as polysaccarides and hyphal filaments help bind the soil into micro aggregates, and hence form stable aggregates (Locke, 1997) (Carter, 1992). Soil is less susceptible to erosion and general structure is improved.

Micro and macro-organisms decompose plant and animal residues to make nutrients available to plants. Macro-organisms like earthworms and termites break down organic matter so it can be processed by micro-organisms, while also aiding transport of organic materials down the soil profile (Chan, 1989). Conservation tillage practices aid development of microbial populations (Mele, 1993) (Gupta, 1994) (Carter, 1992), although a range of factors affect the size of the microbial biomass. Fertile soils have large and diverse populations that allow extensive nutrient transforming ability, a factor largely influenced by soil type. Finer textured soils potentially offer better conditions for microbial biomass than sands, as they provide greater protection against predators, parasites and desiccation. Microbial biomass is also linearly correlated to soil moisture level (Gupta, 1994). Hence stubble retention and minimum tillage, which reduce evaporative losses, will aid microbial populations. Significant increases in microbial populations have been recorded after just one year of stubble retention (Gupta, 1994). Increased microbial populations favour increased rates of nutrient turnover. Conservation cropping has lead to higher rates of nitrogen mineralisation than conventional tillage in a number of studies (Reeves, 1984) (Carter, 1991) and decomposition of residues occurs more efficiently. Cultivation reduces populations and hence structural development. In addition, stubble retention and zero tillage improve moisture holding capacity of the soil and reduce soil temperature, both important factors in the breakdown of stubble over the presowing period (Roper, 1997).

Stubble retention and relative monoculture may aid the development of particular organisms, resulting in disease. Cultivation breaks up fungal hyphae and can reduce the incidence of disease in many situations where rotational diversity is low. Stubble burning may also reduce some diseases by eliminating the food source. Over time, a balance of predative organisms may return to naturally suppress disease severity such as that seen in *rhizoctonia solani* (Roget, 1996).

No-till cropping may increase the amount of herbicide application on-farm. The effect of chemicals on the microbial environment and vice-versa is somewhat clouded however.

Conservation cropping increases microbial populations, which in turn may increase the rate of herbicidal breakdown, actually reducing residual problems but conversely efficacy may be reduced by residue interception (Locke, 1997). The net effect of conservation cropping will be site and herbicide dependent. An extensive summary of research into conservation cropping-herbicide interactions saw a range of chemical half-lives unaffected by residue and tillage management (Locke, 1997). The presence of residues increase chemical susceptibility to volatilisation and photodecomposition however, if washed from residues the moister and cooler environment of conservation tilled soils generally inhibits volatilisation (Locke, 1997). Residue problems appear to be more likely to occur in conventional tillage systems, which incorporate chemicals, thereby protecting them from volatilisation and photodecomposition. Carry-over problems may result for the next crop in the rotation. Improved soil structure in conservation cropping fields may also result in higher amounts of chemical leaching into the subsoil. Offsetting this loss is the reduced susceptibility to chemical running off land in conservation cropping systems (Locke, 1997).

Table 15 – Micro-organism type and function.

Type of micro-organism	***Function in soil***
Organisms that add nutrient to the soil	
Nitrogen fixing micro-organisms	
Symbiotic N2 fixing bacteria (eg. *Rhizobium* and *Bradyrhizobium spp*)	Fix nitrogen in symbiosis with legume plants
Non-symbiotic N2 fixing bacteria (eg. *Azospirillum*, *Azotobacer spp*)	Fix atmospheric nitrogen in bulk soil, near crop residues and in rhizosphere
Organisms that transfer nutrients into plant available forms or facilitate their uptake by plants	
Nitrifying organisms (eg. *Nitrosomonas* and *Nitrobacter spp.*)	Convert ammonia nitrogen into plant available nitrate form
Sulphur oxidising micro-organisms (eg. *Thiobacillus thioxidans*, most heterotrophic bacteria and fungi)	Convert elemental sulphur and organic sulphur into plant available sulphates
Mycorrhizae (eg. *Vesicular Arbuscular Mycorhizae*)	Facilitate the uptake of phosphorus and zinc by most agricultural crops (excepting canola, lupins and a range of other crops.))
Organisms whose action results in loss of nutrients from the soil	
Denitrifying micro-organisms (eg. *Thiobacillus denitrificans*)	Convert nitrate nitrogen into nitrogen and nitrous oxide gases
Sulphur reducing bacteria (eg. *Desulfovibrio spp.*)	Reduce sulphate sulphur into hydrogen sulphide gas.

Source: Farming Ahead, October, 1997 (Kondinin Group Magazine)

2.7. SOIL/WATER INTERACTIONS

In theory, retention of residue and reduced tillage should reduce evaporation of soil water, and improve crop water supply and thus yields (Passioura, 1983). Additionally moisture is retained for longer periods after rainfall events, extending sowing time and aiding mineralisation (Reeves, 1984)

(Fischer, 1987). Still there are many reports of reduced crop establishment and early growth when conservation methods are used (Mason, 1986) (Mead, 1988) (Chan, 1996) (Kirkegaard, et al., 1994) (Chan, 1987) (Cornish, 1987). Differences in early growth result in changed distribution of water availability (Fischer, 1987) and sometimes reduce yield significantly.

Similar sowing times in experimental work often biases results toward conventional cropping methods. Adoption of conservation methods may occur over large areas of individual farms. The result on these farms will be shortened sowing periods. Earlier sowing will generally favor yield, resulting in similar, if not higher production compared to the result of conventional cropping methods (Pratley, 1995). Impaired early growth remains a problem however. A range of reasons for reduced early growth in conservation cropping systems have been proffered including:

- reduced root growth (Passioura, 1983);
- increased impacts of microorganisms (Kirkegaard, 1995) (Chan, 1989);
- allelopathic affects from decaying crop residue (Wu, 1998);
- decreased soil temperatures (Aston, 1986);
- increased incidence of disease such as *Rhizoctonia solani*, and *Pythium* spp.(Kirkegaard, 1995); and
- high soil strength (Masle, 1987) (Cornish, 1987) and reduced soil disturbance (Fischer, 1994).

Significant research investment has resulted in no definitive answers to the question of reduced early growth. It is important to note that the whole of season water use be crops will be altered by early growth patterns. Experimental (Cornish, 1987) and anecdotal data (Group, 1999) has found yield is unaffected by reduced early growth.

The use of conservation cropping methods results in a range of influences on soil-water relations. Temperature of stubble-retained soils are significantly more stable than stubble burnt situations due to insulating effects. Maxima and minima are reduced in amplitude when stubble is retained and the amount of degree-days are also reduced when soil disturbance is minimal (Aston, 1986). This potentially reduces early crop growth and water use, favouring minimal disturbance establishment in dry years but penalising yield when spring is wet. Post anthesis to flowering water stress is the biggest impediment to increasing grain yield in the Australian environment (French, 1984). Thus stubble retention methods offer significant potential to increase yield in dry areas that regularly experience post-anthesis water stress. Early sowing associated with conservation cropping also decreases the risk of anthesis to grain filling water stress. The benefits related to these factors have been associated with high adoption rates of no-till farming methods in dry climates of Western Australia and South Australia (Crabtree, 1999).

2.7.1. THE USE OF GYPSUM AND LIME IN COMBINATION WITH CONSERVATION CROPPING

Modification of the soil environment by tillage and stubble retention methods has occurred in concert with changed on-farm use of lime and gypsum ($CaCO_3$). The adoption of canola as a rotational crop, requiring adequate sulphur nutrition, has altered fertiliser application in many areas. Low cost and an increased awareness of its soil structure benefits has greatly increased applications. Additionally, canola's limited acid tolerance has increased lime applications in acid soil areas.

Gypsum application is recommended in situations where the soil is said to be sodic (ie. where sodium is attached to the clay particles of the soil in greater concentrations than usual). Sodium (Na) naturally occurs in the soil as sodium chloride (NaCl). Over time weakly charged chloride ions are leached, leaving positively charged sodium ions attached to clay particles. The excess of positive ions causes clay particle repulsion, in turn adversely affecting soil structure. Soil swelling, particle dispersion and surface sealing are symptomatic of sodicity, both factors reducing water infiltration and thus production. Sodium concentration is measured by the exchangeable sodium percentage (ESP). ESP's of greater than six are classed as sodic and gypsum application is recommended. The most effective applications of gypsum are likely to occur where

- there is a low salinity level;
- clay content is greater than 30 percent;
- exchangeable calcium to exchangeable magnesium ratio's are greater than two (Chan, 1995).

Tillage can be significantly affected by gypsum application with fuel savings of up to thirty seven percent demonstrated and yield increases of two hundred and thirty percent on poor soils with high rates of gypsum application (McKenzie, 1989). Gypsum, conversely, can increase nitrogen leaching, possibly reducing crop performance. Excessive application can also displace magnesium and potassium ions resulting in deficiencies (Chan, 1995). Similarly in acid soils the concomitant addition of lime with gypsum, which displaces aluminium and hydrogen ions and thus reducing soil pH, is needed.

Application of lime is important in acid, high rainfall, high production areas, that have higher nitrogen application and extensive use of legume pastures and hence increased acidifying potential.

Significant long-term benefits have been demonstrated however. Application of 2.5t of lime per hectare in 1980 increased soil pH by one unit, significantally increasing grain yield. Twelve years later acid tolerant and sensitive wheat yields were twenty-four percent and seventy-nine percent higher respectively (Coventry, 1997). In twelve years soil pH dropped by 0.7 units, almost returning to original values.

Soil structural stability increases with lime application. Lime has different effects on direct drilled and cultivated soils. Cultivated, lime incorporated soils had greater structural stability than those unlimed three years post application (Chan, 1998). Improved structural stability was not observed in the direct drilled soil due to already adequate structure. The impact of lime direct drilled soils is limited to surface layers.

Increased canola production has provided significant soil structural benefits in many areas. Reduced soil dispersion, increased pH and 'biological drilling' by canola's taproot has increased infiltration rates and soil water storage while reducing the incidence of waterlogging, disease and nutrient immobilisation. The canola plant can also be successfully established by conservation methods. The inclusion of the oilseed into the cropping package has enhanced the effectiveness and adoption of conservation cropping in many areas.

2.8. THE IMPACT OF CONSERVATION CROPPING ON GROWTH, WEEDS, DISEASE AND PESTS.

2.8.1. TIME OF SOWING

It is widely recognised that a major objective in the adoption of conservation cropping has been to improve the timeliness of sowing of crops. Reduced cultivation allows improved timing of sowing and hence, higher probability of increased yields than with less timely cultural operations. The balance between vegetative and reproductive growth, determined by temperature and photoperiod relative to sowing time, is critical to yield (Conner, 1992). In southern Australia, maximum yields are achieved when flowering occurs sufficiently late to avoid spring frosts but sufficiently early to allow long grain filling periods before the high evaporative demand and consequent soil water deficits of early summer. Cultivar selection and sowing time are the two management options available to control crop development and effectively use growing season rainfall. Sensitivity of yield to sowing date has increased since the widespread adoption of semi-dwarf varieties in the late 1960's (Fischer, 1996).

Australian wheats were originally derived from photoperiod-sensitive Northern European varieties (ie. long days needed to induce flowering and maturity). These genotypes matured too late in Australian climates, resulting in water stress and yield reductions. William Farrer, among others, identified this limitation and introduced photoperiod-insensitive South African and Indian varieties, which enabled earlier flowering times and reduced moisture stress. Expansion into drier areas followed (Crofts, 1984), in turn greatly affecting the development of rural Australia. Hence, today's varieties are largely photoperiod-insensitive but with the added inclusion of traits derived from the high yielding CIMMYT (Centro Internacional de Mejoramiento de Ma′iz y Trigo) 'WW15', spring wheat, semi-dwarf gene pool based in Mexico (Penrose, 1996). This breeding program used photoperiod-insensitivity as a basis for wide varietal adaptability to environment but susceptibility to post-anthesis water stress is high in these lines (Richards, 1992). Hence, if sown at sub-optimal times, significant yield reductions ensue (Anderson, 1990) and implicitly tillage methods exert large influence on semi-dwarf variety yields in Australian climates.

Earlier sowing, when temperature is higher, will result in increased rates of emergence and above ground biomass accumulation, as plant development is dependant on thermal time (degree-days) rather than time in isolation (Addae, 1992) (Gomez-McPherson and Richards, 1995). This alters crop water use, reduces evaporation, increases waterlogging tolerance and allows greater pre-anthesis nutrient assimilation (Addae, 1992). All of these factors contribute to higher yield, particularly of winter habit cultivars (Conner, 1992). Reduced weed control, increased disease incidence, moisture stress in autumn and overproduction of dry matter in spring can confound theoretical gains on offer however (Penrose, 1993).

Wide variation in the timing of autumn sowing rains and the need to reduce production risk contributes to growers sowing a range of varieties, possibly employing both winter and spring habit varieties to spread risk. Early rain allows earlier sowing but spring cultivars may develop rapidly, resulting in spring frost damage and yield reductions. Delaying development to avoid frost damage by use of photoperiod sensitivity or vernalisation requirements, referred to as 'winter habit', is desirable if sowing early. Sowing can be done much earlier than recommended times for spring wheats, hence conferring substantially increased sowing opportunity (Penrose, 1997).

Hence, selection of cultivar will have an impact on the benefits to crop yields by allowing sowing at optimal times. Winter cultivars have a much longer sowing time without yield penalty than do spring cultivars, because of vernalisation responses. If the autumn rainfall occurs early, then sowing can be spread over a longer period of time with little penalty from the use of both spring and winter cultivars. Late rainfall breaks provide large advantages to growers adopting conservation cropping then, when sowing needs to be completed in a shorter time, it can be done. Hence environment, and the nature of the rainfall pattern of a particular year will be important in determining benefits of conservation cropping over conventional cropping. The ability to sow early will be particularly important in areas that are poorly drained and prone to waterlogging and areas where winter growth is slow (Penrose, 1993). A large review of southern NSW breeding trials in the 1980's saw that mid-April to early-May sowing of either winter or spring type cultivars produced yields fifteen percent higher than mid-May to early-July sowings (Penrose, 1993). CSIRO modelling also saw wheat yields decrease by around five percent for every week's delay in sowing after late-April (Stapper, 1998). Further analysis of seven hundred south-eastern Australian wheat crops established average yield loss of four percent per week after late-April; conferring an eight percent decrease in gross margin. Sowing before April 20 reduced yield substantially. Ten percent of canola yield was lost per week. Thus the advantages of conservation cropping methods can be large in areas like the north-east Victoria and southern NSW where canola, lupins and early sown wheat varieties are prevalent and waterlogging a threat. Similar advantages are not seen in areas like the Wimmera where adoption of pulses and barley is widespread, conferring large sowing windows. In the Mallee, where waterlogging is rare, benefits will also be reduced.

Conservation cropping methods increase soil moisture levels, allowing longer sowing opportunities. Earlier sowing, in combination with conservation cropping methods, increase phosphorus uptake via vesicular abriscular mycorhizae (VAM) growth (Uebergang, 1995), increasing potential yield and/or grain protein.

Earlier sowing also reduces the probability of detrimental, high temperature effects during grain filling. A survey of twenty-eight wheat cultivars revealed reductions in ear weight of three to four percent per one degree celsius increase in temperature above 15 degrees celsius, which is the optimal anthesis temperature in Australian and northern hemisphere wheat growing environments (Wardlaw, 1989). High post-anthesis radiation levels also reduce grain weights. High temperatures at booting and grain fill reduce grain number per ear and individual grain weights respectively, although response is cultivar dependent. Responses in barley are similar, but starch and protein deposition is reduced (Wallwork, 1998). In wheat, higher temperatures increase protein levels but reduce grain yield. Heat tolerance varies widely according to variety (Stone, 1994). Thus the adoption of conservation cropping, and by implication earlier sowing opportunity, reduces the probability of exposure to high temperatures, increasing potential yields. Frost risk is increased however. Widespread frosts over wheatbelt areas in 1998 saw millions of tonnes of damage. Western Australia's adoption of conservation cropping methods perhaps increased frost risk and ensuing losses. The balance between frost risk and yield gains from earlier sowing has to be assessed, with most researchers and advisors advocating early sowing (Sykes, 1998). This trend looks likely to continue, with average sowing time decreasing by one day per year in the last twenty years (Stephens, 1998). Conservation cropping has played its part in this move and the benefits are evidenced by Western Australian regional yields increasing by thirty to one hundred percent in the last fifteen years (Stephens, 1998).

2.8.2. ESTABLISHMENT

Problems with seedling establishment have plagued the adoption of conservation cropping. Correct seed placement and good seed-soil contact are important for high yield. These conditions can be difficult to meet where stubble is retained. Additionally, Australian sowing machinery was primarily designed for cultivated, residue free soil. With strengthening, these machines can be used for direct drilling but stubble handling and seed placement can be compromised. This reduces crop emergence. A new generation of sowing machinery has been developed in a relatively short time, but crop seedling establishment problems remain. Increased tine spacing, greater underframe clearance, and coulters, all enhance trash flow. High breakout strengths and narrow points improve seed and fertiliser placement and press wheels and rotary harrows improve seed to soil contact. This technology can involve additional costs, and this would be a disincentive for adoption (Group, 1999).

Reduced early growth has been observed consistently in research and in commercial practice (Reeves, 1974) (Rowell, 1977) (Hamblin, 1982) (Mason, 1986) (Thompson, 1992) (Cornish, 1987) (Kirkegaard, 1995) (Chan, 1992). Soil biological and physical factors such as soil strength (Chan, 1988) were implicated, along with different surface temperature and water contents, reduced nturient availability and uptake, reduced root growth, increased incidence of foliar and root diseases and an increased presence of inhibitory micro-organisms and phytotoxins. Early wheat growth in southern NSW saw root length at anthesis reduced by 25-65 percent, a factor not related to stubble retention, soil temperature or nitrogen nutrition (Kirkegaard, et al., 1994). When soil was fumigated no difference was seen. Recent work implicates the presence of psuedomonas spp. as a primary cause of reduced growth (Mele, 1998). This work found increased yield where stubble was left standing rather than mulched or bashed. Shallow sowing increased emergence rates and seedling growth within the conservation treatments but reduced growth was observed regardless of sowing depth compared to cultivated soil (Kirkegaard, et al., 1994).

Conservation tillage and residue retention has been shown to alter root distribution compared to conventional tillage (Wulfsohn, 1996) (Merrill, 1996), although this did not significantly improve biomass above the ground or yield. Cooler soil, emanating from residue retention and improved use of sunflower rooting patterns in the no-till system, were the main reasons for improved water retention and root penetration. Changed water use patterns in conservation cropping systems have been evidenced by delayed anthesis and significantly higher surface water contents, indicating reduced spring evaporation (Kirkegaard, et al., 1994).

Soil strength has an impact on root growth, reducing plant population, dry weight post sowing, tillering and anthesis but not affecting yield (Cornish, 1987). Toxicity effects associated decaying residue have also been thought to influence growth. Decomposing annual ryegrass is very toxic to emerging plants (Thompson, 1992) and recent work has seen effects varying with cultivar (Wu, 1998).

The introduction of the semi-dwarf varieties into the Australian cropping environment has also impacted on crop establishment and growth. The dwarfing gene reduces plant coleoptile length, hindering emergence if sown deep. In a stubble-retained situation crop emergence can be reduced dramatically (Richards, 1992) but correct sowing depth will confer higher yield.

2.8.3. WEED MANAGEMENT AND HERBICIDE RESISTANCE

Weed management is inextricably linked with tillage. Herbicides allow substitution of cultivation with chemicals in the conservation system. The Australian herbicide industry quadrupled in size from 1975 to 1990 (Cribb, 1991); a figure likely to have increased in the intervening time, mirroring the increasing adoption of elements of conservation farming practices, and the reduced relative costs of chemical control. The chemical industry generates annual sales worth approximately $750 million. The long-term sustainability of conservation cropping depends on the effectiveness of chemical and integrated weed control measures such as rotation, cultivar choice, strategic tillage, fertiliser management, seed catching, burning increased seeding rates, altered sowing time, pasture manipulation and crop topping. The advent of herbicide resistance heightened the need for, and employment of integrated weed control methods by many growers. A short discussion of resistance issues is outlined below, followed by discussion of the impact of conservation cropping on weed control.

Selection of organisms by a defining characteristic increases the incidence of those organisms in a population over time. The intensity of this selection determines the rate of evolution. This selection is not confined to the development of weeds resistant to herbicides. Extensive use of seed catching carts at harvest in the Western Australian wheatbelt has inadvertently selected short, early shedding ryegrass species (Bowran, 1998), leading to a pre-dominance of these phenotypes in many paddocks.

The evolution of herbicides fundamentally altered the environment in which crops and competitors grew. Changed population dynamics result. The advent of phenoxy herbicides in the 50's reduced the occurrence of *Brassicaceae* species, while tolerant species such as fumitory *(Fumaria spp.)*, corn gromwell *(Lithospermum arvense)*, deadnettle *(Lamium amplexicaule)* and yellow burr weeds *(Amsinkia spp.)* increased in prevalence (Pratley, 1995). The introduction of diclofop methyl (Hoegrass) in 1977 for the first time allowed selective control of grass weeds in the post emergent stage of cereal growth. While some grasses were selected against other species were again favoured, including brome grass *(Bromus spp.)*, soursob *(Oxalis pescaprae)* and wild garlic *(Allium vineale)* and ryegrass *(Lolium rigidium)*. The adoption of minimum tillage has again altered the weed spectrum in many situations, favouring weeds like barley grass *(Hordeum leporinum)*, silver grass *(Vulpia spp.)*, prickly lettuce *(Capsella bursa-pastoris)*, sorrel *(Rumex acetosella)* and shepherds purse *(Lactuca serriola)* which prefer less soil disturbance (Pratley, 1995). Balancing this is reduced densities of annual dicotyledenous weeds (Davidson, 1994). Management requirements have to be altered to combat changed weed spectrums (Code, 1996).

Changed plant populations are a product of differing expressions of tolerance and susceptibility, as is herbicide resistance. Since the first report of a susceptible weed population acquiring resistance in 1970 (Ryan, 1970) there has been a rapid increase in the incidence of resistance worldwide (Powles, 1997). Much of the exponential growth of resistance incidence results from the concentration of chemistries being applied to the world's crops. Of the $14.28 billion dollar worldwide chemical market in 1995, twelve chemical groups accounted for eighty percent of sales. Five groups, triazines, glyphosate salts, amides, sulfonylureas and imidazolinones, make up half of the market (Powles, 1997). Despite the vast array of products on the market a limited number of distinct modes of action exist, enhancing the odds of resistance development in many crop production systems.

The extent of Australian resistance problems are evidenced by a 1997 Western Australian survey which saw 28 percent of farmers reporting resistance problems with anuual ryegrass, 7 percent with wild oats, 16 percent wild radish and 4 percent with doublegee (Powles, 1999). Intensive croppers would undoubtedly have higher incidences of resistance. These figures are likely to be higher than in eastern states due to the WA's higher cropping intensities but the implication is clear. Research in the early 1990's found 16 percent of north-east Victoria's cropping area contained resistant ryegrass (Davidson, 1994).

Resistance to Hoegrass® (diclofop-methyl) in annual ryegrass (*Lolium rigidum*) was first reported in 1982 (Heap, 1982), with reports of resistance now present in all states (Davidson, 1994). The extent of development has grown exponentially with at least ninety-nine species developed resistance to fourteen different herbicides. Fifty-five weed species had developed resistance to the triazine family alone (Holt, 1990). More recent accounts point to greatly increasing amounts of resistance, with official confirmations replicated many times over in the field (Bowran, 1998). Documented cases of resistance are increasing rapidly, as shown in Table 16, which does not include some recent cases of resistance.

Table 16 – Documented cases of herbicide resistance in Australia.

Resistant Weed Species	Common Name	Resistant to Herbicide Family
Artotheca calendula	Capeweed	Diquat
Avena fatua	Wild Oat	Diclofop-methyl

Avena sterilis	Wild Oat	Aryloxyphenoxypropoinates
Brassica tournefortii	Wild Turnip	Chlorsulfuron
Cyperus difformis	Umbrella sedge	Bensulfuron-methyl
Damasonium minus	Starfruit	Bensulfuron-methyl
Digitaria sanguinalis	Large crabgrass	Flusifop-p-butyl
Echium plantagineum	Salvation Jane	Chlorsulfuron
		Metosulam
Fallopia convolvulus	Climbing buckwheat	Chlorsulfuron
Hordeum glaucium	Wall barley	Paraquat
Horduem leporinum	Barley grass	Fluzifop-p-butyl
		Paraquat
Lactuca serriola	Prickly lettuce	Triasulfuron
Lolium rigidum	Annual Ryegrass	Paraquat
		Diclofop-methyl
		Atrazine
		Simazine
		Amitrole
		Glyphosate
		Trifluralin
		Metolachlor
		Metsulfuron-methyl
		Chlorsulfuron
Phalaris paradoxa	Hood canarygrass	Fenoxaprop-p-ethyl
		Sethoxydim
Raphanus raphanistrum	Wild radish	Chlorsulfuron
		Metosulam
		Atrazine
		Simazine
Rapistrum rugosum	Turnipweed	Chlorsulfuron
Sagittaria montevidensis	California Arrowhead	Bensulfuron-methyl
Sisymbrium orientale	Indian hedge mustard	Chlorsulfuron
		Metosulam
Sysumbrium thellungii	African turnip weed	Chlorsulfuron
Sonchus oleraceus	Sowthistle	Chlorsulfuron
Urochloa panicoides	Liverseedgrass	Atrazine
Vulpia bromoides	Barley grass	Paraquat

Source: (Heap, 1999)

As shown, the extent of the resistance problem is large and growing with the move to intensive cropping systems, which increases selection pressure. Repeated application of highly efficacious selective herbicides rapidly increase the prevalence of herbicide resistant phenotypes, as seen in modelling of resistant development (Maxwell, 1990). A consequence of higher levels of resistance is that economically optimal levels of chemical control decreases as the level of resistance increases (Goddard, 1995). This result has been observed in the field (Bowran, 1998) and is presently the focus of extensive research. Issues further related to resistance are discussed in chapter 5.

In practical terms, conservation cropping has had a significant impact on on the way weed control is carried out on Australian farms. Stubble retention and conservation tillage reduces soil moisture loss, thus increasing potential crop yield but also enhancing weed establishment and survival. Beneficial effects of increased water storage and reduced soil erosion can be offset by ineffective weed control, incorrect nutrition, reduced crop establishment and the phytotoxicity of the residues. Optimising weed control in the conservation cropping system continues to be the focus of much research. Stubble retention and, to and extent, direct drilling can inhibit weed control in an intensive cropping rotation (Fettell, 1999) (Roget, 1999). Good weed control in the conservation system has been seen in other research (Minkey, 1999) where knife points significantly reduced long-term impacts of annual ryegrass and wild radish compared to full soil disturbance situations. Rotation, followed by herbicide treatment and least significantly, tillage affected weed numbers in this long term trial. Increased seeding rates and narrow row spacings have also been seen to increase the efficacy of weed control in no-till seeding systems (Minkey, 1999). Extremely effective ryegrass control of up to ninety-seven percent was seen in other work (Crabtree, 1999) in a no-till, stubble retained system. Use of soluble herbicides and minimal disturbance seeders produced this effect. The effect of stubble on weed emergence is distinctly affected by variety due to differing phenolic compounds contents in different varieties stubbles (Wu, 1998). Shading by residue can also reduce weed populations (Lovett, 1982).

Stubble's shading effects can inhibit chemical control if applied without regard to chemistry of the control agent (Crabtree, 1999). A large review of the soil-herbicide interactions in reduced tillage and residue retained systems (Locke, 1997) reveal the complexity of weed control in conservation cropping systems. Soil characteristics such as organic carbon, pH, structure, soil moisture and microbial population impinge on the efficacy of herbicide application. The effect varies greatly according to situation however. For example eighty-five percent surface cover has lead to thirty percent of applied atrazine not reaching the soil surface in a no-till system. Much was volatilised and degraded before reaching the soil surface. Conversely, chlorsulfuron (Glean®) and a range of pre-emergent incorporated herbicides are still effective at stubble rates up to 6t/ha (Felton, 1987). Higher rates of dinitroanaline (Treflan®) have also been effective in high levels of stubble (Crabtree, 1999). Attaining a range of effective chemical and non-chemical control measures in no-till, stubble retained systems is critically important to continued adoption.

2.8.4. NUTRITION

Existing fertiliser technology was primarily developed for cultivated systems. Typically nutrients are stratified in the top twenty centimetres of soil (Cowie, 1996) due to the lack of soil inversion and general reduction in disturbance over an extended period of time. The impact on immobile nutrients in the soil of the changed system is only beginning to be understood and conservation cropping differing nutritional effects are evidenced by the Western Australian release of the 'no-till special' fertiliser. Adoption of stubble retention systems has also increased the need for effective research into the long and short-term effects on soil nutrition. Assimilation of organic nitrogen into the microbial biomass following stubble retention was observed in the earliest direct drilling experiments (Rowell, 1977). This can reduce substrate available to the plant and thus yield. Increased application of nitrogen is hence needed to reduce these effects. It will take some time before a retained system reaches a new equilibrium, where nutrients cycle in a similar manner to that previously.

Much of the perceived benefit of tillage in some areas eminates from the greater organic matter mineralisation that tillage induces. This results in rapid depletion of native soil nitrogen in cultivated systems before reaching equilibrium levels (Rasmussen, 1991). Increased fallowing frequency increase rates of decline (Rasmussen, 1991). Conservation tillage generally reduce mineralisation rates over time but the increased microbial biomass under no-till may compensate for the lack of aeration and oxidative conditions (Blevins, 1993). In a new equilibrium sitation the mineralisation rates of conservation tillage soils have been higher than that of cultivated soils (Stein, 1987). Soil nitrate levels have been higher (Reeves, 1974), the same (Heenan, 1992) (Stein, 1987) and lower (Thomas, 1995) in conservation tilled soils compared to cultivated soils but sampling time significantly effects nitrogen level. Once equilibrium is reached in the soil environment, minimal differences should exist between systems and it is likely that conservation tillage will enhance nutrition availability. Concentration in the top five centimetres of soil under zero tillage conditions (Malinda, 1996) will be a defining feature however.

The influence of fertiliser and other technology improvements complicates the impact of conservation cropping on general productivity improvements in the cropping sector. Table 17, illustrating the growth of Australian inorganic fertilisers use (in '000t) highlights this.

Table 17 – Australian inorganic fertiliser use ('000t) over time.

	Nitrogen	**Phosphorus**	**Potassium**	**Total**
1950	12	130	4	146
1960	34	241	26	301
1965	69	370	47	486
1970	125	370	71	566
1975	175	315	80	570
1980	256	400	116	772
1985	350	340	115	804
1990	394	365	131	890

Source: (Cribb, 1991)

Nutrition is an important issue to consider in the early phase of adoption of conservation cropping techniques. After a period of four to seven years, new nutrient cycling equilibriums will be operating, thereby reducing the impact of crop growing methods on nutrition available in the soil for plants.

2.8.5. DISEASE

Minimum tillage, and in particular residue retention, alters the soil-plant environment. In turn factors associated with crops, such as prevalence of disease are altered. An increased range of hosts for diseases, such as greater quantities of crop residue, different plant species and seed banks, and the alteration of the soil environment, inevitably change the incidence of disease.

Root and crown diseases

A number of diseases are affected by the method of tillage. Reduced soil disturbance has increased the incidence of rhizoctonia root rot *(Rhizoctonia solani)* in many minimum tillage situations, constraining adoption of conservation cropping in many areas. Control strategies in reduced cultivation situations have evolved however. Chemical control of volunteer species three to six weeks before sowing (Roget, 1987) and cultivation below the seed placement zone (Jarvis, 1986) (Roget, 1996) have reduced disease incidence in experimental and field conditions (Crabtree, 1998) in a range of soil types. The application of nitrogen with the plant reduced the area of rhizcotonia infection in the crop by fifty percent, assisting root function rather than affecting the disease directly (Roget, 1996). Altered sowing point design, allowing disturbance below the seed, and fertiliser application have resulted from these findings.

Tillage has not conclusively influenced the incidence of take-all *(Gaeumannomyces gramanis)* (Kollmorgen, 1987) (Roget, 1996). Where the soil was disturbed below the seed, little impact has been seen. Chemical fallowing also reduced take-all incidence due to the reduction in the amount of inoculum present in the soil via removal of the disease host (Roget, 1996). The influence of stubble treatment on the level of take-all is generally minimal but incorporation of stubble has been seen to increase the level of the disease in seedlings (de Boer, 1992). This again confirms that nitrogen nutrition plays a part in the level of disease incidence as incorporation tied up some of the nitrogen. Once the nitrogen was released as the straw broke down, the incidence of the disease was not significant. Stubble burning did not effect disease levels (de Boer, 1992).

Direct drilling has consistently been seen to reduce the level of cereal cyst nematode *(Heterodera avenae)* (CCN) in crops. Reductions by direct drilling in the level of infection by fifty perent compared to that of conventional cultivation were seen in a long term experiment at Lameroo, South Australia but no effect was seen in other experiments at Walpeup and Woomelang in

Victoria (de Boer, 1991). Reduced tillage treatments may be an effective way to lower long-term multiplication and hence nematode impact (Roget, 1996).

Recent research in the northern cropping zone has seen increased levels of crown rot *(Fusarium graminearum)* and common root rot *(Bipolaris sorokiniana)* where stubble was retained (Sumerell, 1989) and minimum tillage practiced (Widermuth, 1997). In no-tillage/stubble retained situations crown rot was significantly higher (32%) than where stubble was removed (4%) and a susceptible cultivar was used (Widermuth, 1997). Cultivation removed stubble retention's deleterious impact. Breeding has reduced crown rot's economic impact but these resistant cultivars account for only two of Queensland's thirteen commercially available lines. In most years the effects are limited but high rainfall increases susceptibility as evidenced in 1998. The level of infection and subsequent yield loss is related to the stubble - cultivation interaction rather than either factor in isolation. Higher water availability in reduced cultivation/stubble retained treatments provide the fungus with substrate to increase sporulation and disease incidence but at the same time provides increased yield potential if control is possible. Rotation remains the most important control option.

Recent investigations have highlighted the effect of root lesion nematodes (RLN) *(Pratylenchus neglectus and P.thornei)* on yield with respect to variety, method of cultivation, and fertilisation. Yield losses due to *P.thornei* of forty to eighty-five percent in susceptible cultivars have been observed in northern cropping regions, while *Pratylenchus neglectus*, which is more prevalent in southern regions, has reduced yield by six to forty percent (Vanstone, 1998). Stressed growing conditions increase nematode effects. Change agronomic practices such as increased frequency of wheat, the introduction of host crops like chickpeas, reduced tillage and chemical fallowing have increased nematode numbers in the soil, thus increasing potential yield loss. Yield loss is correlated negatively to soil nematode number (Vanstone, 1998) but control is possible through chemical application (Taylor, 1999). Rotations that use resistant cultivars and species such as barley and triticale also help while increasing cultivation may reduce nematode numbers, the tools and knowledge now exist to make it possible to use other control options instead.

Of the existing cereal root and crown diseases, only crown rot and rhizoctonia are affected by tillage. Stubble burning increases the incidence of crown rot and eyespot lodging. Thus conservation tillage has only limited impact on most of the common cropping diseases, as summarised in Table 18. Of those affected by tillage and stubble retention, the use of an appropriate rotation of crops and pastures, along with the use of resistant varieties, can overcome many of the limitations imposed by these diseases.

Table 18 – Host mechanisms and method of control for the major cereal root and crown diseases.

	Method of dispersal	Method of control

	Stubble borne	Survival on volunteers	Time of sowing	Resistant varieties	Rotations	Tillage	Stubble burning	Weed control	Chemical control	Nutrients
***Wheat Diseases**- Take-all*		x			very important			very important	moderately important	moderately important
Rhizoctonia		x				very important		very important		important
Cereal cyst nematode		x		very important	very important	moderately important		important	important	moderately important
Crown rot		x		important	very important	very important	very important	important		
Common root rot		x		very important	moderately important				moderately important	
Root lesion nematode		x		very important	very important					
Eyespot lodging	x	x	x	important	important	moderately important	important	important	important	moderately important
Stem nematode				very important	very important		important	important		

[red] = very important

[yellow] = important

[green] = moderately important

Source - "Cereal root and crown diseases" Kondinin group (1989)

Leaf and stem diseases

Reduced tillage and stubble retention effect the prevalence of leaf and stem diseases. Conservation tillage, via the use of wider row spacing and reduced early growth, can produce a less humid environment in the leaf zone, in turn reducing the incidence of many fungal diseases. Conversely, increased moisture retention can favour development. The move to longer and more intense cereal rotations has favoured disease development in many areas. Septoria, barley scald, powdery mildew and leaf rust have been seen to increase with the adoption of minimum tillage. As with the root and crown diseases, many of the diseases favoured by conservation tillage and stubble retention can be countered by use of resistant varieties, favourable rotations and chemical controls (Kondinin Group, 1992).

Table 19 – Cereal leaf and stem disease method of dispersal and control methods.

	Method of dispersal					Method of control				
	Wind spread	Splash dispersed	Stubble borne	Survival on volunteers	Time of sowing	Resistant varieties	Rotations	Clean seed	Chemical control	Tillage
Wheat Diseases- Stem rust	x			x	x	x				
Stripe rust	x			x	x	x			x	
Leaf rust	x			x	x	x			x	
Septoria tritici blotch	x	x	x		x	x				x
Septoria nodorum blotch	x	x	x		x	x	x			x
Yellow leaf spot	x		x		x	x	x			x
Barley yellow dwarf				x	x	x			x	
Ring spot	x		x				x			x
Flag smut	x		x		x	x	x	x	x	
Bunt					x	x		x	x	
Loose smut	x					x		x	x	
Eyespot		x	x			x	x		x	x
Head scab		x	x				x			x
Powdery mildew	x		x	x		x			x	
Downy mildew			x				x			
Ergot		x	x			x	x	x		
Seed gall nematode		x	x				x	x		
Black point	x				x	x				
Barley Disease - Stem rust	x			x	x	x				
Leaf rust	x			x	x	x			x	
Scald		x	x		x	x	x	x	x	x
Powdery mildew	x		x	x		x			x	
Net blotch	x		x		x	x	x	x		
Spot blotch	x		x	x	x	x	x	x		x
Halo spot		x	x			x	x			x
Barley stripe	x				x	x		x	x	
Arno Bay blotch	x		x			x	x			x
Wirrega blotch	x		x			x	x			x
Barley yellow dwarf				x	x	x			x	
Covered smut					x	x		x	x	
Loose smut	x					x		x	x	
Black point	x				x	x				
Oat diseases - Stem rust	x			x	x	x				
Leaf rust	x			x	x	x			x	
Septoria blotch	x	x	x		x	x	x			x
Barley yellow dwarf				x	x	x			x	
Bacterial blights		x	x			x	x	x		x
Red leather leaf		x	x			x	x			x

Smut	x	x	x	x	x	

Source - "Cereal leaf and stem diseases" Kondinin group (1992)

2.8.6. PESTS

Similar to the case with diseases, pest problems have plagued the adoption of no-till farming in many areas. A changed micro-environment inevitably changes the incidence of those living in that environment. For example the wingless cockroach, a minor pest of summer crops, reaches much higher density in a no-till stubble retained situation while some major pests like black field earwigs are greatly reduced by the new system (Simpson, 1999). Numbers of predatory insects like centipedes generally increase under the new system, as does the incidence of nutrient recycling fauna like earthworms and termites. In general, no-till, stubble retained systems have more biological activity due to the increased food incidence but the likelihood of pests suddenly becoming a major threat to crop production is low (Simpson, 1999). The main reason for this is the greatly increased numbers of predators. All soil pests have at least one predator, which in turn can increase under no-till systems.

2.9. CROPPING SYSTEMS AND ROTATION

In cropping in south east Australia, rotations based on wheat and pasture/fallow/wheat were the norm until the 1960's. The imposition of quotas on wheat production in 1969 and low livestock prices forced producers to find alternative crops. By 1971 215,000 hectares of rapeseed *(Brassica napus or B. campestris)*, 13,000 hectares of lupins *(Lupinus albus and L. angustifolius)* and 80,000 hectares of peas *(Pisum arvense)* were being grown. Canola and lupin production in 1999 is estimated to be 1.115 and 1.396 million hectares respectively, while the area sown to wheat has expanded to 11.4 million hectares (Statistics, 1999). These figures show the massive expansion that has occurred in cropping in Australia. Rotations are much more flexible than traditionally was the case. Conservation cropping practices have had a major impact on the adoption of these new crops and vice versa. The nitrogen fixing benefits of legumes have allowed producers to continually crop without large reductions in yield over time, while oilseed production has a range of positive effects on soil environment. Both crops fit in well with reduced tillage technology. Alternative crops grow differently and use alternative chemicals to monoculture, breaking weed and disease life cycles and lessening the chances of resistance development in an intensive cropping situation.

In ley farming situations, pastures offer soil structural and nitrogen improvements which are subsequently reduced by following crops (Reeves, 1984). Nitrogen build up is dependent upon pasture composition, with high legume component via the use of winter cleaning dramatically increasing nitrogen accumulation (Unkovich, 1997) and subsequent crop yield. Pastures can also be used to manage disease and weeds. Improved management and use of techniques such as spray topping and spray grazing is critical to success in the cropping phase. Conquering the demands of the whole system is vital to the adoption of conservation tillage.

In advanced conservation cropping programs the need to disrupt weed life cycles and lower seedbank levels has been recognised by the use of summer crops. Different herbicide groups are used for in-crop weed control while knockdown chemicals prior to sowing reduce seed set of annual weeds, leading to significant benefits for the following rotation. Management of waterlogging with the technique may be a consideration in some areas.

In summation, use of rotation in conservation tillage programs is vital for a range of disease, pest, weed and nutritional reasons. Manipulation of rotations and the farming system can improve farm productivity by allowing increased cropping intensity.

2.10. A REGIONAL PERSPECTIVE ON CONSERVATION CROPPING SYSTEMS.

2.10.1. SOUTHERN NEW SOUTH WALES AND NORTH EAST VICTORIA

Southern NSW and North-East Victoria has a relatively temperate, moist climate of uniform rainfall distribution. Long hot summers and mild winters typify the area. Soils are predominated by red brown earths, brown earths and heavier soils ranging from loam to clay. The range of soil environments that exist in Victoria can be seen in Figure 8. The mainly duplex nature of soils in north-east Victoria and southern NSW are evident.

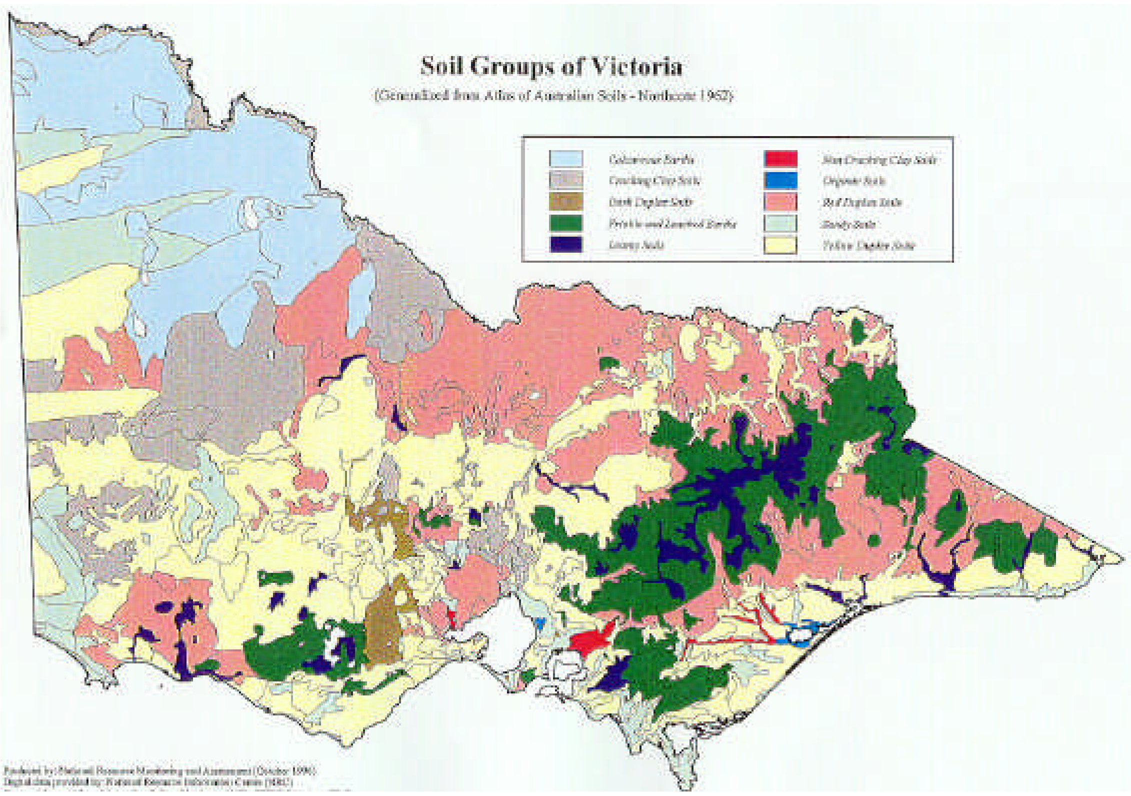


Figure 8. Soil groups of Victoria.(Northcote, 1975).

Early research carried out by an ICI research team was followed by work done from 1967 to 1973 (Rowell, 1977). This was carried out on red-brown earths with the aim of investigating the substitutability of bipyridilium herbicides for mechanical weed control. The results showed that yields from direct drilling were insignificantly different from than that of conventionally cultivated crops. The advantage of conventional cultivation was significant in only one of the seven years.

Table 20 - Yield from Rowell's work (1977)

	1967	1968	1969	1970	1971	1972	1973
DDT	.93	2.47	2.53	1.43	1.71	.97	1.11
DDM	.91	3.96	3.06	1.50	2.08	.95	1.12
DDC	.89	3.95	3.14	1.56	2.01	1.07	1.15
CONV	.86	3.76	3.35	2.44	2.19	.65	.88
CSD			3.71	2.39	2.33	.98	1.46

(DDT = direct drilled with triple disc, DDM=direct drilled with minimum disturbance, DDC=direct drilled with combine, CONV=conventional cultivation and CSD=cultivate, spray and then drill)

Rowell observed in trial work many of the issues that still dominate conservation cropping debate today such as:

- Reduced emergence and growth of crops in the direct drilled treatments (Mason, 1986) (Kirkegaard, 1995) (Reeves, 1974) (Pratley, 1995);
- Increased grass weed pressure in direct drilled treatments, particular in years where rainfall at sowing time was heavy;
- Increased broadleaf weed pressure but reductions in the levels of capeweed with decreasing levels of cultivation;
- Reduced emergence of cultivated crops in years where rain post sowing sealed the surface;
- Poor growth and yield of disc drill type planters due to restricted. root development.

Other methods of reduced tillage and direct drilling with conventional points however resulted in yields that were not different to those of conventional methods. The use of cultivation, spraying and then drilling the seed consistently produced the highest yields of any method (Rowell, 1977).

Increased levels of mineral nitrogen in direct drilled soils were found in early research at Rutherglen (Reeves, 1974). Average direct drilled yields of 2.27t/ha, compared to 1.97t/ha in conventional treatments, were the result. However, they too observed reduced early growth in direct drilled treatments which altered subsequent water use patterns. In response to a need for more information, an experiment was established at Wagga Wagga in the late 1970s that still operates. The production and financial implications of crop treatment can be examined in the analysis of the long-term experiments on page 110 (Chan, 1996) (Heenan, 1994) (Heenan, 1998) (Heenan, 1997) (Heenan, 1995). While the use of direct drilling has not significantly altered production but when analysed in a farming system the use of conservation cropping methods seem to have at least maintained or increased business profitability.

Another long-term experiment in the Wagga area found differences between the yield of conservation and conventional systems (Pratley, 1995).

Direct drilled yields were significantly greater than conventional cultivation in nine of the eleven years. This advantage was explained by the direct drilled treatment's significantly lower weed populations in six of nine years. Additionally a number of diseases favoured the direct drilled treatment (eyespot lodging, take all), which has not been the normal experience. Again early growth was reduced by direct drilling, with much slower canopy closure.

Table 21 - Yield from Pratley's work.

	Wheat yield (t/ha)			
Year	CC	CT	DD	Rainfall (mm)
1977	1.5	1.5	1.48	397
1978	2.89	2.87	3.26	808
1979	2.72	2.78	3.28	420
1980	1.78	1.86	2.12	414
1981	3.1	3.1	3.08	476
1982	1.07	1.27	1.32	313
1983	2.47	2.66	2.74	709
1984	1.28	1.75	1.86	631
1985	2.33	2.35	2.35	672
1986	5.48	5.96	6.29	543
1987	2.33	2.35	3.22	447
1988	0.44	0.49	0.4	616
1989	2.94	2.87	3.54	705
Average	2.33	2.45	2.69	550
Average water use efficiency	*70%*	*73%*	*80%*	

*note that lupins were sown in 1985 and 1988 with wheat in all other years.

More research in southern NSW was carried out at Yanco over a three year rotation (1982-84) (Fischer, 1988). In the drought year of 1982, differences in yield were observed between long and short fallow. Three years of conventional cultivated fallow gave the best yields overall. This was followed by cultivated fallow in the first year and direct drilling in the following two years. They also observed that herbicide fallowing followed by direct drilling gave the poorest yields. Stubble retention reduced yields further.

Research at Harden (Kirkegaard, et al., 1994) found reduced yields associated with both stubble retention and direct drilling of wheat. Seedling growth was reduced by fifteen percent compared to that of the stubble burnt and cultivated crops, a trend also seen at Lockhart (Mason, 1986). Long-term work at Condobolin (Fettell, 1995) saw no significant differences between tillage and stubble treatment on the soil organic carbon, total nitrogen or pH levels in the low rainfall environment.

In summary, research has shown over a run of years that the use of direct drilling methods need not reduce yield significantly. Given the importance of sowing time in the region where trials are conducted, the benefits of the method have resulted in widespread adoption of conservation cropping. Stubble retention is a somewhat more complex innovation however and uptake is still limited.

2.10.2. THE WIMMERA

The Wimmera is the major area of grain production in Victoria. The rich, deep soils of the region makes the Wimmera a profitable cropping area. A number of conservation cropping studies have been undertaken in this region. The Wimmera Conservation Farming Association (WCFA) began a long-term demonstration in 1991. The lack of phase representation in each year makes interpretation of these results difficult. Overall there have been no discernable differences in the returns of the types of cultivation and rotations used (Petheram, 1997), but these conclusions are confounded for the reasons mentioned.

Reduced tillage and stubble retention has been found to increase fallow water storage in the Wimmera (O'Leary, 1997). Compared to continuous cropping, long fallowing increased soil water storage, at sowing, by an average of 76 mm (range of 24-122 mm over four years) at Dooen. Stubble retention added a further 52 mm (range of 36-65 mm). Zero tillage was beneficial also in one year. Reductions in tillage saw water stored at greater depth on the cracking soils at Dooen (O'Leary, 1997).

2.10.3. THE MALLEE

To the north of the Wimmera is the harsher climate of the Mallee. Low rainfall and light, calcerous soils limit potential crop yield. The soils of the area are also particularly prone to wind erosion. Long-term experimentation undertaken at the Mallee Research Station, Walpeup in 1979 (Incerti, 1993) still operates today. General practice in the Mallee is to grow wheat in a three-year rotation of pasture/fallow/wheat with the fallow phase beginning in the year prior to the growth of the crop. A long fallow is considered necessary in most paddocks to be cropped to conserve water, increase soil mineral nitrogen and for the control of cereal root diseases and grass weeds. However cropping of paddocks, using short fallows or direct seeding also occurs as circumstances allow. Fallows are usually mechanically cultivated. Farmers in the Mallee have been less enthusiastic converts to conservation cropping than has happened in the better climatic areas. In areas with high production risks, the use of conservation cropping is quite commonly seen as further increasing risk, and as such has not been widely adopted.

[arquharson (1984)] in a study in northern NSW analysed conservation cropping using linear programming methods and found that slightly reduced yields had adverse effects on income over the long term.

Evidence of increased soil water content resulting from long fallows when compared to continuous cropping is present in the literature (Cantero-Martinez, 1995) (Ridge, 1985) (Fischer, 1987) (Incerti, 1993).

The effect of stubble retention in long fallows compared to conventional cultivation was investigated by O'Leary (1997), who found that water storage increased compared to conventional treatments. The use of zero tillage only increased water storage infrequently. Previously maintenance of residue over the soil had been recommended only for prevention or reduction of wind erosion.

The comparative effectiveness of chemical fallowing in the Mallee is improved in wet winters and springs where frequent cultivation may be needed. On the lighter textured soils of the Mallee reduced tillage systems and the retention of crop residues have been seen to increase water stored by long fallows (O'Leary, 1997) (Sims, 1957) as has also been found in the heavier soils of the Wimmera (O'Leary, 1987). Yield results are given in Table 22:

Table 22 – Yield results from the Mallee.

	1985	1986	1987	1988	1989
Conventional	1.66	3.24	1.74	2.22	2.54
Direct drill	1.31	3.12	1.76	2.17	2.51

Source: (Incerti, 1993)

Over the five years of crops, the only year where significant differences in yields from different cropping systems occurred was 1985. Hence it was concluded that no reduction in yield was seen when cultivated fallow was replaced with chemical fallowing and direct drilling. Retention of residues did not decrease yield either.

2.10.4. NORTH CENTRAL VICTORIA

Long-term experimentation has not been undertaken in this area but in recent years the formation of the Birchip Cropping Demonstration sites has instigated the investigation the use of conservation cropping. The relatively fragile nature of soil in this area make them prime targets for the use of conservation cropping. High levels of soil sodicity and the shallow, duplex nature of the soils require careful management for consistent crop production.

2.10.5. WESTERN AUSTRALIA

Results similar to the above-mentioned results for the Mallee, Wimmera and southern NSW were found by Jarvis (1977 to 1984) in WA. These results showed dependence on soil type. Direct drilling performed worst at Wongan Hills on loamy sand, intermediate for a sandy loam at Beverley, and were comparable for a clay loam at Merredin.

Table 23 - Average yield (t/ha) (1977-83) under different treatments in WA.

	Treatment	Merredin (t/ha)	Beverley	Wongan Hills
Continuous cropping	*Convent. Cult. (CC)*	0.814	2.514	1.525
	Direct drilling (DD)	0.968	2.529	1.313
Rotationally cropped	*CC*	0.849	1.932	1.868
	DD	0.991	2.041	1.710

Source: (Jarvis, 1986)

2.10.6. OTHER AREAS

Interesting work on conservation tillage has also been done in summer rainfall areas. Successful winter crop production in these areas is highly dependant on stored soil water accumulated in the 6-8 month fallow period between crops. For example, Goondiwindi has an average rainfall of 620mm, of which 62 percent falls in the October to March period. Any increase in the amount of water stored in this period has the potential to increase yields. This can, and has been, achieved through the retention of stubble and reduced cultivation (Thomas *et al*, 1995; Radford *et al*, 1992; Gibson *et al*, 1992). The higher water storage has generally lead to yield advantages with the use of minimum tillage and stubble retention except in years of high rainfall where fungal disease incidence increases (Thomas *et al*, 1995). This was the case in Thomas et al's work but they also found that the application of gypsum increased yield as it allowed greater water storage but lower mineral N concentrations. This could be due to reduced mineralisation and/or increased leaching of nitrate into the deep water table. This has been seen in other research results for parts of Queensland, regardless of soil type.

3. ADOPTION OF CONSERVATION CROPPING

3.1. ADOPTION SURVEYS IN SOUTH EASTERN AUSTRALIA

The adoption of new technology is always a complex process, especially in systems such as the integrated farming systems of south-eastern Australia. The wide range of influences affecting adoption, combined with the vagaries of climate, soil and business situation, create an individual risk profile for every producer pondering adoption. A number of surveys have explored adoption phenomena related to conservation cropping in the south-eastern Australian environment (Group, 1999) (Latta, 1998) (Truscott, 1997) (Harding, 1995) (Harvey, 1990) (Karunaratne, 1996). A brief summary of selected surveys follows.

3.2. THE SURVEYS

3.2.1. EYRE PENINSULA

A survey of seventy-three Lower Eyre Peninsula land managers (Truscott, 1997) reflected what continues to occur in the mixed cereal-sheep zone of Southern Australia. The winter-dominant rainfall area (350 to 500 millimetres) covers a wide range of soil types, and at the time of surveying most growers in the survey appeared to be undertaking change. Key findings included:

Cropping intensity averaged 72 percent. Wheat and barley comprised 82 percent of crop area.

Stubble management

70 percent had changed stubble handling in the last five years by purchasing and altering machinery and burning less.

62 percent wished to retain more stubble in the future.

42 percent were still burning some stubble but this was decreasing. Lack of machinery, and cost and difficulty of modifying machinery, nitrogen tie-up, and disease control, were seen as the main constraints to adopting stubble retention.

Soil quality and health had improved but this was not evidenced by higher yields.

Cultivation

Decreased cultivation; 30 percent had reduced cultivation by three or more workings, 36 percent by two workings and 48 percent by one working.

86 percent had tried direct drilling in the last five years. Advantages included saved time, increased management flexibility, moisture retention, cost savings and decreased soil disturbance.

42 percent had increased the use of direct drilling, with 30 percent claiming over 300 hectares were put in by this method. However over half indicated that less than one hundred hectares was the maximum sown by direct drilling.

Some growers had changed back to cultivation before sowing for weed, disease, machinery, yields, crop germination and chemical reasons.

62 percent had increased the use of conservation methods in the last five years to reduce erosion and preserve soil moisture. Nearly 50 percent of farmers use conservation tillage on more than 70 percent of their crops and only 11 percent do not use it at all.

The largest perceived disadvantage of conservation tillage was the need for more nitrogen fertiliser. Different and often increased weed and disease problems and machinery difficulties were also perceived to be major difficulties.

Herbicide usage

96 percent used non-selective herbicides before sowing in 1996. 70 percent had increased herbicides use in the last 5 years.

Herbicide use improved management flexibility, decreased erosion, improved soil structure and weed control, reduced equipment wear, saved time, reduced fuel usage, allowed longer grazing periods and reduced capital requirements.

The main problems associated with conservation cropping were herbicide resistance, herbicide residue build up, health risks, weed control, cost, disposal of excess chemical and lack of appropriate machinery.

Nutrition

Increased fertiliser use due to increased soil and plant testing

Higher rates of nitrogen and phosphorous were applied following canola crops in comparison to pasture, cereal and pulse crops.

Nitrogen application varied more than that of phosphorous due to dependency upon previous management. An average of 31 kilograms of nitrogen was applied to crops following a cereal, 55 kilograms following canola and 25 kilograms following pasture or pulse.

3.2.2. MALLEE

In the Victorian, SA and NSW Mallee region of low soil fertility and less than 350 millimetre rainfall, one hundred and forty-six farmers were interviewed (Latta, 1998). In this region low clay and organic matter contents combined with high water infiltration rates produce rapid leaching of nutrients and high susceptibility to erosion. Incidence of soil erosion caused by farming practices have induced a long history of community and public sector efforts to encourage adoption of less erosion-prone farming practices. However adoption has been very low (>1 percent) compared to the higher rainfall area, even though much research has shown that the conservation methods can be incorporated to varying degrees in the operation of farms in the region. This study aimed to reveal some of the factors that were inhibiting adoption. Key findings included:

Rotation

52 percent used the traditional pasture-fallow-cereal rotation, 21 percent a fallow-cereal rotation and 13 percent used a four-year cereal-cereal-pasture-fallow rotation. Economic imperatives and root disease resistant varieties appear to have hastened the move to higher intensity cropping rotations.

Legumes were not considered a viable for 96 percent of growers.

Extended mechanical fallow was still used, either in isolation or combination with chemical fallowing by nearly all growers (84 percent of wheat crops). Soil erosion was considered to be the major drawback with this practice. Those who used chemical fallowing claimed better weed control and improved soil structure.

No cereal crops achieved water use efficiencies of greater than 10 kilograms per hectare per millimetre of growing season rainfall.

Perceived issues affecting sustainability were wind erosion, soil nutrition, root diseases and weed control. 86 percent claimed that they would like to retain more stubble to increase organic matter levels, reduce erosion and improve soil structure. The benefits of stubble retention were widely known but few retained stubble because of disease and machinery problems.

76 percent of respondents used long fallows in the rotation but 46 percent recognised the need to change in the future. The perceived benefits of long fallows were moisture retention, disease control and increased yields. Those that recognised the need to change saw the main problems of fallowing as erosion, opportunity cost, high costs and reduced soil health.

30 percent of fallow preparation began the previous winter and were then worked four times on average before sowing. 15 percent was fallowed in autumn but these paddocks were still worked 2.5 times on average. 55 percent of crops were fallowed for more than six months prior to sowing. Barley crops were cultivated marginally less and 40 percent of barley fallowing was started in autumn to reduce erosion. There was no interaction between the number of cultivations and the water use efficiency of wheat crops. Yield is thus likely to decrease with higher cultivation intensity.

Chemical fallowing was perceived to improve weed control, reduce soil damage, machinery wear and fuel use while allowing longer grazing periods. Herbicide resistance and poor seedbed preparation were seen to be problems with the use of the method.

Nutritional inputs were low.

Only around five percent grew legumes due to low rainfall.

Grower research priorities included disease in minimum tillage, sustainability on sandy soils, fallowing, weed control in different rotations, profit margins for minimum tillage, nitrogen fertiliser, higher cropping intensity rotations, stubble retention, direct drilling equipment, sowing rates and erosion control.

In essence, growers seem to recognise that problems existed with cultivation based cropping and conservation cropping was potentially beneficial; such recognition was not reflected by actions however. A widely-held perception was that direct drilling does not work well in the Mallee, although this was not borne out in the surveyed crops. Changes in actual, or percieved, levels of farm risk always an important factor in adoption of innovation in farming. There are two tupes of risk involved here – risk associated with whether the changed method will not work successfully and risk associated with yield and price variability. If yield risks are percieved to be different between alternative systems, or if total variable costs and gross margins are perceived to be different between systems, then these are reasons farmers might resist change. More effective extension of existing research and investigation of factors limiting adoption, especially risk aspects is probably needed to better inform farmers in the area about changes to cropping practices.

3.2.3. OTHER AREAS

Adoption of conservation cropping methods away from the southern Australian cropping zone has been high. North American growers have readily adopted conservation cropping (Lal, 1997) with thirty-seven percent of the total American grain crop planted with conservation cropping methods in 1998 (Reeder, 1999). Total United States cropland is estimated at 188 million hectares.

By 1988 50.9 percent of the key corn belt state of Indiana, and around 50 percent of the total corn belt was established with conservation tillage practices (Martin, 1991).

Table 24 – Adoption of conservation cropping in the USA.

Year	Land area (mill. ha)	Percentage of planted area
1968	2.43	2
1970	4.05	3.4
1972	4.86	4.1
1974	6.88	5.2
1976	8.10	5.9
1978	12.55	9.2
1980	15.79	10.9
1982	26.72	18.2
1984	35.22	25.3
1986	39.68	32.9
1988	35.64	32.3
1990	29.65	26.1
1992	35.91	31.4
1994	40.21	35
1996	41.03	36

Source: (Martin, 1991)

It is estimated that seventy-five percent of the American crop will be sown by conservation cropping methods by 2020 (Lal, 1997). Worldwide conservation cropping now covers one hundred and fifteen million hectares, up from forty-five million in 1990 (Reeder, 1999). Further indications of Australian adoption phenomena exist. It is estimated that over fifty percent of the Western Australian crop was sown by conservation methods in 1998 (GRDC, 1999). This figure has increased in 1999 with the successful crop of 1998 (Crabtree, 1999).

3.3. SUMMARY OF A FARMER SURVEY OF AUSTRALIAN MINIMUM TILLAGE FARMING METHODS

3.3.1. BACKGROUND

In late 1998 the Kondinin Group surveyed its members about a range of conservation cropping related issues, using the group's monthly magazine 'Farming Ahead'. The resulting responses, totalling around five hundred in number, provided a wealth of information and highlighted the complexity of farming systems and the issues growers face when considering adopting conservation cropping.

Despite the high level of response to the survey, its representativeness should be taken into account. Magazine distribution, although wide, is concentrated on producers keen to access to new information about farming decisions. This may to some extent predispose respondents to be early adopters of change, and maybe, supporters of no-till/minimum till methods. The results reveal some important factors however for the whole of the grains industry; results that will be important as Australian growers strive to maintain their record of increasing productivity growth in recent times.

This survey adds significant context to the study presently being undertaken. It is the most comprehensive and current snapshot of Australian cropping practices. The survey has shown that minimal tillage cropping is now widely accepted by some of the farming population in most cropping areas of Australia. The survey has also outlined the significant complications and advantages associated with the adoption of conservation cropping.

3.3.2. ADOPTION OF NO-TILL AND CROPPING AREA

The first part of the survey aimed to establish the profile of the producers who responded to the survey. The opening question simply asked producers if they were using some form of minimum tillage operations on their farm. A resounding 88 percent claimed that they were, although the loose definition of minimum tillage may have lead some farmers using relatively frequent cultivation for most of their crop area to reply in the affirmative. The 12 percent who were exclusively using conventional cultivation were then asked if they thought that they that would be using reduced tillage methods in five years time; 73 percent replied positively.

The average cropping area of respondents was 623 hectares. Those using minimum tillage methods grew an average of 739 hectares in 1998. Conventional croppers averaged 475 hectares. The 556 responses accounted for approximately 350,000 hectares of cropping land, representing a significant sample size. The soil types of respondents varied greatly, with each type represented in relatively even proportions.

Farmers were then asked which method of weed control was most representative of what occurs on their farms.

Table 25 – Weed control methods most representative of their farm.

	Number	**%**
Cultivation to kill weeds	21	4%
Spray to kill weeds	287	55%
Cultivate and spray to kill	216	41%

As we can see, nearly all farmers used some form of chemical weed control. It is interesting to note the high proportion of farmers not using any form of cultivation to control weeds.

3.3.3. TILLAGE METHODS AND SOWING MACHINERY

The type of sowing methods growers were using varied greatly as we would imagine. The survey first asked respondents to categorise the degree of soil disturbance that seeding caused.

Table 26– Sowing method most representative of operations on their farm.

	Number	%
Full soil disturbance for sowing	183	33%
Partial soil disturbance for sowing	206	37%
Zero or no-till sowing	169	30%

The move to no-till and direct drill sowing can be seen from Table 25 and Table 26. A combined 67 percent of farmers were using some form of reduced soil disturbance sowing. Interpretation of the question may have been a problem however as definitions of no-till and zero-till vary regionally. However, the trend is clear. This is supported by the fact that 58 percent of growers indicated that they were using narrow points (lucerne, spear, inverted T or disc) of some description on their sowing machinery.

Table 27 – Type of point used in sowing operations.

	Number	%
Sweep or shear	171	34%
Narrow point - Lucerne	71	14%
Narrow point - Spear	104	20%
Narrow point - “T” boot	83	16%
Disc	37	7%
Other	44	9%

The results of Table 27 are further supported by the fact that 71 percent of those surveyed use points of less than ten centimetres in width. Given the high proportion of growers indicating the use of narrow points we should conclude that of those using points between 25 and 100 millimetres in width, many are using narrow points closer to 25 millimetres in width than 100 millimetres.

Table 28 – Width of points on sowing machinery.

	Number	%
Less than 25mm	142	34%
25-100mm	150	36%
100-400mm	111	27%
More than 400mm	11	3%

If using some form of cultivation, growers were asked if they only added extra tillage operations after pasture?

Table 29 – Use of extra tillage operations after pasture phase only?

	Number	**%**
Yes	153	34%
No	159	35%
Sometime	140	31%

Again the trend to reducing tillage operations was evident. Over a third of farmers stated that they only use additional tillage operations (other than sowing) after the pasture phase. The poor definition of the question may have confused this result as over one third of growers responded that they used tillage in the crop phase as well as immediately after the pasture phase. Given that 88 percent claimed that they were using reduced tillage it would seem that a large proportion of growers defined minimum tillage as being a cultivation plus sowing, or simply a reduction in the amount of cultivation that they previously practiced.

The next question asked; “do you use different tillage methods for different crops?”

Table 30 – Use of different tillage methods for different crops.

	Number	**%**
Yes	231	48%
No	154	32%
Sometime	98	20%

Over half of the growers responded that different tillage methods are used for different crops. Given the preceding results this would probably mean that tillage was increased for some crops. Canola may be a good example of this. Many growers without the use of one-pass, deep banding technology like to pre-drill nitrogen below the canola crop due to increase returns. This also allows trifluralin application for grass weed control and creates a fine seedbed, which improves emergence of the small-seeded canola. Alternatively the large seeded legume crops respond to reduced cultivation.

The next section related to specifically to the sowing machinery on surveyed farms. Producers were asked if they vary tine spacing for different crops? As shown in

Table 31 most producers did not alter their sowing configuration when sowing different crops.

Table 31 – Do you only alter the tine spacings for different crops?

	Number	%
Yes	73	15%
No	373	78%
Sometime	31	6%

Most cereal crops were sown on 17 centimetre row spacing but a large number of respondents had gone to 25 and 30 centimetre spacing to improve trash flow.

The average number of sowing tines across the 470 sowing machines surveyed was 44. Given that the average row spacing was 20 centimetres, average machinery width was 8.8 metres, or twenty nine feet in the old scale. Sowing widths varied from three to nineteen metres. Overall each respondents seeder sowed an average of 848 hectares, in addition to the machine being used for other operations totaling more than 650 hectares. Only 197 responses were given to the second part of the question however due to the fact that traditional sowing machinery has limited other uses. Airseeders and converted tillage equipment can be used for primary and secondary tillage in many cases. Crops were sown at a speed of eight to ten kilometres an hour.

Most machinery in the survey was relatively new. Purchase dates varied from 1963 to 1998 but the average date of purchase was seen to be 1993.

The type of ground engagement of the sowing machinery was then queried. This question was again not formatted correctly. Many seeding machines have a range of ground engaging tools. For this reason the total amount of ground engaging tools is much greater than the number of seeders surveyed in earlier questions.

Table 32 – Indication of what component(s) form the ground engaging tools on seeding machinery

Ground engaging tool	Number	%
Tines only	440	50%
Coulter disc not seeding	22	3%
Single angled disc seeding	7	1%
Double disc seeding	137	16%
Triple disc seeding	138	16%
Press wheels	102	12%
Other (please describe)	31	4%
Total	877	100%

Of interest was the high proportion of disc seeders in use. These have gained popularity in the sandy soils of Western Australia for their precise seed placement and minimal soil disturbance. A regional breakdown would, again, have been of use. Most farmers were still using tines to open the soil at seeding however. The integration of press wheels in many seeding operations is also of note. Some growers using press wheels did respond to the question above. Table 33 shows that press wheel use is quite widespread.

Table 33 – Use of press wheels at seeding.

Press wheel use	Number	%
Yes	156	35%
No	287	65%

These press wheels were on average, 60 millimetres in width. Twenty eight percent were flat with another 38 percent being wedged in shape.

Despite the increased use of press wheels harrows use is still high. 482 growers indicated that they used a soil leveling device of one sort or another.

Table 34 – Type of harrows or levelling equipment used on seeding machinery.

Leveling device	Number	%
Rolling chain (no spikes)	10	2%
Levelling pipe or grader blade	13	3%
Rotary prickle chain (Phoenix etc)	90	19%
Finger spring tine	140	29%
Ridge dividers	8	2%
Coil landpackers	16	3%
Rubber tyred rollers	39	8%
Steel roller (ribbed or smooth)	13	3%
Rotary spikes on shaft	27	6%
Steel mesh	12	2%
Leaf drag	89	18%
Home made	25	5%

The move to conservation cropping, and the high capital cost of new tillage equipment has necessitated the modification of many existing machines. Responses were grouped into general areas to give some idea of what were the most important areas addressed in the move to reduced tillage.

Table 35 – numbers of growers who made various changes to sowing machinery.

Modification	Number of
Increased number of sowing rows	55
Increased row spacing	14
Raised seed box	16
Air distribution	18
Different sowing tines	38
Increased tine breakout pressure	9
Narrow points	46
Discs	6
Added press wheels	37
Added prickle chain	16
Added rotary harrows	6
Finger harrows added	4
Added coulters to accommodate trash	6
Depth wheel	4
Shields to stop soil throw	2
Deep banding sowing	14
"Big N" anhydrous ammonia injection kits	3
Sowing box enlargement	4
Extended sowing width	7
Centre section width decreased for transport	1
More flotation wheels on seeder	8
Small seeds box	6
Exteded loading platform	4
Airseeder box on A frame	4
Hydraulic changes	2
Controlled traffic	2
Boom put on	2
Markers put on	2

As shown, the main changes that growers were making was a shift to sowing over more ranks of tines on the sowing machine, allowing the option to sow through larger amounts of trash. Increasing the number of ranks allows increased distances between tines, hence increasing the flow of trash. Also in the process of this change many growers had changed the tines on their machines to allow greater breakout strength. This allows improved soil penetration in tough conditions and improved probability of constant sowing depth. Many growers had also added press wheels, prickle chains and finger harrows to cover the seed at sowing. Quite a few had also increased their row spacing to allow greater trash clearance, while a few had added coulters to cut trash preceding the tine. Air delivery systems had also been added to many sowing machines. This would remove the need to raise the height of the seed box on combines. Quite a few had also set their machine up to deliver fertiliser at depth with the seeding operation. The rest of the changes did not really relate to conservation cropping to a great degree. Of interest to note was the conversion of machinery to controlled traffic in two cases.

3.3.4. WEED CONTROL

The survey of weed management demonstrated the relatively high chemical use occurring on Australian farms.

Table 36 – Number of responses, total and average acreage and expenditure on different chemical classes.

Chemical used	No.	Total (ha)	Av. area (ha)	No.	Total ($)	Av. spent ($)
Knock down-Fallow	206	132,250	642	149	715,759	4,803
Knock down–Pre-emergent	255	211,147	828	187	1,297,060	6,936
Selective-Pre-emergent	228	176,008	772	169	1,839,537	10,884
Selective - Post emergent	277	224,166	809	197	2,629,403	13,347
Insecticides	226	163,650	724	167	696,350	4,169
Fungicides	47	11,535	245	36	157,849	4,384
Other	26	18,877	726	29	236,876	8,168
Total	**1,265**	**937,633**	**4,746**	**934**	**7,572,834**	**52,694**

Given that the average area sown to crop over the survey responses was 623 hectares, average chemical use in all classes indicated that many growers sprayed more than once in each of the chemical classes. On these figures the average chemical bill for each grower was $52,700. Almost all crop area was sprayed once with a knockdown and then a selective chemical at both pre and post-emergent stages. The extent of selective herbicide application, in combination with the limited availability of different modes of action, indicates the high risk of widespread resistance development in Australia's cropping areas. Selective chemicals are also of higher cost than knockdowns. Limiting the dependence on selective herbicides would have significant long-term benefits for the industry.

3.3.5. STUBBLE MANAGEMENT

Stubble management is vital to the success of no-till cropping in many areas. Insufficient spreading will hamper trash flow in many cases, affecting seeding depth and crop development. The first two questions asked if crop residues were spread.

Table 37 – Extent of chaff spreading at harvest time.

Chaff	Number	%
Yes	262	60%
No	178	40%

Table 38 – Extent of straw spreading at harvest time.

Straw	Number	%
Yes	369	83%
No	73	17%

A high proportion of growers said that they spread chaff at harvest. An even higher percentage said that they spread straw. The effectiveness of many spreaders is questionable however. Even distribution of material across the header width is difficult to achieve even given the best spreaders.

The next question asked what happened to stubble from prior crops before seeding?

Table 39 – Stubble management prior to seeding.

	Number	%	% without
Slash	114	12%	18%
Hot or cold burn	167	17%	26%
Graze	312	32%	
Harrow	88	9%	14%
Cultivate	83	9%	13%
Nothing	135	14%	21%
Bale	64	7%	10%

The figures above are somewhat misleading as many growers will graze and then burn. Totalling these figures to one hundred percent is misleading. If we remove the grazing responses however, 26 per cent of respondants burnt, 21 per cent retained and the rest is manipulated to some degree.

The responses from the question above are at odds with the following response to the question; “do you retain cereal stubble as much as possible?”

Table 40 – Growers retaining as much cereal stubble as possible.

	Number	%
Yes	357	77%
No	34	7%
Sometimes	72	16%

Again, an unintended anomaly in the question structure exists. Many growers may, as they have stated, retain as much stubble as possible. If however, they do not have the machinery to cope with this stubble load they will have to dispose of it in some way. The same can be said of answers to identical questions regarding legume and oilseed stubble treatment.

Table 41 – Growers retaining as much legume stubble as possible.

	Number	**%**
Yes	301	85%
No	27	8%
Sometimes	28	8%

Table 42 – Growers retaining as much oilseed stubble as possible.

	Number	**%**
Yes	205	72%
No	41	14%
Sometimes	37	13%

It seems from these responses that an overwhelming majority of growers aim to retain stubble but are unable to do so for a range of reasons. These responses may also indicate that many growers are aware that retaining stubble would be beneficial for soil structure etc. but they are not willing to deal with the other problems arising from stubble retention. This is an important issue for the continued adoption of conservation cropping.

3.3.6. COMPARING CONVENTIONAL AND NO-TILL SYSTEMS

In the last section growers were asked that if they were using minimum/no-till, to compare it with conventional seeding systems with respect to crop emergence, crop vigour, weed control, erosion control, herbicide incorporation etc. The resulting response ranged from expanded answers of five lines or more, to two words. The results give an indication as to how some farmers of Australia perceive what is happening in their paddocks when using no-till and minimum tillage methods. Most concentrated on the questions asked and did not offer full comment. The results are shown below.

Table 43 – Number of responses when asked to compare no-till crop establishment to conventional cropping treatments.

Crop production factor	Positive or neutral	Negative
Effect of direct drilling on crop emergence	105	60
Effect of press wheels (specifically) on crop emergence	10	0
Total	*66%*	*34%*
Direct drilling did not reduce emergence in stubble	10	
Stubble did not retard emergence of small seeded crops (canola)	11	
Effect of direct drilling on crop vigour	79	56
Effect of press wheels on crop vigour	5	0
Total	*60%*	*40%*
Vigour catches up over the course of the season	18	
Effect on crop weed control	72	35
Effect on herbicide incorporation	38	64
Increased reliance on post emergent chemical control		10
Improved herbicide-crop safety		4
Chemical can move into seeding furrow		2
Residues from chemical carries over		3
Increased chemical cost		9
Increased resistance risk		6
Effect of direct drilling and stubble retention on erosion risk	132	0
Nutritional problems with no-till		6
Banding increases vigour	2	
Need good rotation		2
Improved management needed		5
Improved soil structure	17	
Increased moisture retention	23	
Decreased waterlogging	10	
Improved trafficability	7	
Reduced machinery wear and tear	4	
Improved sowing time and general timeliness	8	
Increased insect damage	2	
Increase in disease	7	
No-till increased irrigated yields greatly	1	
J-curve of yield improvement with no-till	2	

The results of this question revealed much about the adoption problems that are present in the Australian cropping environment. An interesting dichotomy emerged in the responses, which may be due to regional influences or specific adoption phenomena. When asked to compare the emergence of crops using no-till/direct drill with conventional cultivation a majority of respondents agreed that no-till/direct drill improved or at least did not affect the emergence of the crop. Of interest to note was the fact that ten growers specifically mentioned the positive effect that press wheels had on the emergence of the crop. A high proportion of growers however stated that emergence was reduced by no-till methods. Interpreting these results is difficult without knowing the specific circumstances surrounding the seeding and cropping system that each grower is using.

Constraints to some systems employed by growers stating that emergence was reduced, may be able to overcome by changed management.

Emergence in various crops differed in some cases. A number of growers remarked that stubble retention improved the emergence and growth of legume crops. A number of growers also said that stubble retarded the emergence and vigour of canola and other small seeded crops. About the same number of growers said that stubble (rather than minimum tillage) reduced the emergence of crops.

The second part of responses related to the vigour of crops in a minimum tillage situation. Fifty six respondents stated that minimum tillage reduced the vigour of the crop. Seventy nine stated that crop vigour was enhanced or at least not retarded in the early growth stages. Interestingly 18 growers (which were included in the negatives) said that although the early vigour was reduced by minimum tillage, growth of these crops caught up over the course of the season. This agrees with research stating that reduced early growth lowers soil water usage, which in time is used by the crop. Again the important point to note is that the adoption of minimum tillage need not reduce early crop vigour.

Of vital importance to a minimum tillage system is weed control. Accepting a change from cultivation to control weeds to reliance on chemical and integrated weed management techniques, is likely to be a major impediment for many growers adopting conservation cropping technology. Surprisingly a majority of respondents said minimum tillage improved or had no effect on the weed management on their properties. The other side of this response is the fact that a majority of growers said that minimum tillage reduced the effectiveness of chemical incorporation into the soil. Hence the conclusion would be that the overall package of weed control was improved with the adoption of minimum tillage but the effectiveness of some soil residual chemicals needing incorporation into the soil is reduced. This was borne out by the response of some growers who said that there was now a much greater reliance on post-emergent chemicals on their properties. Concomitant with this assertion was mention of an increased risk of resistance developing in no-till systems. In terms of crop safety, a number of producers mentioned that crop safety was greatly increased with the use of minimum tillage. The minimal disturbance of narrow pointed openers meant that chemical was not coming in contact with the emerging seedling and that the chance of injury from chemicals like Trifluralin and Diuron was reduced. Again this was offset by a few growers saying that wet or windy conditions had seen chemically covered soil and soluble chemicals move into the seeding furrow. This had caused crop injury in some instances. Quite a number of farmers in the survey mentioned the increased cost of chemicals as being a negative for the system. The issue of chemical residues carrying over into following seasons was also raised.

The one thing that all growers agreed on was the positive effects that minimum tillage and stubble retention was having on the wind and water erosion risk on their properties. In one instance a grower recalled an overnight rainfall event of seventy five millimetres. No erosion was visible on his property, while surrounding properties saw significant erosion occurring. Many clearly stated that the reduced wind erosion risk had saved them significant amounts of money that had been spent reseeding windblasted crops in times past.

The other major factor mentioned by respondents was the change in soil structure associated with minimum tillage and stubble retention. Seventeen respondents stated that structure had improved significantly. Twenty three observed improved moisture levels were much greater without cultivation, waterlogging was reduced and trafficability was enhanced. As a result one grower mentioned that dams now do not fill on his property due to improved water infiltration . Another said that with no-till he has not been bogged in the paddock for ten years.

Another important area surveyed related to crop nutrition. Nutrient tie-up noticeably reduced the growth of the crop with stubble retention and the crops needs were much more specific. The importance of rotation was mentioned, along the greater management skill needed in a minimum tillage system.

Of interest was the lack of reference to disease and insect damage in minimum tillage crops. This has been suggested as a major barrier to adoption by many sources, particularly in Victoria, but it hardly rates a mention in this nationwide survey. One grower specifically mentions the fact that rotation has the ability to overcome any disease problems. A number of growers also mention the positive effects of minimum tillage on operational timeliness, sowing time and machinery wear.

One grower stated that minimum tillage greatly increased the yield of summer crops while another mentioned the positive effects on an irrigated crop. Two growers mentioned the fact that yield in a minimum tillage system was like a J-curve in that yield initially was lower and then increased to be much greater than that of conventional treatments.

In summary the responses showed that minimum tillage has the potential to work on many farms in the Australian wheatbelt. Without having knowledge of where respondents were from it would appear that minimum tillage can work in most environments. However a number of areas of concern remain to be ameliorated to convince more crop farmers to adopt conservation cropping methods. Areas of concern that need improving include improving the incorporation and activity of chemicals in a minimal soil disturbance situation, increasing plant vigour, particularly in cereal and canola crops, and improving crop growth in stubble retention situations.

3.3.7. BARRIERS TO ADOPTION

Following from the previous responses to the survey questions, producers were asked what they thought were the three main barriers to the adoption of minimum tillage farming. This question appeared to split respondents into two parts. The tone of responses by adopters showed an obvious disdain for those who did not adopt conservation cropping. On the other side of equation there were those that obviously had not adopted conservation cropping. These growers found a range of reasons why they had not, and probably will not, adopt conservation cropping. A summary of the responses is given in table x below.

Table 44 – perceived barriers to adoption of conservation cropping

Barrier to adoption	Number of responses
Machinery costs	177
Stubble	72
Lack of suitable machinery	38
Poor establishment, decreased seed-soil contact	16
Ignorance/lack of willingness to change	93
Peer pressure	3
Untidy look of paddock	5
Lack of demonstration of results in that area	26
Lack of agronomic and departmental help	6
More intensive management needed	26
Resistance	82
Decreased herbicide incorporation	6
Lack of chemical knowledge	22
Weed control	68
Cost of chemical	37
Increased reliance on chemicals	36
Danger of chemicals	15
Lack of summer weed control	5
Chemical residues for livestock	1
Disease increase	64
Insects, mice and snails	18
Trace element deficiencies	1
Allelopathy	2
Soil type and variability of results	24
Lower yield in early years	20
Lack of rotation available	12
Lack of rainfall	10
Decreased moisture	3
Poor mineralisation	7
Cotton operations and the presence of beds	2
Decreased soil temperature for summer crops	2
Decreased timeliness	2
Need to manipulate pasture/effect on stock	1
Low prices	1
Like tractors	1

The main stated barrier to adoption was the cost of machinery conversion encountered when moving to a system of minimum tillage. This seemed to be an across-the-board response with no distinction between those that had or had not adopted the technology. Many stated that there was a "perceived" cost of machinery conversion, implying that many growers thought that conversion of machinery could be done for a reasonable cost, but the cost was still thought to be high. This response ought to be seen in the light of uncertainty about whether the change would work sufficiently well for to it to be of a medium to long term nature – which it may need to be if existing plant was going to be disposed of and new, different plant purchased. Reinforcing the machinery limitations to adoption was the fact that many growers (72) placed limited stubble handling ability as a barrier to adoption. Either there was too much stubble for machinery to get through in their area or that stubble handling machinery available was just not available. Another thirty eight stated that suitable sowing machinery did not exist for their area. The importance that growers placed on machinery can be seen graphically in figure x below.

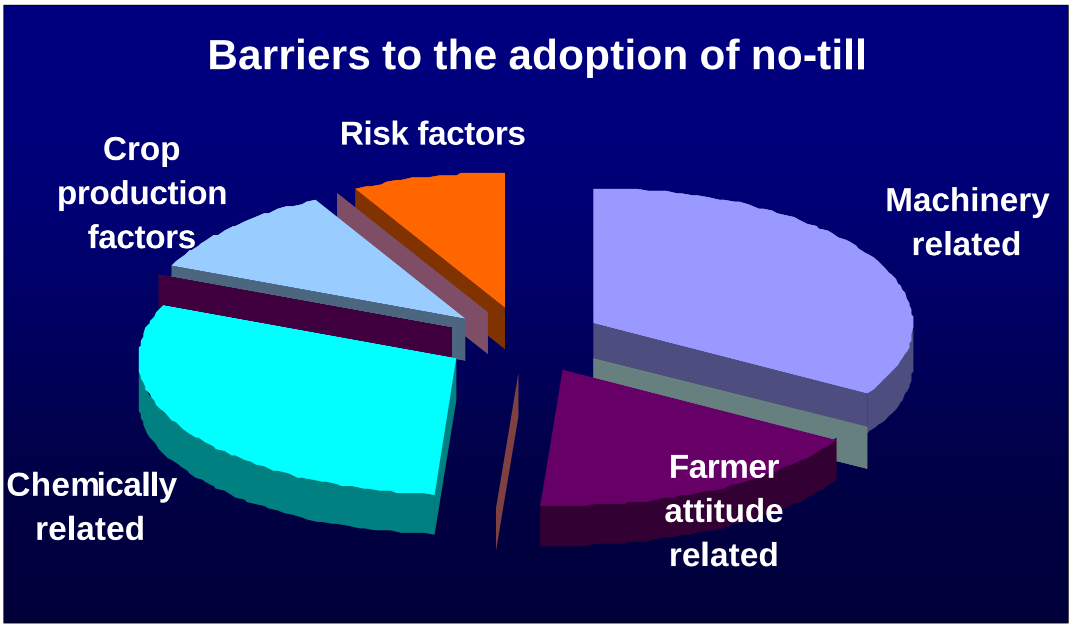


Figure 9 – Barriers to adoption of no-till/ minimum tillage farming in Australia.

The next response related to specifically to the psychological aspects of adoption. Many growers, presumably adopters, stated that there was a lack of willingness to change to a minimum tillage system. A range of emotive descriptions were used such as 'ignorance', 'laziness', 'head too far in the sand', 'apathy', 'lacking initiative', 'having mental barriers' and 'being set in their ways'. Clearly many of the growers surveyed saw that it made sense to be trying to make conservation cropping work in their area. Some of the responses from growers who had not adopted the technology use emotive expressions. Some growers stated that 'chemicals were poisoning the soil' and quite a few others were clearly concerned with the overuse of chemicals and the perceived danger to the environment. The unknown is the amount of 'unwilling to adopt' responses who were simply that – unwilling to adopt due to the risk of crop failure or other reasons. Related to an 'unwillingness to adopt' were responses that stated that the methods had not been shown to work in their area (26), that either they or their advisors lacked knowledge of chemicals (22) or that the management requirements in a no-till system would be overwhelming for many growers (26). Many other growers (26) also stated that results were too variable in their area or that their soil types were not suited to no-till. Many of these were on non-wetting sands, presumably in Western and South Australia. Twenty producers also stated that the lower yields in the early years of adoption impact on adoption.

The other major area of concern that would seem to warrant attention is weed control and chemical use. Eighty two producers stated that resistance was a major factor limiting the adoption of minimum tillage. Many (36) also stated that there would be an increased reliance on chemicals for weed control, implying an awareness of the resistance risks. Again there is an unknown in that there is no distinction between growers who used these reasons not to adopt on their own farm or whether they saw this as limiting their neighbors adoption. It is clear however that the resistance risk is at the forefront of grower's minds. Communicating that there are ways to obviate the risks of resistance should be a major facilitative goal to ensure the continued uptake of conservation cropping technologies. The wider weed control issue also concerned many growers (68). There was a perception that weed control was more difficult to attain in minimum tillage systems and combined with the high cost of chemicals (37) significant barriers to adoption were in place.

Interestingly disease was seen to be a major factor reducing adoption, although this was not stated explicitly in previous sections of the survey. Sixty four growers stated that they were concerned about disease at present or in the future. Again without the specific data it is hard to know which is the case. The potential increase in insect and mice damage to crops was also seen to be a problem along with allelopathy from stubbles (2). Trace element deficiencies were also mentioned.

A factor seen to limit the effectiveness of many minimum tillage systems in some situations was a lack of rotation available to growers, an impediment mentioned by twelve growers. A lack of rainfall was also seen to be a problem by some farmers from the Victorian Mallee. Decreased mineralisation of nitrogen from the lack of cultivation was also seen to be a problem. Other miscellaneous factors included the need to cultivate when forming cotton beds, decreased soil temperature for summer crops, low prices of commodities and recreational tillage.

In summary, the question produced the range of outcomes that perhaps would have been expected. The machinery issue is still being tackled by many growers. Capital outlay in times where cash flows and profits are low can be a difficult decision for the most optimistic of growers. When combined with a lack of knowledge, motivation or willingness to make a system work, adoption will be limited. Also at the core of crop production issues is the use of chemicals weed control. The perception that minimum tillage cropping will increase the risk of resistance development is obviously seen as a major deterrent for many existing and intending growers. Addressing this issue will be an important step in the adoption of minimum tillage by remaining adopters.

3.3.8. REASONS FOR ADOPTION

The final question asked growers to rank three reasons why they had adopted no-till cropping on their farms.

Table 45 – Reasons for the adoption of no-till/minimum tillage cropping

Reasons for adoption	**Number of responses**
Improve soil health	220
Reduce erosion	159
Decreased costs	85
Increase profit, efficiency and area able to be cropped	40
Decrease capital costs	34
Decrease risk and improve versatility	7
Chance to opportunity crop	3
Moisture retention	90
Increase in rotation length, allow continuous cropping	25
Increase yields	18
Better rotation	2
Improved timeliness and trafficability	120
Decreased tractor hours	74
Decrease labour requirements	26
Improve weed control	16
Increase range of chemicals available	2
Improve crop establishment	14
Suited to climate and soil	5
Didn’t want to burn	11
Pasture retention	10
Ease	4
Trendiness	1
Challenge of a new system	2
Suppression of disease	1
Tradition since early 80’s	1
Controlled traffic	1
Deep banding ability	3

As can be see from Table 45 most farmers saw that the conservation of soil was the primary reason for the change in crop establishment methods. This was split into perceived improvements in structure and fertility and reductions in the erosion of the soil. Wind and water erosion equally were seen to be a threat to Australia's cropping soils. Some growers did not distinguish between different types of erosion however. A total of three hundred and seventy nine indicated that concerns about soil erosion was at the heart of the adoption of conservation cropping. In areas of limited erosion potential, or limited acknowledgement of the erosion problems, the incentive to adopt no-till/minimum tillage will be lower. There is little doubt that the high cost of erosion in the WA wheatbelt instigated much initial adoption. In the other areas however, the methods have to be able to stand on their own production performance. This has obviously been the case judging from the additional comments summarised below.

Improved operational timeliness, decreased tractor hours and reduced labour requirements were the next set of reasons why growers had adopted no-till/minimum tillage methods. Over 220 responses mentioned at least one of these factors. Some growers went as far as to say that they were lazy and no-till/minimum till allowed them to still be farmers. Many commented that they had better things to do than sit on a tractor for endless hours.

The third area related to reducing operational and/or farm costs. Eighty five growers said that costs were decreased. Another 40 stated that they their adoption was driven by the desire to increase the profitability, efficiency and area able to be cropped on their farms. Some even commented that they adopted conservation cropping to reduce the risk on their farms. The chance to increase opportunity cropping was also seen to be a factor for some growers in the northern grain belt.

Another major factor underlying adoption was the potential benefits for the crop. Although only eighteen growers stated that they adopted to increase yield, 80 respondents stated that moisture was conserved with no-till. The implication for this statement is that increased moisture would increase the chances of improving crop yield. Another 25 growers stated that a factor behind their adoption of no-till was the fact that the length of rotation could increase or that continuous cropping could be implemented. This again would link to the responses indicating that adoption was undertaken to improve profitability.

Thirty two responses indicated that weed control would be improved with the adoption of no-till. Some stated that there was increased range of chemicals now available to them and that control was easier. Another group of growers stated that no-till adoption was done to improve the establishment of crops on their farms.

The breakdown of the main factors motivating adoption can be seen in Figure 10 below.

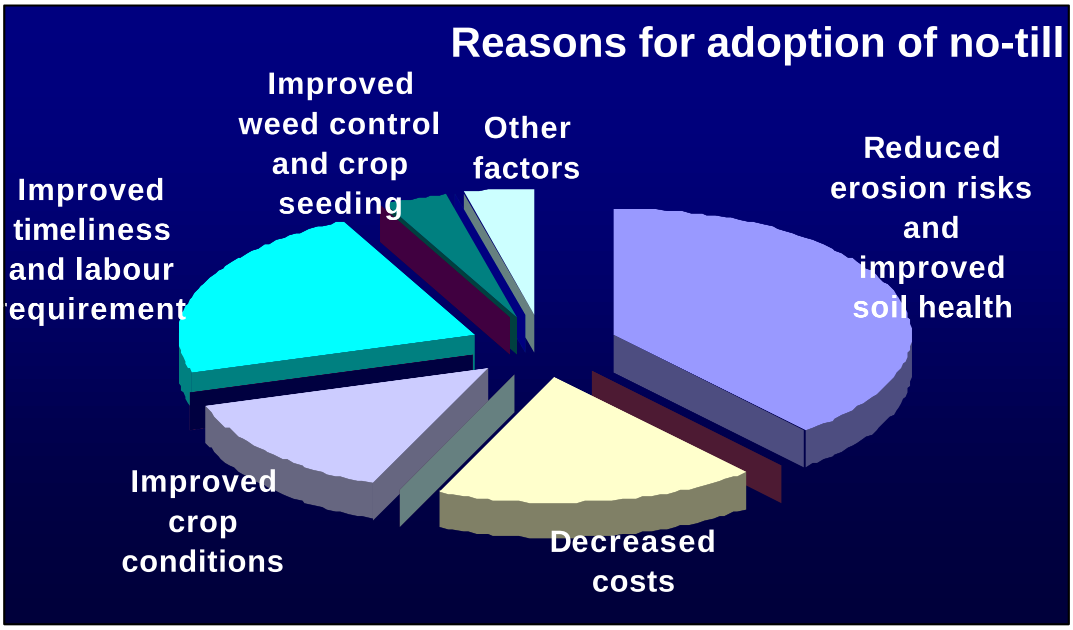


Figure 10 – Graph of reasons that no-till was adopted on Australian farms.

Other factors for adoption included: taking on the challenge of working out a new system, the suppression of disease, the ability to use controlled traffic, the integration of deep banding, the preservation of pastures and interestingly the fact that the methods were now regarded as being traditional in their part of the world.

3.3.9. SUMMARY

This survey goes some way to demonstrating the complex array of interactions that play a part in the adoption of conservation cropping systems in the Australian wheatbelt. It reveals that a majority of croppers returning this survey were using no-till/minimum till methods in the 1998 season. A range of factors made them adopt this system of crop production, namely soil conservation and improved operational efficiency and profitability. A range of factors were hindering adoption, including the cost of machinery conversion, the risk of herbicide resistance developing and an unwillingness to adopt new methods.

3.4. ADVISOR SURVEY OF CONSERVATION CROPPING

3.4.1. AIM

1. To use farm advisors to source of information on:
trends in cropping systems across cropping regions
the use of conservation cropping systems and
the benefits, costs and risks of these systems.

2. In so doing to use this information to complement other sections of this project.

A survey of advisors was chosen ahead of a grower survey for a range of reasons. Advisors often increase the rate of change in farming systems through appropriate extension of knowledge and advice. As such, their thinking would in turn influence the adoption of various technologies on farm. Thus a survey may indicate future trends likely to occur on farms. Secondly, an extensive survey of growers was already being undertaken by the Kondinin Group, as reported in the previous section. The logistics of a grower survey, in addition to project time constraints, were prohibitive. Hence it was thought that the use of advisors would gain a greater concentration and distilment of thinking without the logistic requirements of the larger survey.

3.4.2. METHODS

The survey form (attached) was sent out with a regular (GRDC) newsletter to all farm advisors in south eastern Australia.

Of the 54 questions in the survey, those most relevant to this project have been chosen for analysis. In summary this report analyses survey responses about attitudes to conservation cropping, focussing on identifying the problems and benefits.

3.4.3. RESULTS - HOW WILL THE AREA OF CROP IN YOUR AREA CHANGE OVER THE NEXT 5 AND 15 YEARS.

Table 46 shows that, on balance, advisors expect the area of cropping in the Wimmera to remain similar to current levels, but cropped area is expected to increase in the Mallee, and in Southern NSW/north-east Victoria. As the level of cropping in the Wimmera is already very high it is reasonable to assume that the capacity of this region to increase is limited.

3.4.4. WHAT IS THE CURRENT TREND FOR AREA OF DIRECT DRILLING (DD) IN YOUR REGION AND WHAT DO YOU PREDICT FOR THIS TREND OVER THE NEXT 15 YEARS.

In the Wimmera, respondents were divided over current trends in direct drilling. Most believed that conservation cropping was presently increasing but that it would stay the same in the long term. In the Mallee there was similar uncertainty, the belief was that the use of direct drilling is not changing and would not change in the future. In contrast, there was a strong belief that conservation cropping is increasing in north-east Victoria and southern NSW and that this trend will continue.

3.4.5. EXPLANATION OF TRENDS FOR DIRECT DRILL/ NO TILL

The following summarises how respondents explained their predictions for trends in direct drilling or zero till. Of those who predicted an increase in direct drilled, improved soil health, reduced time/ labour costs and trends to more appropriate equipment dominated the reasoning.

More direct drilling

Better understanding of soil health (number of responses – 12)

Less time on tractor, reduced costs of sowing.(9)

Trend to bigger farms, bigger sowing equipment, need to sow on time.(6)

Yield improvements/ profitability starting to become apparent.(2)

Where respondents thought the use of direct drilling would decrease, the reason was always the same: risk of lower yields and profits.

Less direct drilling

Poor yields, low returns, increased risk.(5)

3.4.6. PERCENTAGE OF CLIENTS WHO REGULARLY RETAIN – A. WHEAT STUBBLES (W) AND B. OTHER STUBBLES (O)

In general the percentages given for this question were surprisingly high. Seventy percent of both Wimmera and Mallee grain growers regularly retain wheat stubbles and seventy five percent of the same farmers regularly retain other crop stubbles (Table 48). The question arising from these figures is "how much of their crop stubbles are retained?" Do many farmers retain stubbles, but only when they are finishing a crop phase, or are they actually practicing stubble retention in their crop system?

Stubble retention was less well adopted in the wetter, mixed farming regions of NE Victoria and Southern NSW. It is possible to speculate that on these farms the specialised sowing equipment is less available than on the larger grain farms of the Wimmera-Mallee.

3.4.7. STUBBLE MANAGEMENT TECHNIQUES

The answers to this question reinforced those of the previous question. Stubble burning was less common in both the Wimmera and Mallee than it is in Southern NSW and North East Victoria (Table 49). Stubble mulching and working in are more practiced in the Wimmera and Mallee, whilst grazing is more common in the mixed farming regions of S NSW/ N Vic.

3.4.8. DISADVANTAGES OF STUBBLE RETENTION

From the survey, issues which scored above 3 (5 = big problem) were tabulated. Clearly suitable equipment, probably sowing equipment, was seen as the biggest barrier to using stubble retention. Associated with unsuitable equipment was the cost of equipment (Table 50). Crop diseases and weed control were also significant deterrents to stubble retention. Eleven respondents nominated reduced yields and, perhaps surprisingly, fourteen were concerned about the tie up of nutrients in stubble systems.

3.4.9. OPPORTUNITIES TO INCREASE ADOPTION OF STUBBLE RETENTION

Following identifications of the problems associated with stubble retention respondents gave their opinions on what conditions/activities would improve the use of stubble retention in crop systems in their region. The following were the most common suggestions:

Increased range of suitable equipment

Reduced cost of suitable equipment

A market for wheat straw

Improved disease resistance in wheat

Improved profitability/ yields

Legislation against stubble burning

Specialised weed control for stubble systems

Of these, the equipment factors were clearly the highest scorers. This emphasises the conclusion that sowing problems, real and perceived, are the biggest barrier to the adoption of conservation cropping systems in south eastern Australia. Poor seed- soil contact and resultant poor crop emergence are the obvious in-crop outcomes of sowing difficulties.

3.4.10. ADVANTAGES OF STUBBLE RETENTION

Improved soil health and reduced soil erosion were the most recognised Table 51 advantages of stubble retention. Four respondents could not find any advantages for retaining stubble. In the “soil health” category, improved soil structure and increased organic carbon were frequent answers. In fact only small increases in organic carbon levels have been measured in long term stubble retention experiments. This suggests that instead of relating stubble retention to significant improvements in soil carbon, we should be talking about improved soil structure, better trafficability and better water infiltration.

Despite reaching a wrong conclusion, respondents correctly relate conservation cropping systems to improved soil conditions.

3.4.11. CHANGES IN FARM MANAGEMENT OR OPERATIONS RESULTING FROM CONSERVATION CROPPING

Advisors from all regions were in almost total agreement about changes in farm management resulting from adoption of a conservation cropping systems. These are:

Improved timeliness of operations (less time to sow the crop)

Decreased labour requirements and

An increase in the level of management skill required.

Obviously the first two points are significant benefits for profitability, whilst the skill requirement will often be a barrier to farmers who are not confident of their ability to learn new ways of managing crops. One respondent pointed out that good management is essential to successful adoption of conservation cropping systems, and reducing risk.

3.4.12. EFFECT OF CONSERVATION CROPPING ON RISK

When asked whether conservation cropping/ no till systems increased or decreased either cropping or general farm risk, respondents were exactly evenly divided. Fifty percent said that conservation cropping increased risk, and fifty percent believed that it decreased risk.

3.4.13. SUMMARY

The survey had a low response rate as was expected but did highlight the distinctly regional patterns of cropping intensity and conservation cropping's adoption and use in south eastern Australia.

Continued poor returns from livestock enterprises have seen the Australian crop area increase in size. In the south eastern zone it was predicted that this trend was likely to continue, with the exception of the Wimmera area where existing high cropping intensities will limit expansion.

Present adoption of direct drilling was seen to be increasing presently in southern NSW/NE Victoria but mainly stagnant in the Wimmera and Mallee. Over the next fifteen years adoption was again predicted to remain at similar levels in the Wimmera and Mallee but opinions were distinctly divided.

The perceived benefits of conservation cropping among responding advisors were numerous and familiar. Acknowledgment of improved soil health, operational timeliness and, interestingly, profitability was given. Opposing this view were the stated disadvantages of reduced yields, increased risk and reduced profits. These diametrically opposed opinions may explain the patchy adoption of conservation cropping in Western areas of the state. If the advisors have no firm view regarding the effectiveness of adoption then the farmers that they service will struggle to form a view as well. Obviously some farmers have had profitable experiences with conservation cropping. What defined these growers is the next question that should have been asked.

Awareness of the benefits that stubble retention can bring to soil health was high. This awareness was translated into adoption in the Wimmera and Mallee, but not other areas. A high awareness of problems associated with stubble retention was also shown, with a lack of machinery able to cope with stubble retained conditions apparently being the main constraint to further adoption.

The survey has shown a high awareness of the benefits, costs and risks associated with the adoption of conservation cropping methods among agricultural advisors. Increasing the skills and knowledge of conservation cropping among this demographic will go a long way toward overcoming costs and risks associated with the methods, thus improving the adoption.

Table 46 – Expected change in cropping area in the next five and fifteen years.

Using 1998 as a base, how do you expect crop area to change:
a) in the next 5 years
b) in the next 15 years

Respondent	Wimmera a	Wimmera b	Mallee a	Mallee b	NE Vic/ Sthn NSW a	NE Vic/ Sthn NSW b	Other a	Other b
1					inc	inc		
2							same	inc
3	inc	inc	inc	inc				
4	same	same						
5					inc	inc		
6					inc			
7					inc	inc		
8	same	same						
9					inc	same		
10	dec	dec						
11							dec	same
12			inc	inc				
13			inc	inc				
14					inc	inc		
15							inc	inc
16			inc	same				
17					inc	inc		
18	same	same						
19					inc	dec		
20							inc	inc
21			inc	inc				
22					inc	inc		
23					inc	same		
24			same	dec				
25							same	same
26	no answer							
27	inc	inc						
28					inc	inc		
Trend	**same**	**same**	**increase**	**increase**	**increase**	**increase**	**same**	**sa/inc**

Table 47 – Expected trend in the use of conservation cropping in the next five and fifteen years

Is the number of farms using direct drilling increasing, decreasing or the same
a)now
b) in the next 15 years

Respondent	Wimmera		Mallee		NE Vic/ Sthn NSW		Other	
	a	b	a	b	a	b	a	b
1					inc	inc		
2							same	inc
3	dec	dec	dec	dec				
4	inc	same						
5					inc	inc		
6					inc	inc		
7					inc	inc		
8	same	same						
9					same	same		
10	inc	dec						
11							inc	inc
12			inc	inc				
13			inc	inc				
14					inc	inc		
15							inc	inc
16			same	inc				
17					inc	inc		
18	inc	same						
19					inc	inc		
20							dec	same
21			inc	inc				
22					inc	inc		
23					inc	inc		
24			same	dec				
25							dec	dec
26	inc	same						
27	inc	inc						
28					inc	inc		
Conclusions	**increase**	**same**	**same**	**same**	**increase**	**increase**	**same**	**same**

Table 48 – Percentage of growers who regularly retain wheat and other stubbles.

Q15 - % of clients who regularly retain
a) wheat stubbles (W)
b) other stubbles (O)

Respondent	**Wimmera**		**Mallee**		**NE Vic/ Sthn NSW**		**Other**	
	W	O	W	O	W	O	W	O
1					2	70		
2							NA	
3	60	80	60	80				
4	80	80						
5					5	50		
6					80	-		
7					80	50		
8	70	80						
9					60	30		
10	60	80						
11							50	90
12			90	95				
13			50	70				
14					20	60		
15	western disctrict						1	5
16			na					
17					15	15		
18	90	90						
19					5	80		
20							10	20
21			60	30				
22					10	95		
23					20	80		
24			80	100				
25	west plains NSW						5	5
26	50	30						
27	70	90						
28					5	10		
Average:	**70**	**75**	**70**	**75**	**25**	**50**	**15**	**30**

Table 49 – Percentage of farmers using various stubble management techniques.

	Stubble Management					
			% of farmers who:			
Respondent	**Burn**	**Retain**	**Mulch**	**Work In**	**Graze**	**Bale**
Wimmera						
3	40	60				
4	20	5		60	10	5
8	20	30	40			10
10	10	80	50	80	70	
18	5	80		30		10
26	40	25	30	5		
27	15		30	40	30	5
Mallee						
3	40	60				
12	10	90	20	15		
13	10	10	50	20	10	
16	no response					
21	5	60		20	15	
24		20	80	80		
S NSW/ N Vic						
1	60	5		10	40	5
5	85	3	2	3	5	2
6	10	60		30	10	
7	95	5			90	5
9	30	15		35	15	5
14	60	20		5	30	5
17	30	10	10		30	20
19	80		10			
22	85	15				
23	80	10				10
28	80	15		5		
Other						
2	40	30				30
11	60	20	5	5		10
15	90					
20	20	10	10		30	30
25	95	5		95		

Table 50 – Disadvantages of stubble retention.

	Disadvantages of stubble retention						
	Lack of adequate Machinery	/Cost	Waterlogging	Nut tie up	Disease	Weeds	Low Yields
Wimmera							
3	X	X			X	X	X
4	X	X				X	
8	X	X		X	X	X	
10	X	X		X	X	X	X
18		X	X	X	X	X	X
26	X	X			X	X	
27	X	X					
Mallee							
3	X	X			X	X	X
12							
13	X	X				X	
16	no response						
21	X					X	
24	X	X		X	X		
S NSW/ N VIC							
1	X				X	X	X
5		X					X
6	X	X		X			
7	X	X			X	X	
9	X	X			X	X	
14	X	X		X	X		X
17	X			X	X	X	
19	X	X		X	X	X	
22	X	X		X		X	X
23	X	X		X	X		
28	X	X		X		X	X
Other							
2	X			X	X		
11	X				X		
15	X			X	X		
20	X	X		X	X	X	X
25	X	X			X	X	X

Table 51 – Advantages of stubble retention.

TABLE:6 Advantages of stubble retention

	Soil Water	Soil erosion	Soil health	increase yields	feed	reduced costs
Wimmera						
3	X	X		X		
4			X		X	
8		X	X			
10		X				
18						
26			X			
27	X		X			
Mallee						
3	X	X		X		
12		X	X			
13						
16	X			X		
21		X	X			
24		X	X			
S NSW/ N VIC						
1	X	X				
5	X	X				
6	X					
7		X	X			
9			X			X
14		X			X	
17			X			
19						
22			X			
23		X	X			
28		X	X			
Other						
2	X		X			
11		X			X	
15			X			
20						
25						

4. ECONOMIC ANALYSIS OF CONSERVATION CROPPING

4.1. INTRODUCTION

The whole farm approach is required when investigating the impacts of conservation cropping on individual farm businesses. Comparing gross margins of establishment methods and of rotations is meaningless, as the profitability of the whole system is the measure of the net benefits from adoption. Despite this, few studies consider change at the farm level. Those that do are outlined below and are then followed by a summary of Australian and overseas studies based only on changes in the variable costs of production. Firstly however, mention should be made of the range factors and context in which systemic change to farm operations need to be considered.

Producers aim to increase their financial health by a range of strategies. Gaining greater prices, improving yields, increasing operational intensity and lowering costs all improve bottom lines. The problem for growers is deciding what extent to concentrate on each of these areas. Producers have little ability to influence commodity prices but it may be relatively easy to increase business intensity. One simulation modelling exercise has suggested that higher prices, higher yields, higher intensity and lower costs, respectively, have decreasing impact on farm business profitability (Lloyd, 1982). However, improving yields may be easier to do than altering farm enterprise mix. Conservation cropping potentially impacts on three factors; cropping intensity, yield and cost.

Increasing cropping intensity potentially increases profit over time although not necessarily continuously. Expanding the cropping area may require equipment purchase, as illustrated in the idealised expansion function in Figure 11.

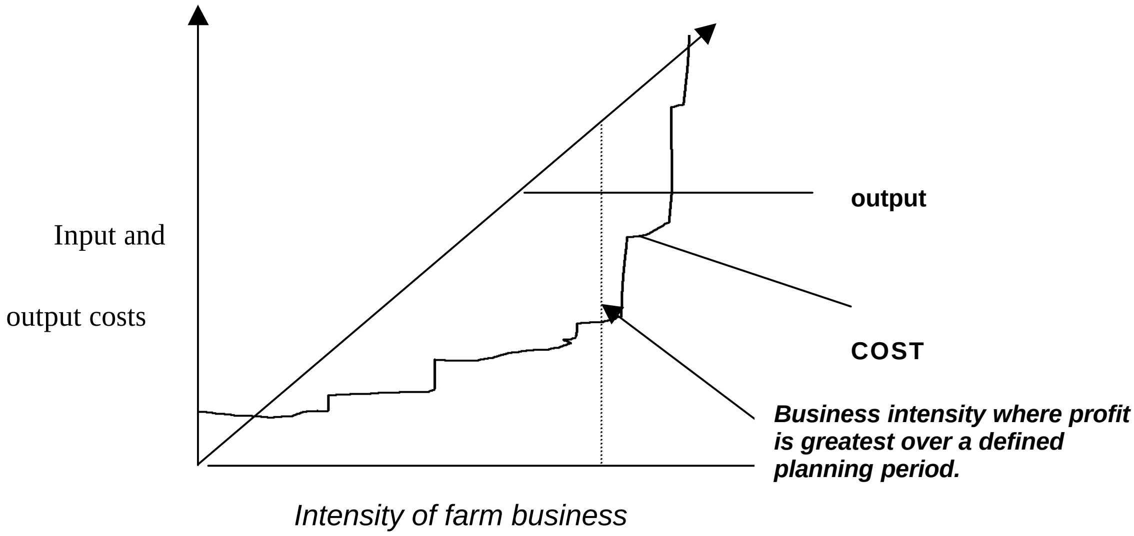


Figure 11 – An idealised production function of increased farm business intensity.

Increasing output will require additional variable and/or fixed costs. Purchase of capital items such as land and machinery is 'lumpy', like the shape of the graph above. The shape and position of the output and cost lines in Figure 11 alter with different seasons also. Every farmer will face a unique production function and planning horizon based on the quality and quantity of resources that is under control, and the range of variables that exert influence on objectives and outcomes.

4.2. REVIEW OF ECONOMIC ANALYSES

4.2.1. VARIABLE COST STUDIES

Economic analyses have shown that variable costs such as chemicals and fertilisers increase in conservation cropping situations, while costs associated with labour, land preparation and machinery decrease (Mahli, 1988) (Zentner, 1991) (Tamblyn, 1990) (Godyn, 1984) (Zentner, 1992) (Brennan, 1993) (Weersink, 1992).

Analysis of rotational work in Southern NSW showed that a wheat-lupin rotation, direct drilled into burnt stubble, produced the highest gross margin among eleven treatments (Brennan, 1993). Direct drilling, as an average over rotations, returned greatest profit.

A twelve year (1979-90) Canadian rotation (fallow-oilseed-wheat, oilseed-wheat-wheat) and tillage (zero, conventional tillage) study, based on 1990-91 prices; showed that rotation was the primary determinant of gross income. The intensive oilseed-wheat-wheat rotation ($310/ha) returned on average forty-six percent more annually than the fallow-oilseed-wheat rotation ($213/ha). This was offset by the oilseed-wheat-wheat rotation's higher input costs ($217/ha) compared to fallow-oilseed-wheat ($166/ha). Increased moisture retention in zero tillage treatments (Brandt, 1992) increased gross returns in nine of the study's twelve years. However higher herbicide costs produced similar net returns.

Table 52– Summary of mean results from (Zentner, 1992).

	Fallow-oilseed-wheat		Oilseed-wheat-wheat	
	Conventional tillage	Zero tillage	Conventional tillage	Zero tillage
Gross return	209	217	304	316
Input costs	149	183	209	225
Gross margin	60	34	95	91

Source: (Zentner, 1992)

Simulated reductions in herbicidal costs increased returns from zero tillage. Additional risk analysis postulated that low grain prices increase the use of fallow-oilseed-wheat rotation and conventional tillage for risk averse grain growers. Conversely, increased grain price and/or lower herbicide costs would increase incentive for adoption of more intense rotations and conservation tillage. This eventuality has been realised since this study was completed, with conservation tillage being used on an estimated forty-five percent of Canadian farms in 1998.

Another Canadian study foud lower production and profitability ($48/ha) with zero tilled barley compared to conventional barley (Mahli, 1988). Higher chemical costs require break-even tillage treatment yields to be significantly higher in zero-till compared to conventional tillage. Similar results were seen in three other rotational evaluations on different soil types, providing little incentive to adopt conservation tillage in this area of Canada (Zentner, 1991).

Table 53 – Net returns on silt loam, sandy loam and heavy clay soils of Saskatchewan in seven-year trials.

	Continuous wheat		Fallow-wheat	
	Conventional till	Zero till	Conventional till	Zero till
Silt loam	29	0	40	24
Sandy loam	-84	-108	-16	-21
Heavy clay	-46	-52	29	20

Source: (Zentner, 1991)

Similar work on fertile loess soils of north-west America saw a six year wheat-barley-pea rotation under conservation tillage outperform other permutations of conventional tillage and monoculture wheat treatments (Young, et al., 1994). Additionally, risk was significantly decreased with the use of conservation tillage and diverse rotation due to moisture conservation in dry years and reduced disease occurrence. Environmental damage, measured by erosion, was also least in wheat-barley-pea: conservation tillage treatments. Effective weed control was vital to conservation cropping's profitability, with less intense weed control programs much less profitable. Sub-optimal control in related conservation tillage research may account for poor conversion of saved moisture into production and profitability (Young, et al., 1994).

In summation, North American research results have been somewhat ambiguous in their findings due to site, soil, rotational, topographical and managerial specific factors (Stonehouse, 1994). Conventional tillage systems were economically superior in cooler temperate zones or where topsoils are deeper and/or less sloping (Henderson, 1988) (Stonehouse, 1991) (Zaintage, 1986) (Martin, 1991). Similarly, returns were reduced on the prairies with barley (Mahli, 1988), the Great Plains under sorghum and wheat (Williams, 1993) and the Mid-west under soybeans and corn (Klemme, 1985). Conversely, a range of works have seen conservation tillage improve profitability in the Great Lakes (Fletcher, 1988), the Great Plains (Dhuyvetter, 1996) (Zentner, 1992) (Harman, 1985) (Mikesell, 1988) (Henderson, 1988) (Aakre, 1995), the Corn belt (Doster, 1983) (Williams, 1990) and the Pacific north-west (Young, et al., 1994) of America. Long-term evaluation will also tend to favour conservation cropping in areas of shallower topsoil and/or greater slope soil losses begin to reduced yields (Stonehouse, 1991). Documented risk analyses did not conclusively provide evidence for tillage advantage, however drier areas like the Great Plains favoured conservation tillage to provide lower risk due to greater available rotational intensity and moisture conservation (Stonehouse, 1991) (Dhuyvetter, 1996) (Aakre, 1995). The use of rotation and conservation tillage were complementary, with less favourable results seen in monocultural and cereal-fallow rotations (Aakre, 1995). Risk was seen to increase with conservation tillage on the Great Plains (Williams, 1993) (Klemme, 1983), although it was noted that the level of risk associated with tillage practice is largely dependant upon managerial ability (Weersink, 1992). Soil type was also seen to affect risk as conservation tillage performed better, and with less variation, on sandy soils compared to clay soils (Weersink, 1992). Risk and return altered depending on farm size and soil type however no-till crop establishment was not favoured in this Ontario study.

In northern Australia the use of conservation tillage increased yield, profits and reduced risk associated with cropping (Kirkby, 1996). Annual labour inputs were estimated to fall by four hundred hours on a five hundred hectare Northern Territory farm (Tamblyn, 1990). Enterprise analysis

Gross margins are often used to compare systems, often to the detriment of one system or another. Limited whole farm analyses exist. The impact of a new system on whole farms is vital to land managers. Comparison of farms is using alternative systems is fraught with danger due to management diversity. As such comparisons of conventional and conservation treatments have often been carried out on simulated farms (Farquharson, 1984) (Godyn, 1984).

Adopting conservation cropping on a southern NSW farm, where yields of direct drilled crops were the same as conventional methods, resulted in lower gross margins but improved overall farm performance due to improved livestock feed availability and reduced overhead cost (Godyn, 1984). Hence profit was 2.5 percent greater in the direct drill system when labour was not considered and 6.2 percent greater when labour was costed. When the rotation was extended in a direct drill situation profit was 9.7 percent greater than a conventional cultivation system.

In this study, to take full advantage of conservation cropping increased livestock numbers were needed (Godyn, 1984). Alternatively, cropping intensity could be increased, benefitting farm income.

4.2.2. MODELLING STUDIES

(Farquharson, 1984) investigated the effect of using conservation cropping over a ten period using linear programming techniques. Using farmer wealth as the ‘objective function’, simulations where yield was similar regardless of establishment technique saw the use of conservation cropping predominate cropping establishment due to the higher stocking rates and reduced workload (labour costs). This result altered when yields associated with direct drilling were reduced in comparison to conventional cultivation, indicating similarities between establishment methods in a whole farm context (Farquharson, 1984). If direct drill yields increased over ten years then the value of the objective function was greater when the crop was direct drilled. Changed input prices, such as reduced chemical and fuel costs, saw increasing amounts of crop established by direct drilling (Farquharson, 1984), alluding to possible resource reallocation under conservation tillage conditions. This phenomena is currently being observed in the Australia's cropping zones (Knopke, 1995). New capital expenditure has dropped in real terms by 2.5 percent annually over the period 1977-94, in turn lifting annual total factor productivity by 0.6 to 0.8 of the total 4.6 percentage point gain in productivity for grain producers. This was associated with structural adjustment but also the use of conservation cropping (Knopke, 1995).

A linear programming model of a Queensland central highlands farm, maximising annual net farm income as the objective function, saw that conservation tillage was more profitable than conventional tillage as well as significantly improving soil conditions after the ten years (Morfe, 1994). The optimal outcome in a sunflower-wheat rotation used zero tillage and lost only fourteen of one thousand millimetres of topsoil. Conventional tillage lost most topsoil, leading to poorer production and profitability. Additional summer crop options saw pigeon pea replace sunflower as the most profitable rotation in combination with wheat.

Another linear programming model developed in Western Australian (MIDAS) also found minimum tillage crop establishment as a more profitable option than conventional cultivation to increase whole farm income (Morrison, 1985). An American linear programming study saw conventional tillage increased the objective function regardless of farm size, rotation or weed management system (Martin, 1991).

4.2.3. MACHINERY INVESTMENT

Machinery costs dominate many cropping operations, particularly in times of high interest rates. Getting the big decisions, such as the nature and timing of machinery investment, right has the potential to be a major determinant of long term business profitability (Malcolm, 1993) (Kingwell, 1995). Proponents of conservation farming technologies have often cited increased or changed machinery requirements as a reason for slow adoption of the new methods. The reality is often different, with the switch to direct drilling potentially reducing capital requirements. Machinery formerly used for cultivation may become surplus to requirement, hence reducing capital investment.

Machinery investment research has centred on timeliness. Edaphic, climatic and physiological factors determine benefit or cost on regional and seasonal bases. Taxation, investment lumpiness, changed technology and cropping situation have all received research attention but the issues are perhaps best represented by a model constructed by Kingwell which takes (Kingwell, 1995) account of grain price, crop area, fixed, opportunity and variable costs. Profit, represented by Π_i, equals $Q_i.p - rS - f - g$; where p equals crop price ($/t), r equals variable costs per ha, S equals cropping area, Q_i equals total grain production in tonnes over S hectares in the weather year i, f equals is the fixed costs over the farm and g is the opportunity cost of investment in the seeding gear.

Both Q and g are functions of the seeding workrate. Using calculus Kingwell deduced that the optimal sowing rate per day (Ropt) equals $S\sqrt{pc/2b}$, where b is the cost of achieving another metre of sowing width and c is the yield that is forgone by sowing one day later. Hence, as logic would dictate, the optimal sowing rates are positively correlated to crop area, crop price and yield penalty. There was a negative relationship between optimal sowing rates and marginal increases to the cost of increasing sowing rate. Investment in larger machinery allows faster sowing, theoretically increasing overall yield but at the cost of capital investment. Various scenarios involving interrupted sowing, use of two varieties, different soil types and different sowing methods. Conservation tillage theoretically reduced the workrate, and hence capital investment, needed to generate optimal profit.

A survey of two hundred and seventy three Queensland wheat farms in 1979 found forty-three percent of farm capital tied up in land preparation machinery. Conservation cropping allows this component to be reduced.

Table 54 – Profile of capital investment on Queensland farms in 1979.

Machinery item	Percentage of total
Tractors	29
Planters	5
Tillage	9
Sub total	(43)
Headers	20
Drying	1
Transport	11
Storage and handling	8
Machinery sheds	12
Miscellaneous	5
Total	100

Source: (Blomfield, 1984)

Total machinery investment, on average, was $134,000 or $242 per hectare sown. Average machinery investment fell from $148,000 on conventional farms to $76,000 on equivalent conservation farming properties. Many farms have not reduced machinery investment however due to system uncertainty.

The use of conservation cropping methods became an option for growers in the mid-to-late 1970's. Like all new technologies in farming, adoption of conservation cropping depends on demonstration of benefits and acceptance that they will occur in particular systems over an extended period of time at the regional level. The long-term effects of reducing cultivation on soil, diseases and plant growth were simply not known. Many related questions remain unanswered. To evaluate the new cropping system a number of long term trials were established in south-eastern Australia. Those analysed by this project include trials at Wagga Wagga (NSW), Avon, Halbury, Kapunda and Tarlee (SA). Other trials have been carried out at Lameroo (SA Mallee), Condobolin (NSW), Rutherglen, Horsham and Walpeup (Vic). These were not analysed due to the either inability to get data (Condobolin, Walpeup, Lameroo), lack of replication over time and space (Horsham) or a lack of relevance to today's farming systems (Rutherglen).

Long term conservation farming trials are valuable sources of information for estimating the economic impact of conservation practices, as direct comparisons can be made between contrasting practices under similar soil and climatic conditions. Limitations to the value of the information, in terms of limited production areas and replication of practical management techniques still apply as to this and all scientific trial results.

The analysed trials have shown, in general and over time, that conservation cropping has not depressed grain yields or profitability. Yields were comparable in all locations, indicating the potential for adoption of conservation cropping in many areas, depending on net economic effects. Demonstrating the net benefits of a technology at a localised level, and then a farm level, is an important component of the adoption process (Pannell, 1999). In the case of conservation cropping, it was firstly a case of proving that the technology did not produce any disadvantages. Savings in workload and the resulting economies of scale would provide enough benefit, monetary and non pecuniary, in many cases to influence adoption, provided net incomes and non-measurable advantages of the alternative systems were not reduced significantly.

4.3. THE ECONOMIC ANALYSES

To analyse the technical trial results in an economic context the trial results were modelled over a regionally representative farm area to estimate the subsequent medium term impact on operator equity. As the trials look at different farming systems it is important to analyse these effects in terms of the potential impact on the whole farm system, profit and risk considered, rather than the paddock basis. The way in which the final effects of the treatments are judged will vary according to the individual aims of farmers, so the analysis focussed on a range of economic indicators including equity, activity gross margins and yearly operating profits, and the variability of the performance of these measures.

4.3.1. EQUITY

Analysis of average gross margins of crop sequences in alternative cropping systems reveal little regarding overall farming profitability. The analysis of changes in equity over time is a more comprehensive indication of gains. Average gross margins are superimposed over a simulated farming operation's cropping and grazing areas to help measure annual profits and resulting effects on equity. The use of equity to measure the long-term effects of a farming system can be a little simplistic due to the incalculable range of influences having an impact on business equity. Countering this weakness is the ability of equity to measure the cumulative effects of small differences between treatments over an extended period of time. Even though it would have been informative to include estimates of the impact of direct drilling on overhead costs this was not done in this 'first look' analysis in order to simulate the reality of growers 'making do' with existing equipment in the initial stages of testing and adoption. Alternatively the analysis is valid for changed systems where the same level of capital investment has been maintained. Most growers trialling a new system will retain machinery needed for the old system until convinced of the new system's profitability. Hence the business structure was held constant regardless of cropping system.

4.3.2. OTHER FACTORS

A range of associated factors (if available) were also analysed. These include

tractor hours worked,

sowing times as compared to activity gross margins,

activity gross margins compared to growing season rainfall and

the impact of the different treatments on a range of soil related factors such as nitrogen, pH, phosphorous and carbon levels.

4.3.3. MODEL STRUCTURE

A range of assumptions are used in the model based on the stated treatments of the crops. These are outlined below.

Table 55 - Assumptions used in the modelling of the experimental data at a farm level.

Total overhead costs	$85,000
Total land value	$1,136,000
Total machinery assets	$260,000
Initial equity	85%
Debt	$209,000
Interest on overdraft	10%
Interest on profit	3%
Average wheat price	$150/t
Lupins	$220/t
Superphosphate	$160/t
Urea	$330/t
Roundup	$7.50/l
Sprayseed	$7.35/l
Igran	$17.50/l
Hoegrass	$24/l
Glean	$0.32/g
Simazine	$5.60/l
Yield	$10/l
Fusilade	$59.80/l
Spraying	$2.50/ha
Cultivation	$8/ha
Harvesting cereals	~$20/ha
Sowing	$9.00/ha
Stocking rate (DSE/ha)	7
First X merino gross margin/DSE	$16/DSE

The cost of these inputs will have changed over the course of each trial's history but these average costs have been applied to operations in each year using constant dollar values. For example the cost of glyphosate was once fifteen dollars per litre. Since coming out of patent the price is now around six dollars per litre. As a result, profitability of reduced tillage is much improved. The use of average grain prices does not affect outcomes as separation of production methods, rather than absolute values, is the analytical aim.

4.4. AGRICULTURAL RESEARCH INSTITUTE – WAGGA WAGGA

In 1979 a long-term trial (SATWGL) was founded at the Agricultural Research Institute, Wagga. The site aimed to investigate the interaction of rotation, tillage, stubble management and fertiliser application on crop yield and a host of soil properties. The trial, over time, has become a standard for the investigation of the long-term effects of conservation cropping techniques. This part of the report aims to investigate the impact of the results on the profitability of a simulated farming system.

The site is located approximately five kilometres north-west of Wagga in southern NSW. The soil is a red earth (Gn 2.12 – Northcote; 29% clay and 15% silt in surface 10cm). At the commencement of the trial with a pH_{CaCl} was 4.93, organic carbon 1.3% and total nitrogen 0.13% (Heenan, 1998). Rainfall over the course of the trial averaged five hundred and sixty three millimetres annually. These conditions constituted a fertile site.

Fourteen different treatments (outlined in table x) were originally examined. This has been expanded in recent times to include the analysis of lime application and the effect of other crops such as canola (Heenan, 1998) but the economic analysis does not include these treatments due to a lack of availability of data.

Table 56 – Rotation, stubble and fertiliser treatment and average wheat and lupin yield from 1979-1992 at the Wagga site.

Treatment No.	Rotation	Stubble management	Tillage	Fertiliser	Average 1979-92 wheat yield (t/ha)	Av. wheat gross margin yield ($/ha)	Standard deviation of GM	Average 1979-92 lupin yield (t/ha)	Correlation with GSR	Correlation with Annual
1	WL	Mulch	Direct drilled		3.29	368	157	1.49	71%	64%
2	WL	Mulch	1 Cultivation		2.95	303	146	1.43	73%	67%
3	WL	Mulch	3 Cultivations		3.20	326	200	1.44	64%	73%
4	WL	Burn	Direct drilled		3.59	408	176	1.59	83%	75%
5	WL	Burn	1 Cultivation		3.29	355	178	1.44	86%	76%
6	WL	Burn	3 Cultivations		3.53	375	202	1.44	80%	81%
7	WL	Early Bury	1 Cultivation		3.05	319	165	1.42	84%	73%
8	WWL	Mulch	Direct drilled		3.36	373	167	1.52	75%	67%
9	WW	Burn	3 Cultivations	Zero N	2.47	202	142		34%	10%
10	WW	Burn	3 Cultivations	Plus N	2.90	281	178		67%	70%
11	WC	Mulch	3 Cultivations		3.12	290	147		65%	69%
12	WC	Mulch	Direct drilled		3.05	327	177		69%	62%
13	WC	Mulch	3Cultivations		2.94	311	176		62%	64%

Treatments two, five, seven and eight were discontinued following the 1992 season.

Soil nitrogen at the start of the experiment was high following many years of clover based pasture which limited the response to nitrogen fertiliser n the early years of the experiment. Thereafter positive effects of nitrogen application were seen in the wheat/wheat rotation. Slightly higher grain yields and harvest index was seen under the direct drilling system but also lower grain protein. Stubble retention consistently reduced yields however due to the build up of disease and brome grass populations. Lupin yields were higher in direct drilled systems.

1991 wheat yields were estimated by using the average water use efficiency of the treatments over the previous twelve years as no data could be obtained.

4.4.1. THE SIMULATED FARM AT WAGGA

The simulated farm at Wagga consists of 810 hectares, or two thousand acres of land. Various cropping intensities are modelled over the farm. Land is estimated to be worth $1400 per hectare, or $570 per acre. These values were chosen to keep the total land value consistent with the other analysed experiments. Machinery on this and other farms is valued at $260,000. This may or may not reflect the capital requirements of particular areas but keeping capital values at constant levels is a reasonable approximation that removes any distortion from this angle. The farm is a one-person operation.

The intensity of cropping was altered to see the effect on equity over time. The standard cropping intensity is 60 percent. Hence 486 hectares will be cropped each year. Thus in a wheat-clover rotation only 243 hectares will be cropped and the rest of the farm will be in pasture.

This trial has been difficult to interpret in recent times due to the difficulty in getting results of the experiment post 1990.

4.4.2. RESULTS

In terms of the work the project is primarily concerned with the effect of tillage and stubble treatment on equity rather than rotation; a factor that will be concentrated on in the study.

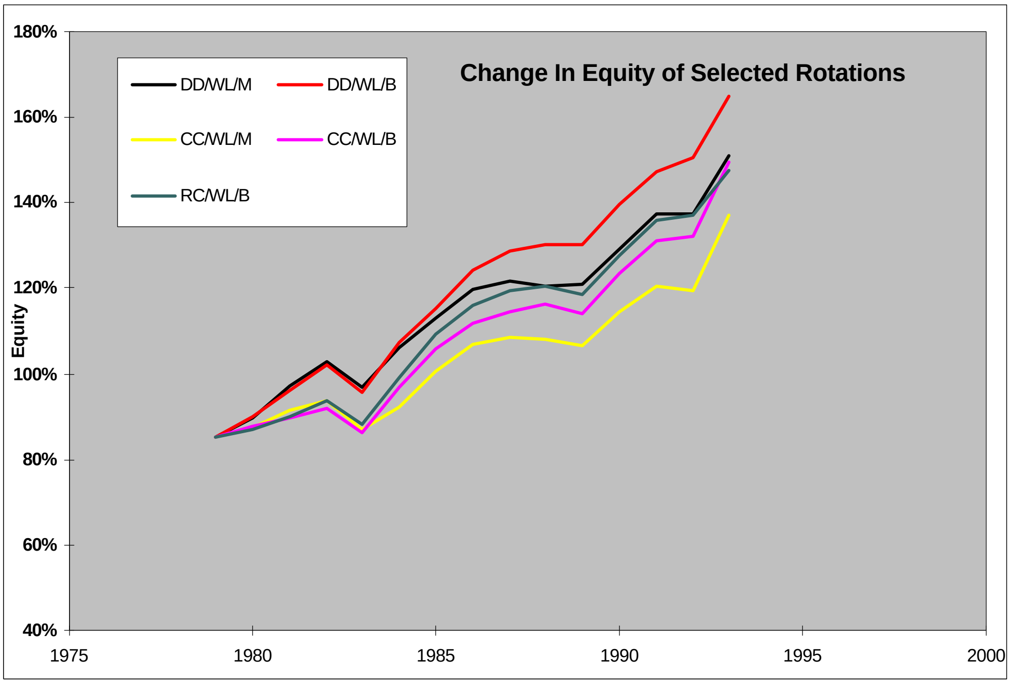


Figure 12 – Change in equity in real dollars in wheat-lupin rotations depending on tillage and stubble treatment at sixty percent cropping intensity.

The use of direct drilling in a wheat-lupin rotation, in combination with stubble burning, produced the greatest returns for the simulated farm over time. Conventional cultivation methods lagged behind the direct drilled treatments. It is of interest to note the direct drilling and burning is the generally accepted crop establishment method in southern NSW presently.

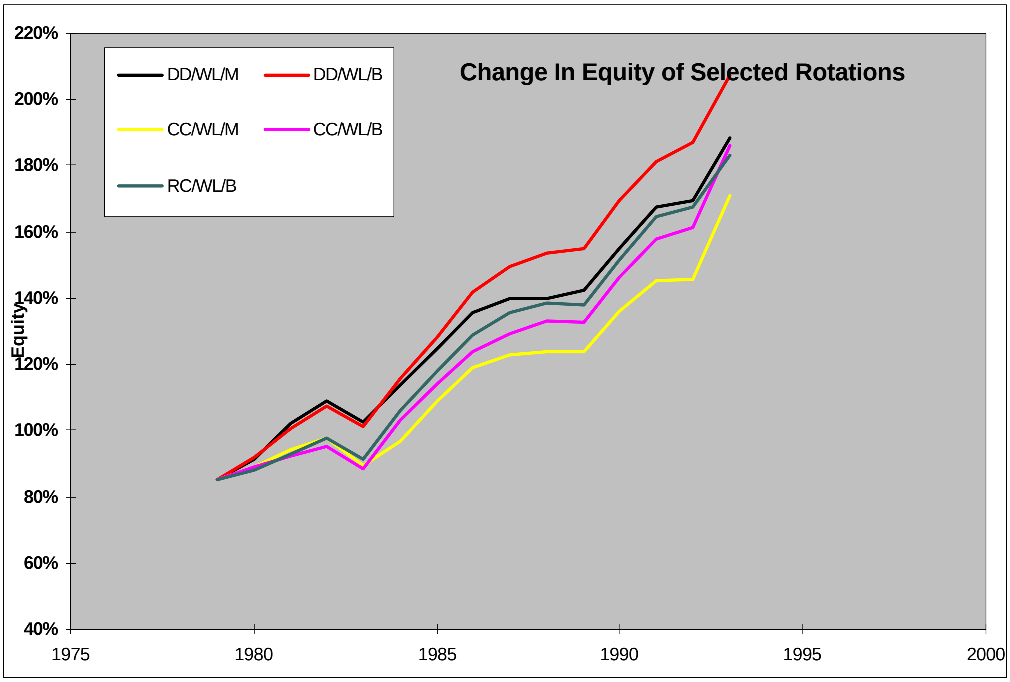


Figure 13 – Change in equity in wheat-lupin rotations depending on tillage and stubble treatment at eighty percent cropping intensity.

When the cropping intensity is increased to eighty percent of farm area the returns and separation between treatments, as shown in Figure 13, is greater. Equity reaches two hundred percent at the greater simulated cropping intensity, compared to one hundred and sixty percent at the lower cropping intensity.

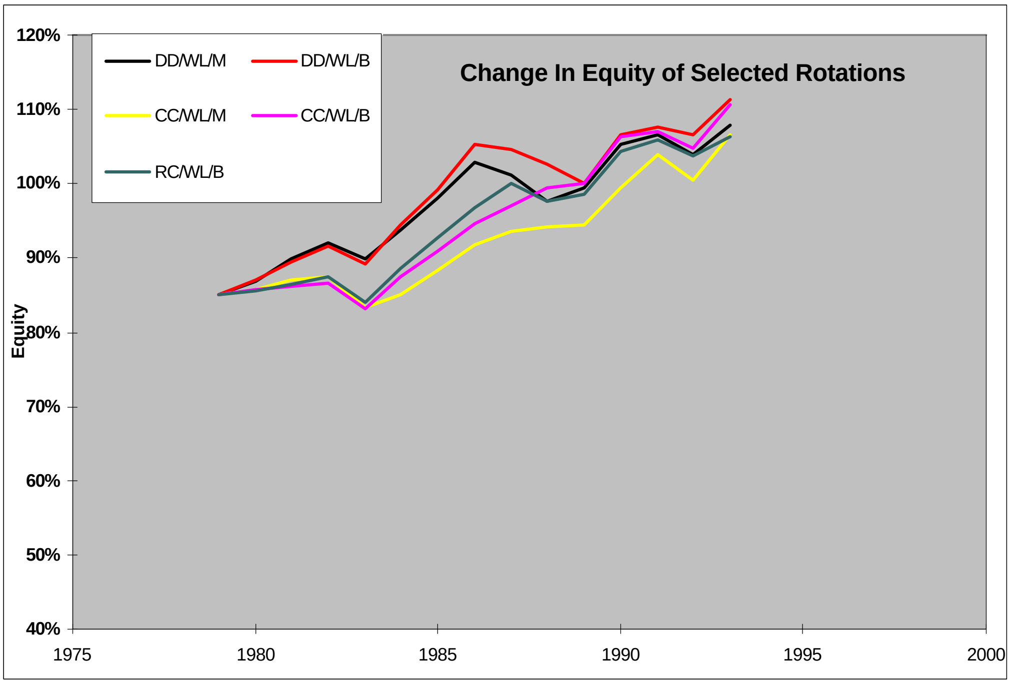


Figure 14 – Change in equity in wheat-lupin rotations depending on tillage and stubble treatment at thirty percent cropping intensity.

If the cropping intensity is lowered to thirty percent of farm area the difference between treatments is minimal. This may explain why adoption of conservation cropping is less attractive to smaller farmers of the region. Why adopt a different system different to what they know when potential gains are minimal? The absolute level of equity is also much less. Returns to the pasture phase are modelled on a district average stocking rate of seven dry sheep equivalents (DSE) per hectare, returning $16 per DSE. As we might imagine, the returns can not keep up with the cropping enterprise in this medium to high rainfall area.

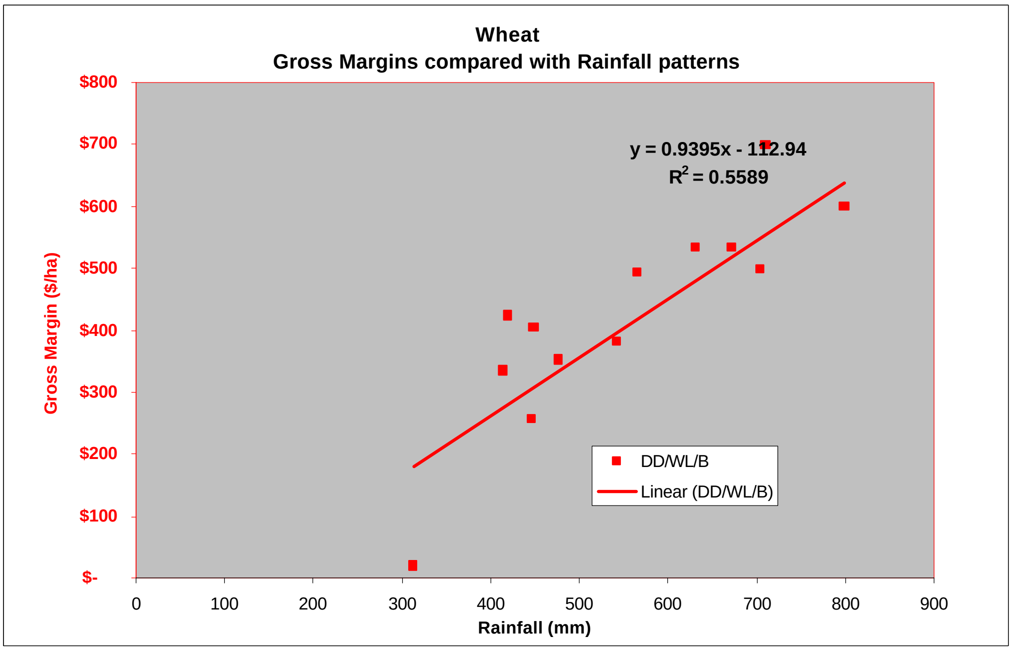


Figure 15 – Regression of total annual rainfall with annual gross margin (direct drill, burnt, wheat-lupin rotation)

The gross margin returns per hectare are strongly correlated with the annual rainfall. The regression equation for the direct drilled, burnt, wheat-lupin treatment estimates that if rainfall is zero for the year, the gross margin will be -$112. For every millimetre of rainfall over the range covered gross margin increased by ninety four cents per hectare. The strength of this relationship is reasonably good with an R^2 co-efficient of 0.56.

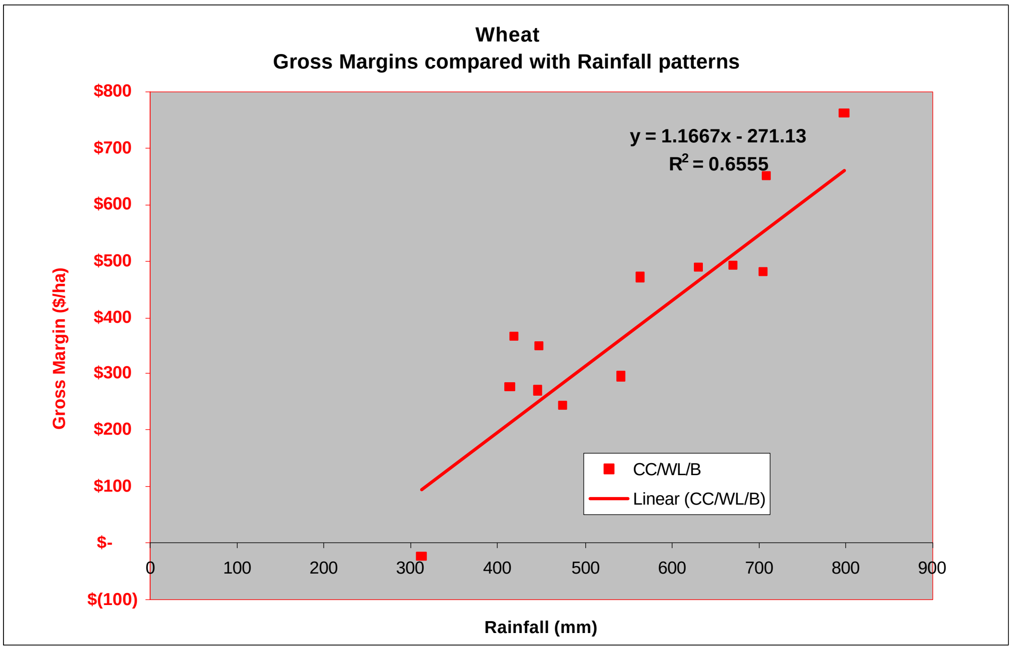


Figure 16 – Regression of total annual rainfall with annual gross margin (conventional cultivation, burnt, wheat-lupin rotation)

The regression equations of annual rainfall with gross margin indicate that conventionally cultivated gross margins were more dependant upon rainfall than the direct drilled system. This may be due to the moisture saving effects of reduced cultivation. Thus, by default direct drilling offers reduced gross marginal variation with respect to annual rainfall. In wet years direct drilled returns may be less, as indicated by lower returns per millimetre of rainfall received ($0.94 per millimetre versus $1.17 per millimetre) over the range of rainfalls represented.

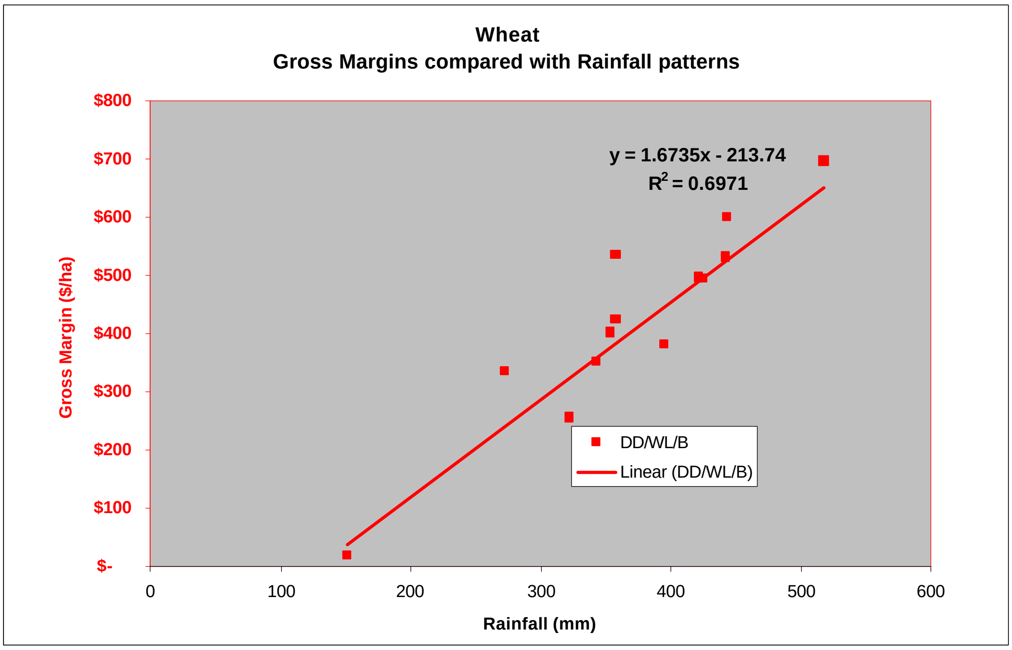


Figure 17 – Regression of growing season rainfall with annual gross margin (direct drill, burnt, wheat-lupin rotation)

Similar conclusions could be made from the regression of growing season rainfall with gross margin. The direct drilling of wheat and lupins into burnt stubble resulted in an additional $1.67 for every millimetre of growing season rainfall over the range of rainfall covered.

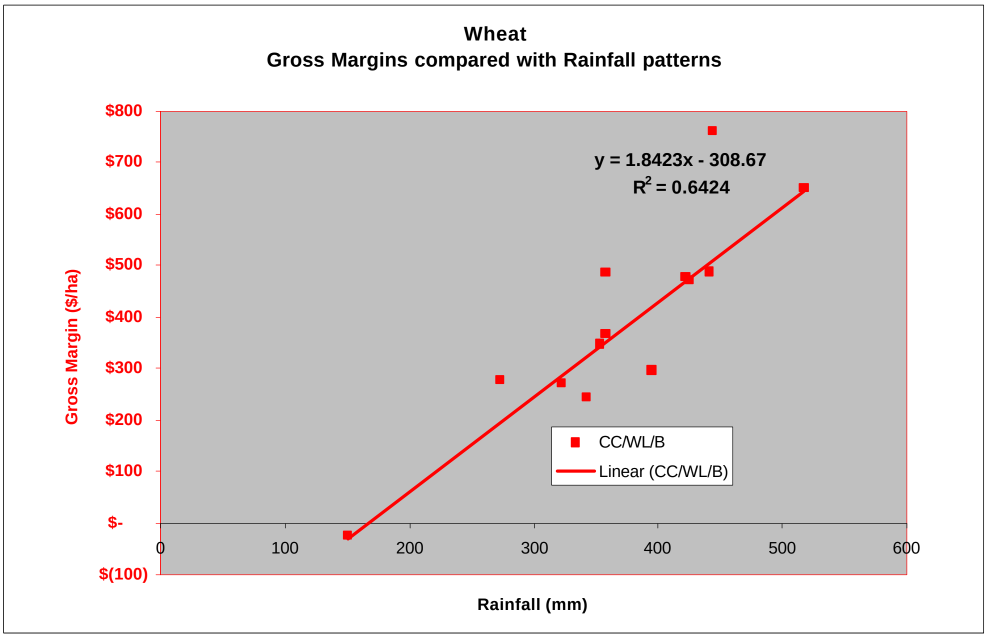


Figure 18 – Regression of growing season rainfall with annual gross margin (conventional cultivation, burnt, wheat-lupin rotation)

Similar to the previous regression of total annual rainfall with gross margin, a stronger relationship between rainfall and gross margin exists in the conventionally cultivated plots.

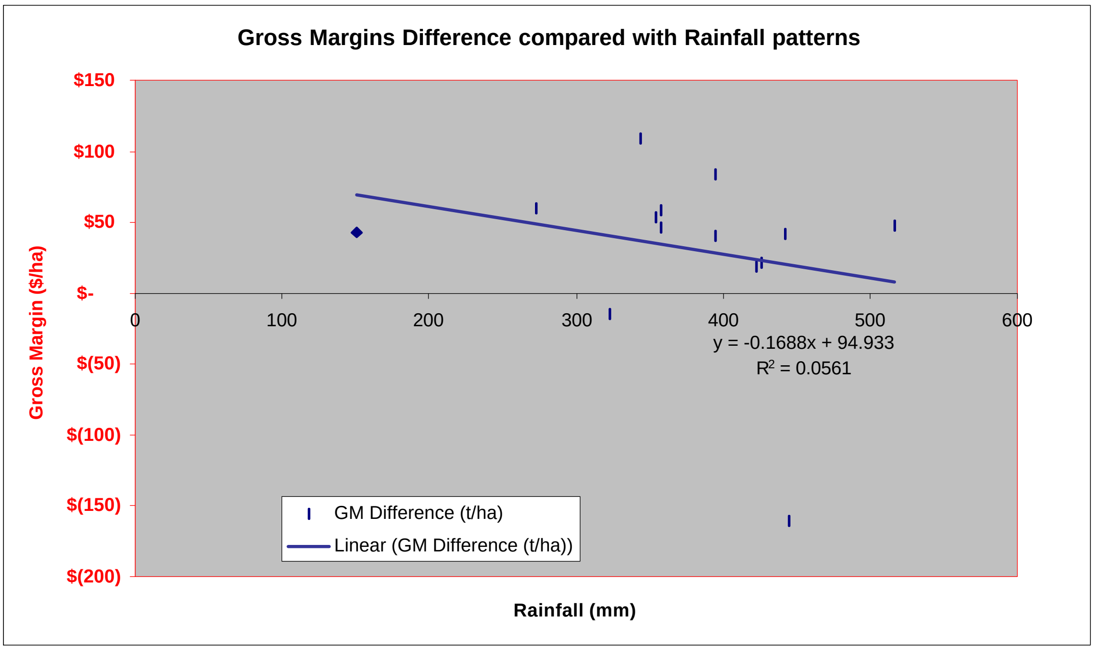


Figure 19 – Regression of growing season rainfall with the difference in annual gross margin of burnt, wheat-lupin treatments (burnt GM minus conventional GM).

The regression in Figure 19 tends to indicate that as rainfall increased, conventional cultivation returned more than direct drilling, although the strength of the relationship is low (only five percent of the data can be explained by the regression equation). The assertion is that direct drilling improved moisture use in dry years at the Wagga experimental.

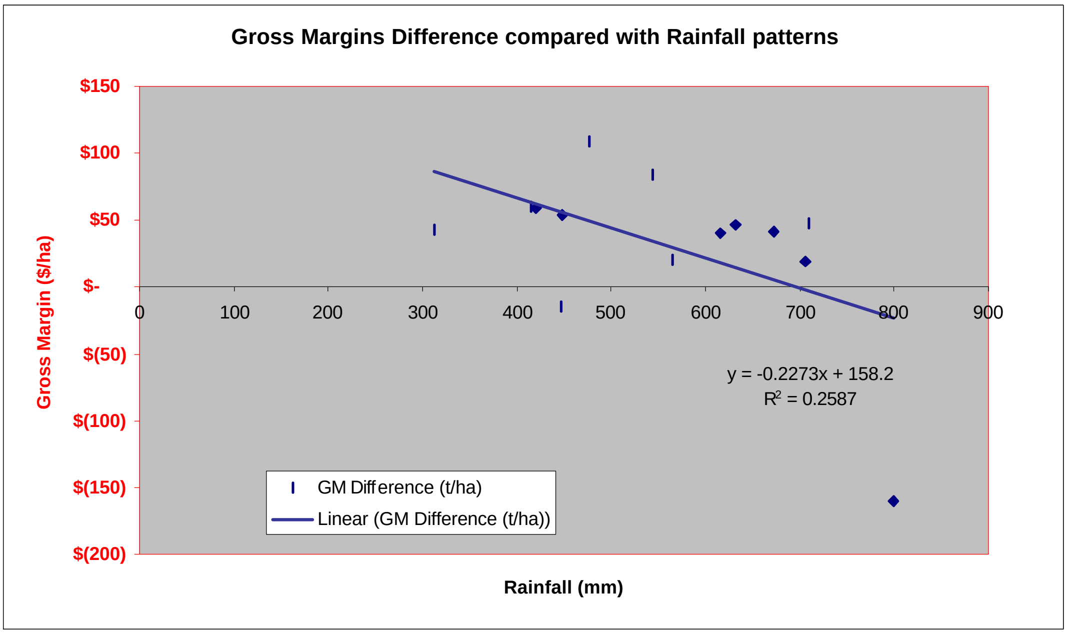


Figure 20 – Regression of total annual rainfall with the difference in annual gross margin of direct drill and conventional cultivation treatments (burnt, wheat-lupin rotation).

The strength of the assertion is improved if we consider total annual rainfall, which again indicates that direct drilling has the ability to reduce the decline in drier in returns in drier years compared with conventional cultivation.

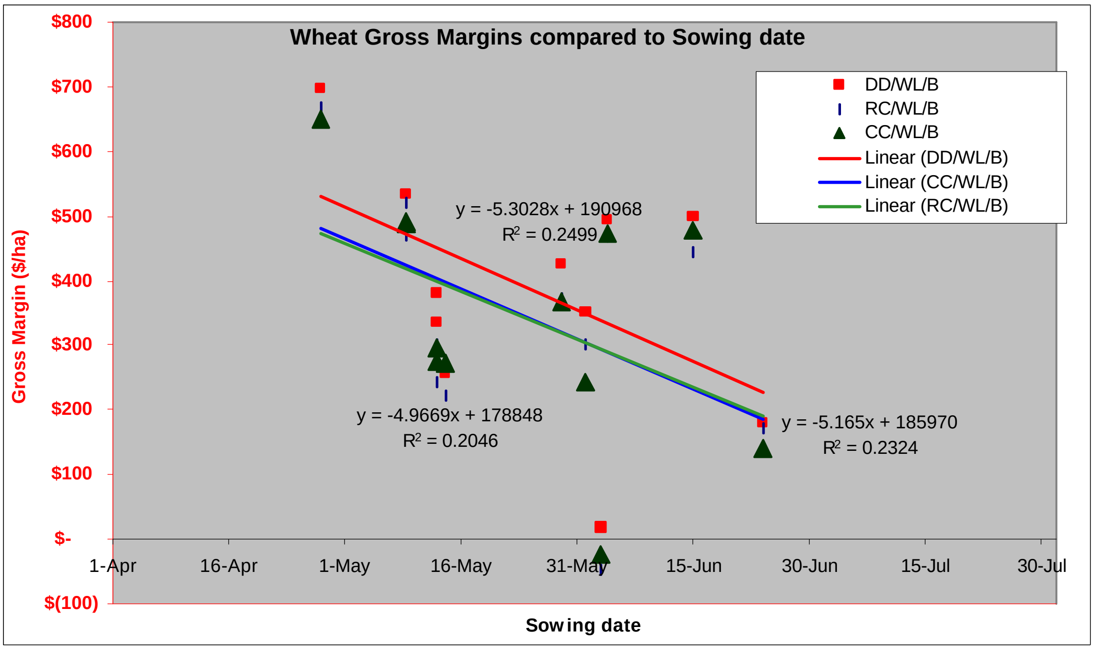


Figure 21 – Regression of annual gross margin of direct drill, reduced cultivation and conventional cultivation treatments with sowing date (burnt, wheat-lupin rotation).

The regression equations in Figure 21 demonstrate the importance of timely sowing in southern NSW. Although the strength of the regressions are not high the trend indicates that earlier sowing increased the chances of high yields being achieved. In all years the sowing of the comparative tillage and stubble treatments was carried out on the same days. This would not be the case on a whole farm situation and thus biases the study toward the conventionally cultivated treatments. Sowing by conventional methods is slower over a whole farm than direct drilling, creating a later average sowing date than direct drilling.

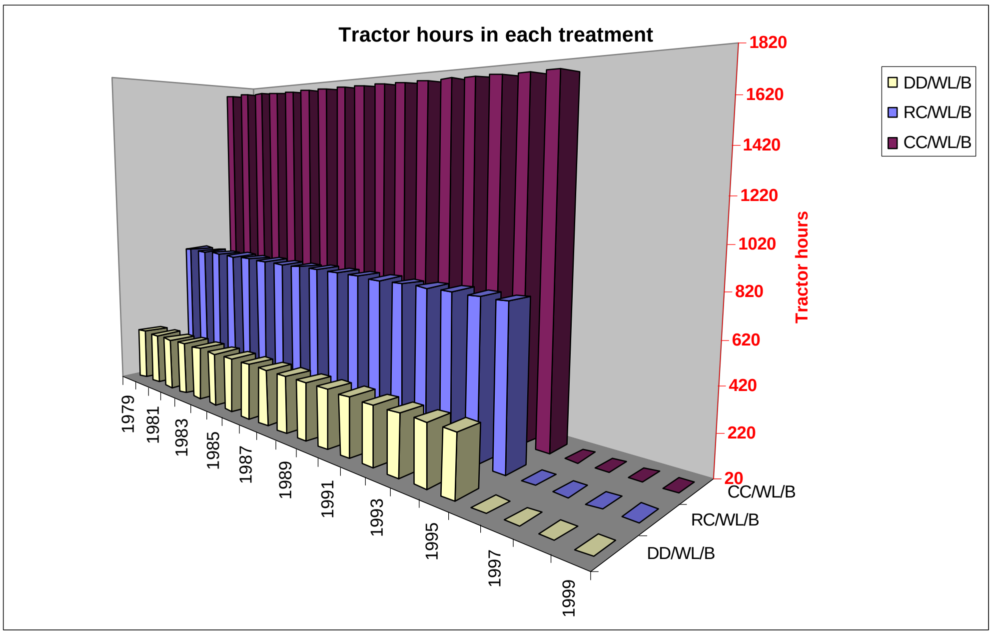


Figure 22 – Estimated tractor hours required to produce cropping enterprise using direct drill, reduced tillage and conventional cultivation treatments (burnt, wheat-lupin rotation).

Figure 22 highlights one of the main advantages of reduced tillage methods of crop establishment. Tractor hours in direct drilled treatments are a fraction of that seen when multiple passes are needed before sowing.

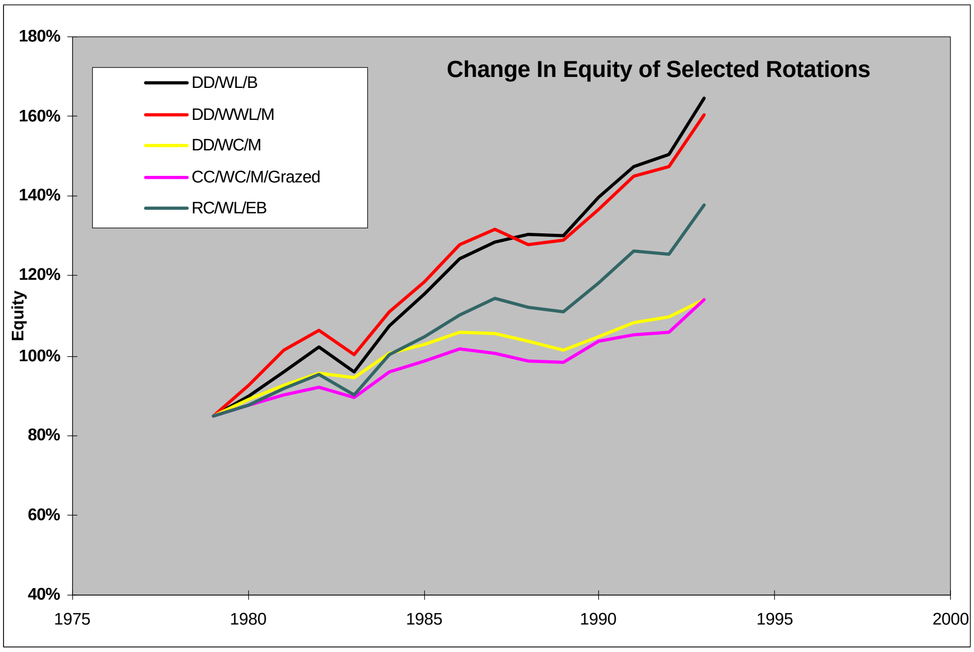


Figure 23 – Change in equity of various rotations at 60% cropping intensity.

The effect of rotation is clearly seen in Figure 23's estimation of equity. The more intensive wheat-wheat-lupin rotation was seen to be almost as profitable as the direct drilled wheat-lupin rotation even though average yields were less (3.36t/ha c.f. 3.59t/ha). A greater proportion of the farm was sown to wheat however due to the higher cereal intensity. Wheat is a much more profitable crop in southern NSW than lupins. If a greater area of land can be sown to wheat profits will generally be higher even if yields are reduced. This was seen to be the case in analysis. A poor year in 1987 reduced the overall profitability of this rotation. This would be closer to the rotation that is practised in the area as it generally has the ability to return greater profits than a cereal-pulse rotation. In comparison, the use of a wheat-clover rotation was seen to reduce equity significantly. This simply reflects the generally lower long term returns from livestock in the area.

4.4.3. SUMMARY

The long-term trial at Wagga reveals a range of important factors. Direct-drilling was the most profitable method of crop establishment in a wheat-lupin rotation. Direct-drilling benefited the yield of lupins in particular, though average wheat yield was slightly better with conventional cultivation. At higher cropping intensities the benefits of direct-drilling on farm equity was greater.

In a predominantly pasture based rotation the differences between treatments were negligible. This may explain why adoption on livestock and smaller farms is lower than on cropping based farms. Direct drilling was seen to be of greater benefit to gross margin in drier years. This effect was greater when analysed with total annual rainfall, indicating the potential moisture saving affects of direct drilling.

Rotation had a major impact on profitability. Higher intensity cropping rotations of wheat-lupin and wheat-wheat-lupin returned greater profits than livestock based systems of wheat-clover.

The experiment continues to the present day. Incorporation of more up to date results would have added some additional strength to the conclusions but results were unobtainable. Anecdotally, the experiment's results have not altered dramatically in the mean time and the use of direct drilling continues to impress as the most profitable system of crop farming in southern NSW.

4.5. – WAGGA TILLAGE TRIAL

This trial was set up in 1977 to investigate tillage impacts in a monocultural wheat situation (Pratley, 1995). The trial was terminated in 1989. Out of many tillage experiments, this is one of the few trials to show significant yield gains in favour of direct drilling. This is borne out by the modelling of the farm and the effects on equity. Again the farm size was 810 hectares and cropping intensity was assumed to be sixty percent of the arable area.

Table 57 – Factors investigated in the experiment.

Rotation	Tillage
Wheat-wheat, except for 2 years (1985 and 1988) which were lupin.	Direct drilled – knockdown only prior to sowing
	Reduced tillage – 1 cultivation and knockdown
	Conventional tillage – at least 3 workings-pre sowing

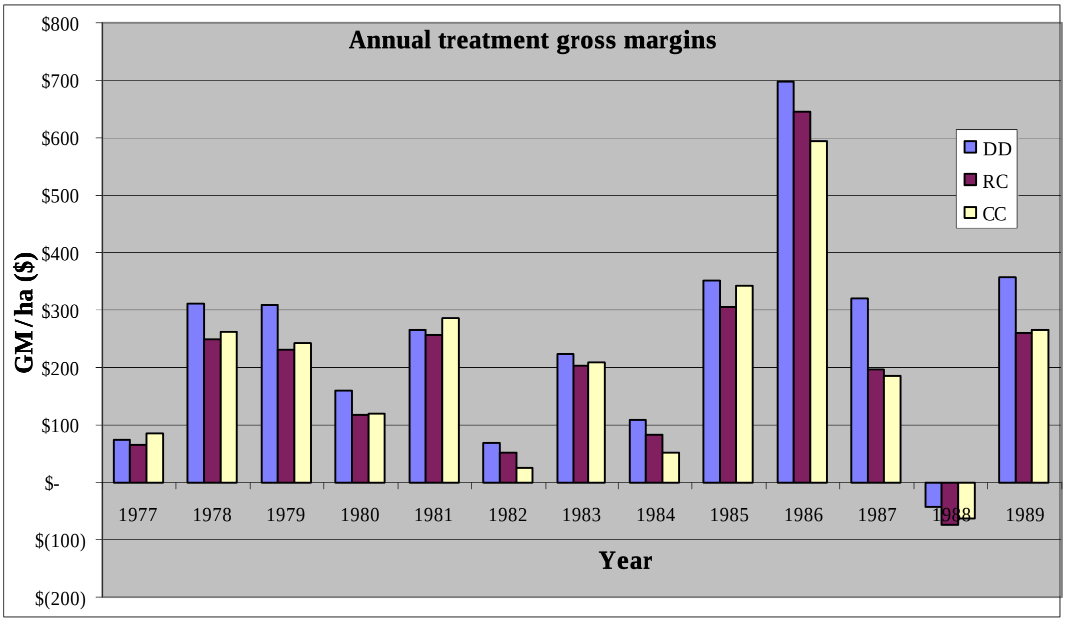


Figure 24– annual gross margins of trial (1977-89)

Table 58 – Average gross margin of tillage treatments.

Tillage method	Average yield (t/ha)	Gross margin per hectare
Direct drilling	2.69	$295
Reduced tillage	2.45	$244
Conventional tillage	2.33	$243

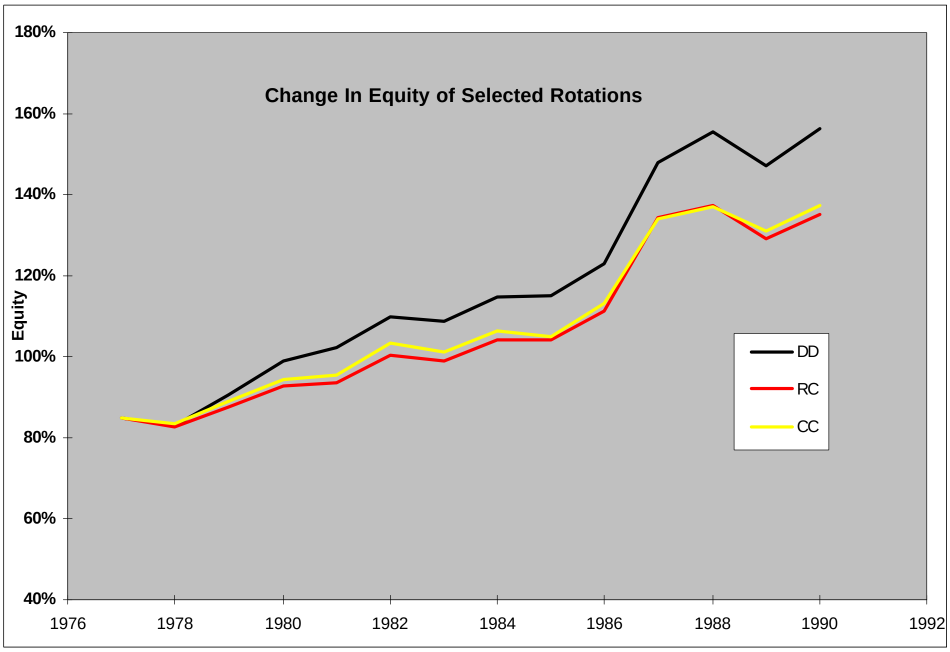


Figure 25 – Simulated effect on equity as affected by tillage method (overhead costs of $85,000).

The direct drilled treatment had a greater increasing effect on equity of the model farm compared to the reduced and conventional cultivation. An increased equity level reflects the higher yields that were attained with the direct drilled treatment. The level of overhead costs greatly affected equity over time. If $85,000 overhead costs per annum was used the growth seen above results. If a higher cost structure of $110,000 overhead costs applied, growth was significantly retarded over time, with final equity being reduced by about twenty percent.

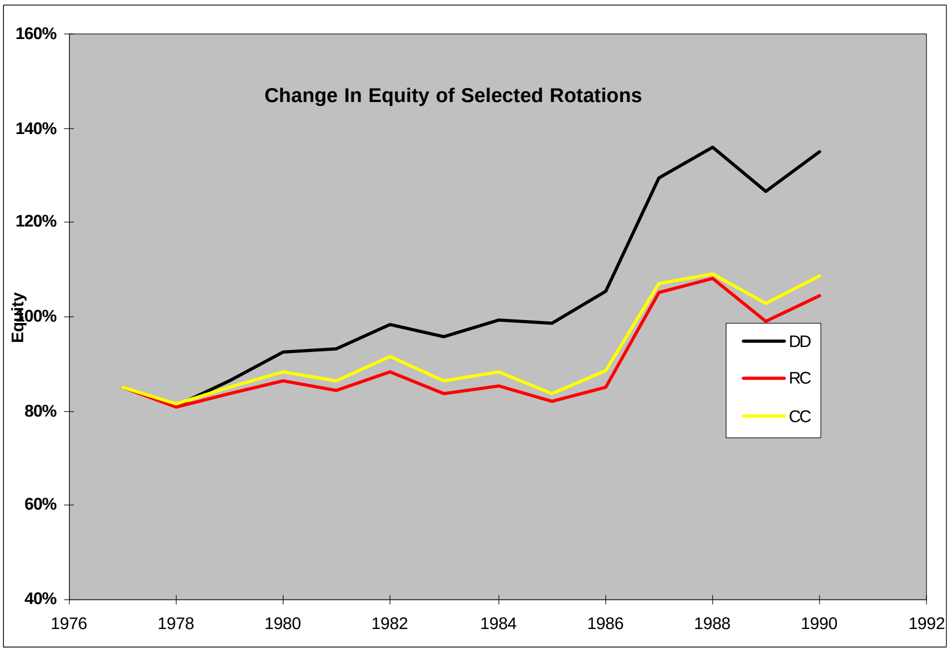


Figure 26 – Simulated effect on equity as affected by tillage method (overhead costs of $110,000).

There was no interaction with sowing time and gross margin in this analysis. The sowing times of trial plots were late by district standards. Direct drilling lends itself more readily to early sowing and the potential yield advantages that it offers. This opportunity may have been lost by the consistently late sowing times of this experiment.

Yield patterns, and hence gross margins were positively correlated with rainfall in all years. Separation of rainfall into growing season rainfall, winter rainfall, spring rainfall and then regressing these figures with gross margins brings out some interesting although insignificant trends. The best correlation is seen in the relationship between spring rainfall and gross margin. This is no surprise as moisture in the spring grain-filling period is vital, particularly if sowing is late. The regression (R^2) coefficient is still relatively low however and reflects the complex interrelationships associated with grain production.

Table 59 – the relationship between gross margins and rainfall patterns.

Tillage method	Relationship of total GSR with GM/ha	R^2 with growing season rainfall	Relationship of winter rainfall with GM/ha	R^2 with winter rainfall	Relationship of spring rainfall with GM/ha	R^2 with spring rainfall
Direct drilling	.6736x-.61	.1469	1.1144x+75	.1089	2.0321x+46	.3446
Reduced tillage	.6002x-20	.1357	1.0572x+38	.1141	1.8763x+15	.342
Conventional tillage	.6645x-42	.1763	1.0964x+33	.13	1.9541x-9	.3931

4.5.1. SUMMARY

The impact of good seasons can again be seen in terms of farm equity. Making the good years count greatly affects the probability and growth of businesses over time. The use of a monocultural system possibly biases the study toward a conventionally cultivated system. Reduced control of various diseases may be encountered in the direct drilled system, and the fact that despite this, average yield was still greater seems significant. No-till systems are traditionally dependent upon sound rotations to control factors such as disease and weeds. The analysis is flawed in that a rotational system was not used. Hence the true farming operations of the area could not be simulated due to the lack of rotation. The trial has shown some benefits of direct drilling however. Yields were not only maintained but increased when crops were sown by direct drilling methods.

4.6. SOUTH AUSTRALIAN LONG TERM SITES - AVON

Five South Australian long-term trials were used to assess the economic consequences of conservation farming techniques (eg. rotation, tillage and stubble retention). Based around the mid-North area the sites consist of a range of soil and climatic conditions. Tillage, stubble treatment and rotation were analysed over the experiments. Similar to the Wagga trial the effectiveness of direct drilling and stubble retention was demonstrated in all trials.

4.6.1. BACKGROUND

This trial is located 70kms nor north-west of Adelaide on Calcereous sandy loam soil (Northcote GC1) with a pH_{CaCl} of 8.3. Avon is approximately 10kms from the coast. Annual rainfall is 320mm and the trial commenced in 1979. Plots of one hundred metres by one and a half metres are used in what is essentially a tillage and rotation trial.

Table 60 – Tillage, rotational and nitrogen variable at the Avon site.

Rotation	Tillage	Nitrogen
Wheat-wheat	Conventional tillage	Nil N
Wheat-oats (in CC only)	Direct drilled	40kgs N as urea since 1990

Wheat-peas		
Wheat-sown medic		
Wheat-volunteer pasture		

The modelled farm is 1428 hectares in size with an average value of $800 per hectare ($320 per acre). This farm size is chosen to keep the same total value of the farm compared to the other experimental sites. Average equity at the start of the rotation was eighty five percent.

There were numerous difficulties in the analysis of this site, again due to the lack of phase replication. Phases were fully represented in the first five years of the experiment until 1983. From this point on only phase was seen. This lead to one phase of the rotation being superimposed each year over the whole cropping area rather than each type of crop being modelled over half the cropping area each year. This may lead to bias developing. The generation of long-term profits often occurs in one 'bumper' year. In a rotation one crop is often much more profitable than another. This is particularly so if the alternate year is a pasture based enterprise. If good rains occur, half of the farm's cropping area will usually have a good wheat crop. Due to the lack of data however, if this year is only represented by pasture then wheat returns are not represented and hence any analysis would not be wholly sound. To complicate matters further, nitrogen was added as a treatment in 1992.

4.6.2. - ROTATION 1 - WHEAT-WHEAT

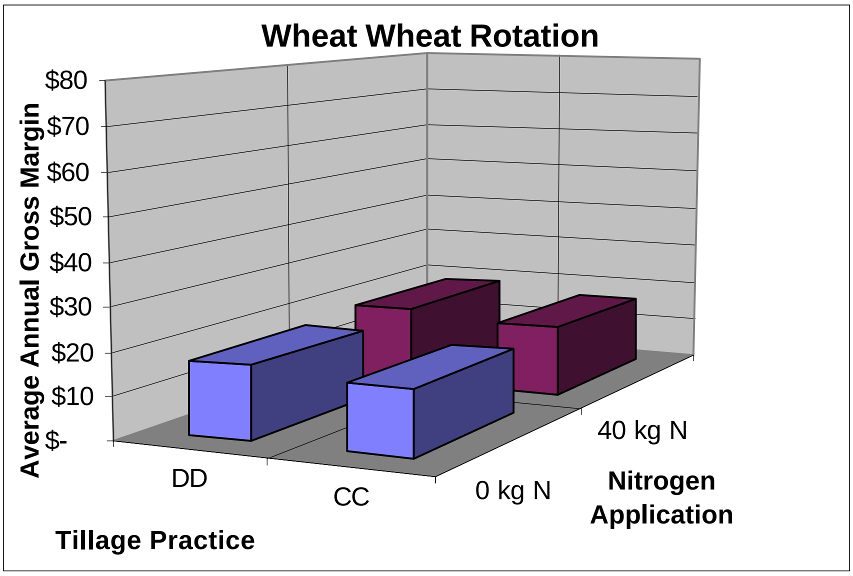


Figure 27 – Average gross margin of rotation 1 (Wheat-wheat)

The average gross margin of the continuous wheat treatment was low. This is due to the excessive weed growth in the treatment and the very high rates of chemical used in the experiment. These rates were unrepresentative of accepted agronomic practices. The experiment culminated in the complete non-sowing of crops, except peas, in 1997 in order to try to reduce the weed seed bank present. The conclusion about the rotation is that direct drilling had a slightly positive impact on the average gross margin.

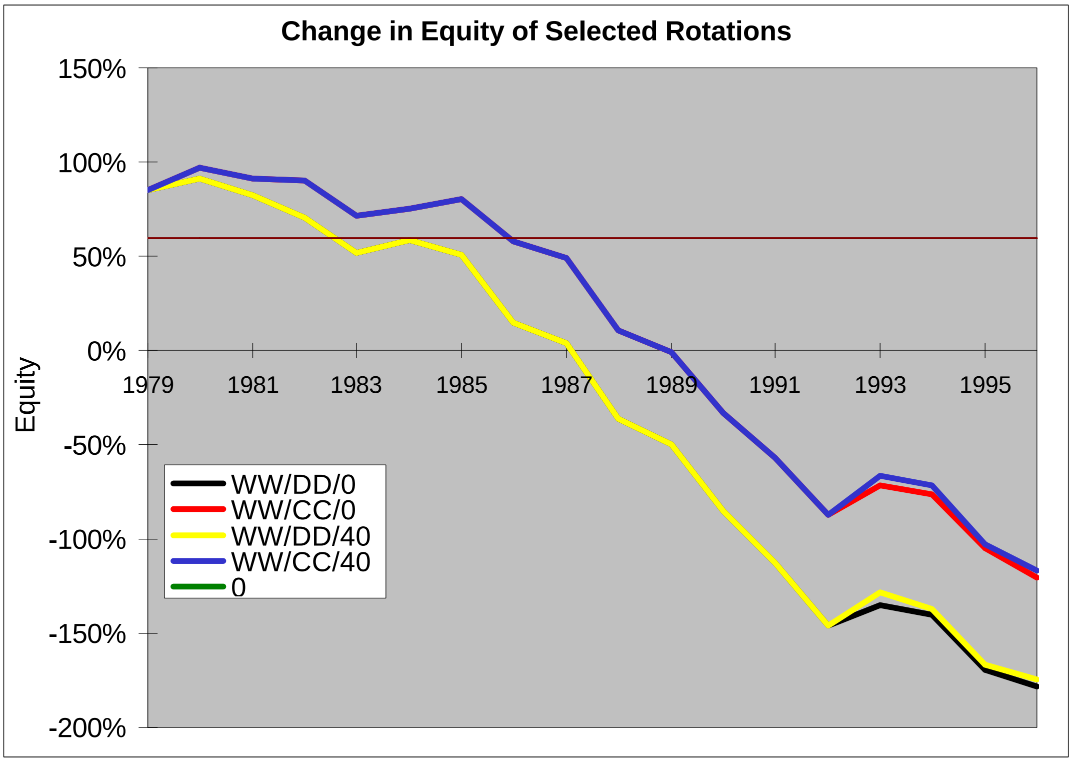


Figure 28– change in equity of continuous wheat treatments.

As shown in Figure 28 above, although the average gross margins were greater when direct drilling was used, the timing meant that conventional cultivation decreased the rate of equity decline. Greater returns early in the experiment reduced the amount of interest payable later with the conventional treatments. As the returns were very low in this rotation the interest bill grew, steadily producing the result where conventional cultivation performed comparatively better.

4.6.3. ROTATION 2 - WHEAT- OATS

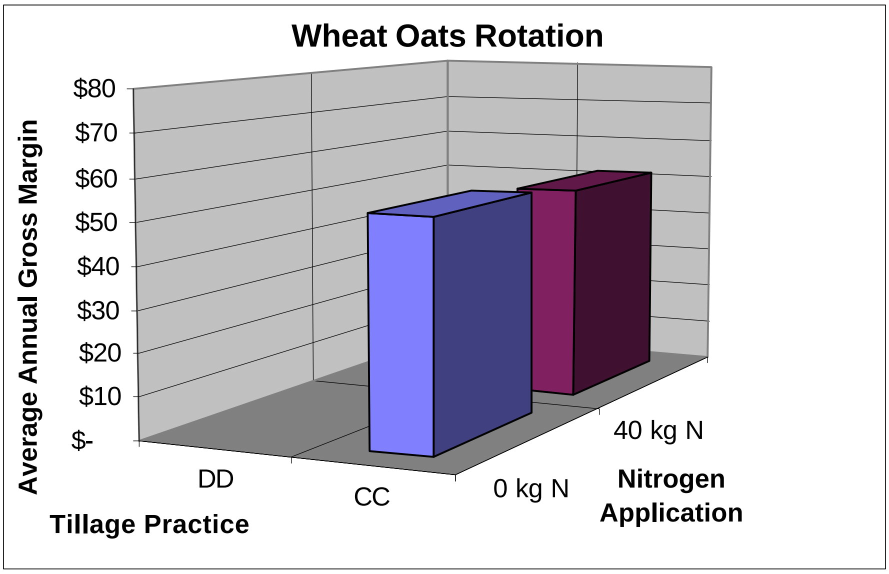


Figure 29 – Average gross margin of rotation 1 (Wheat- oats)

The wheat-oats rotation again saw a little difference in nitrogen treatments. Good responses to nitrogen would have been expected in this intensive cereal rotation.

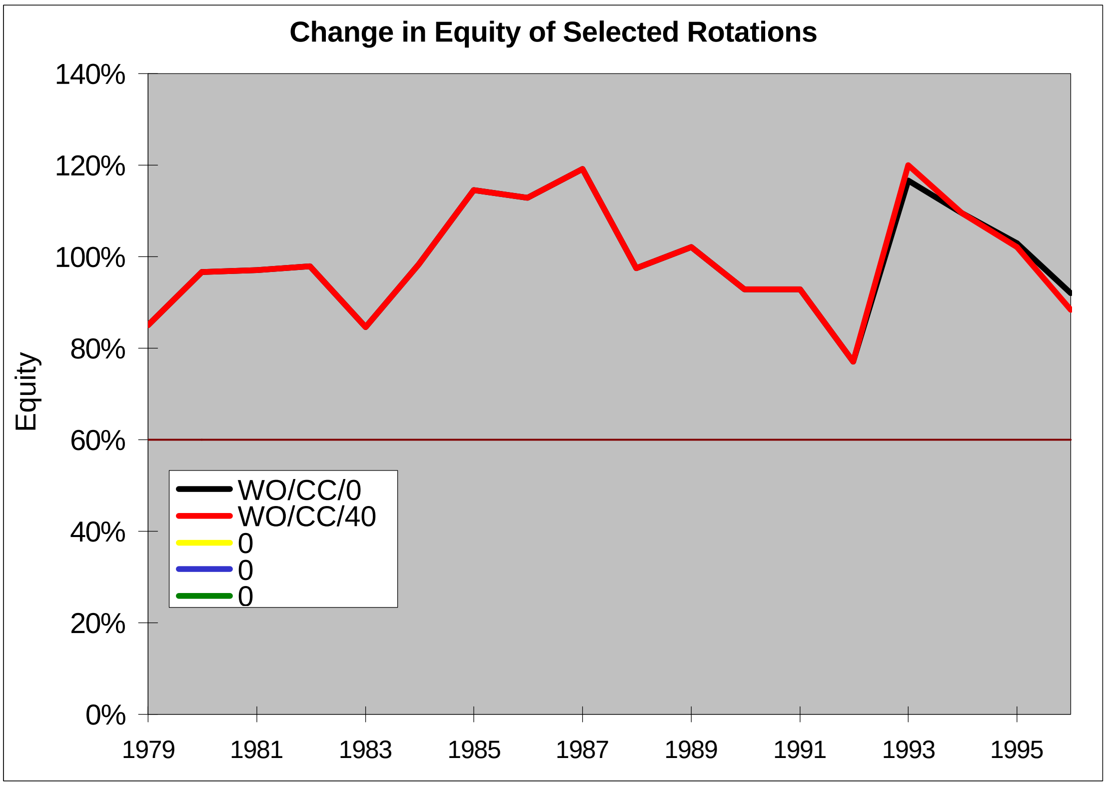


Figure 30 – change in equity of continuous wheat-oat rotation.

There was little difference between the nitrogen treatments over time, as is to be expected.

4.6.4. ROTATION 3 - WHEAT-PEAS

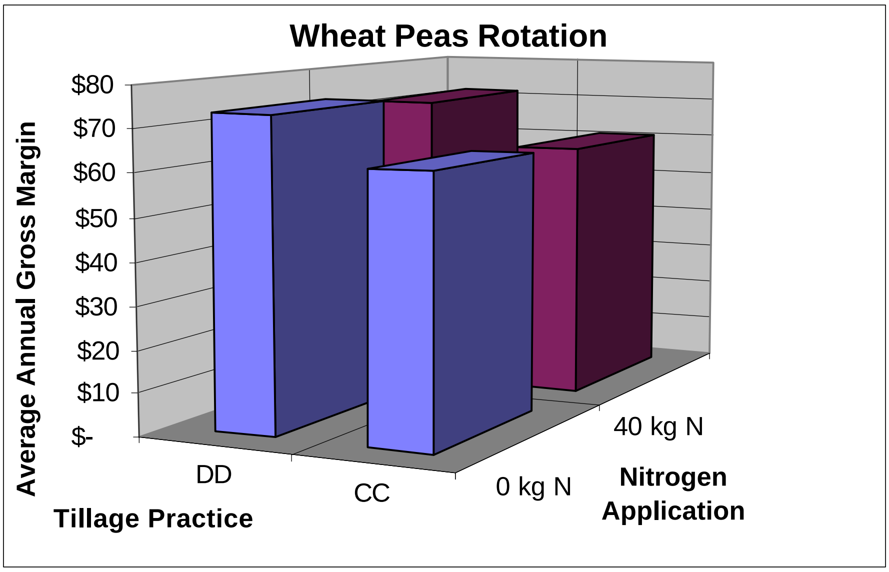


Figure 31 – Average gross margin of rotation 1 (Wheat-peas)

The wheat-pea rotation saw the highest rotational gross margins of all treatments. The crops responded, with the direct drilling method suiting the pea crop. Wheat was then able to use the fixed nitrogen, reducing the effect of applied nitrogen. This treatment was also advantaged in that all other treatments in 1997 were sprayed out to reduce brome grass numbers except the wheat-pea treatment. This increased the financial returns from this rotation in comparison to other treatments. This is of significance however, with the broadleaf-cereal rotation not being as susceptible to a build-up of grass weeds.

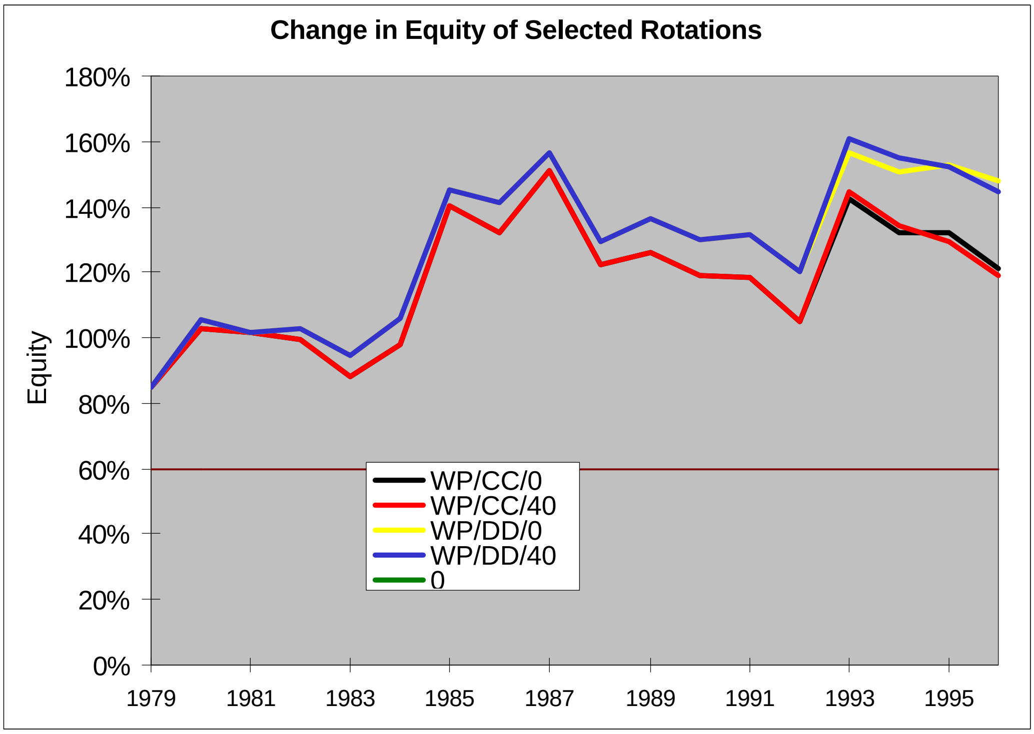


Figure 32 – change in equity of continuous wheat-pea rotation.

The rotation produced the greatest increase in equity, with direct drilling, regardless of nitrogen treatment, outperforming the conventionally cultivated treatments.

4.6.5. ROTATION 4 - WHEAT-SOWN MEDIC

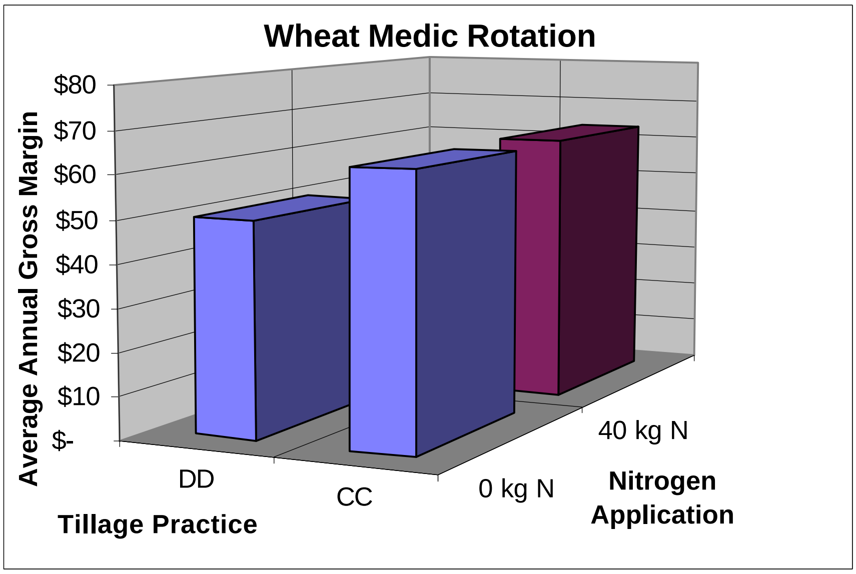


Figure 33– Average gross margin of rotation 1 (Wheat-medic)

The wheat sown medic treatment produced the results that would be predicted. Cultivation increased the establishment of the small-seeded medic, which in turn increased the amount of nitrogen fixed. This was then released by cultivation in the following years wheat crop. The differences in gross margin were significant when seen over the period of time.

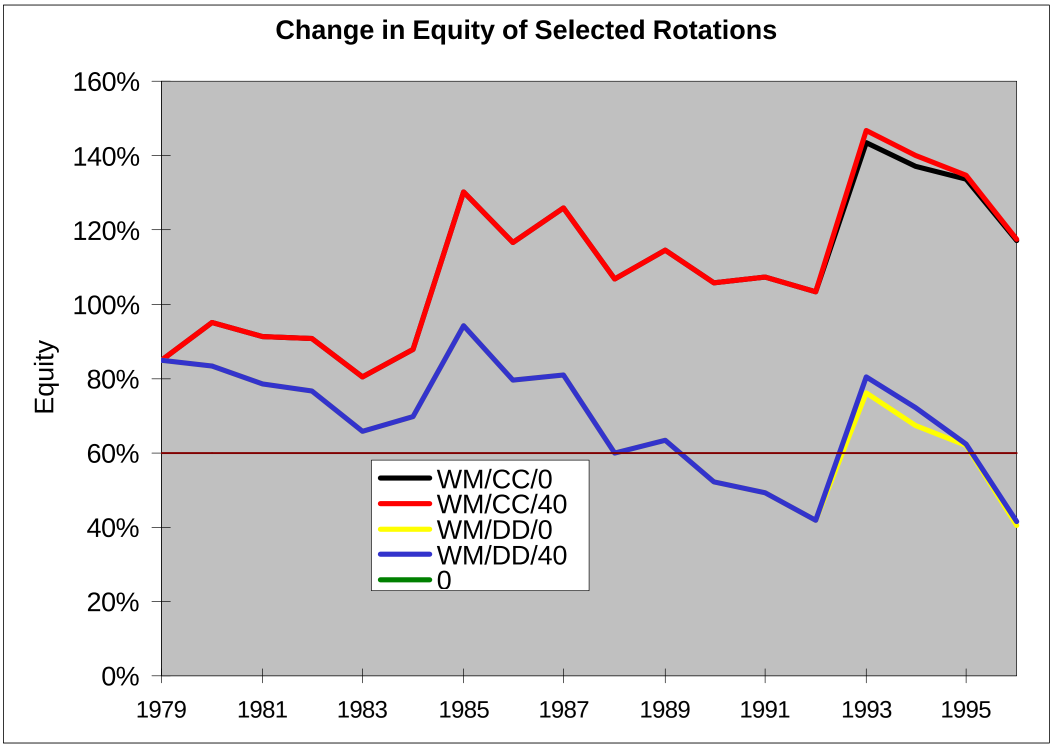


Figure 34 – change in equity of continuous wheat-sown medic rotation.

Cultivation increased the equity of the farm greatly over time, with no nitrogen effect being observed.

4.6.6. ROTATION 5 - WHEAT-VOLUNTEER PASTURE

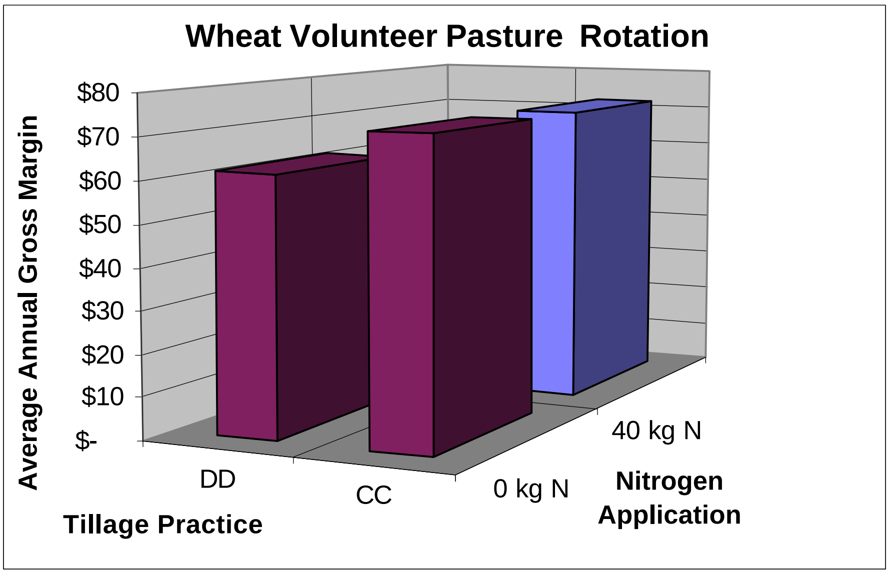


Figure 35 – Average gross margin of rotation 1 (Wheat-volunteer pasture)

The wheat-volunteer pasture rotation saw similar results to that of the medic pasture. This was reflected in the distinct gap in the equity over time of the tillage treatments. Equity was maintained at levels that were above what are considered dangerous levels however. Once again the difference in average gross margin would not have been thought to be of significance but over a whole operation the difference will produce a significant effect in time.

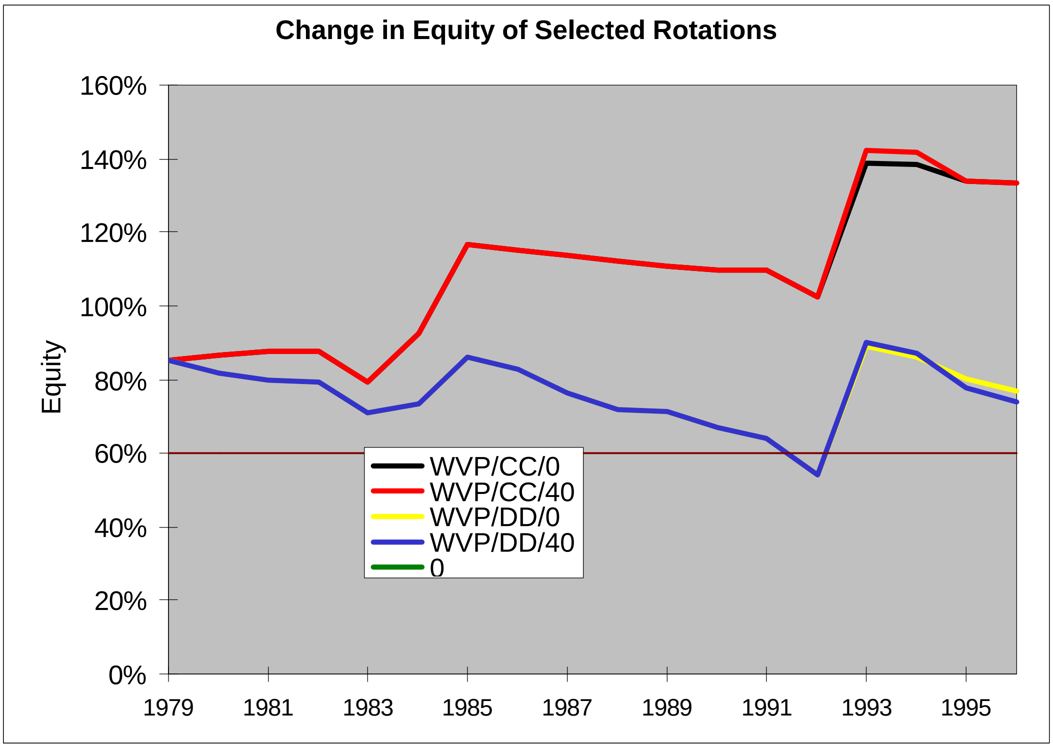


Figure 36 – Change in equity of continuous wheat-sown medic rotation.

4.6.7. CONCLUSIONS

Rotation has been the major influence on productivity with continuously cropped treatments that allow control of root disease and brome grass giving the best results. The ability to maximise production was seen to be a major source of profitability. This experiment was the site where the development of 'disease suppressive' soils was first noted. Prior to this, the use of direct drilling was observed to increase the incidence of root disease due to the lack of tillage to disrupt fungal hyphae. Over time however, natural predators to the pathogens increased and balance was restored. This has the potential to alter the economics of the trial in favour of intensive cereal production. This has yet to be noted in terms of yield however, possibly due to the large infestations of grass weeds. Tillage and nitrogen had little overall effect on production. Water use efficiency increased over time, indicating an improved soil environment.

The trial also confirms that one of the keys to the use of no-tillage cropping is the use of diverse rotations. Rotation allows diversification of chemical usage, alters the soil environment and can allow complementary effects for the different crops. Continually these experiments will see that rotation rather than tillage type is the greatest determinant of profitability rather than tillage or nitrogen. This can be seen in the graph below.

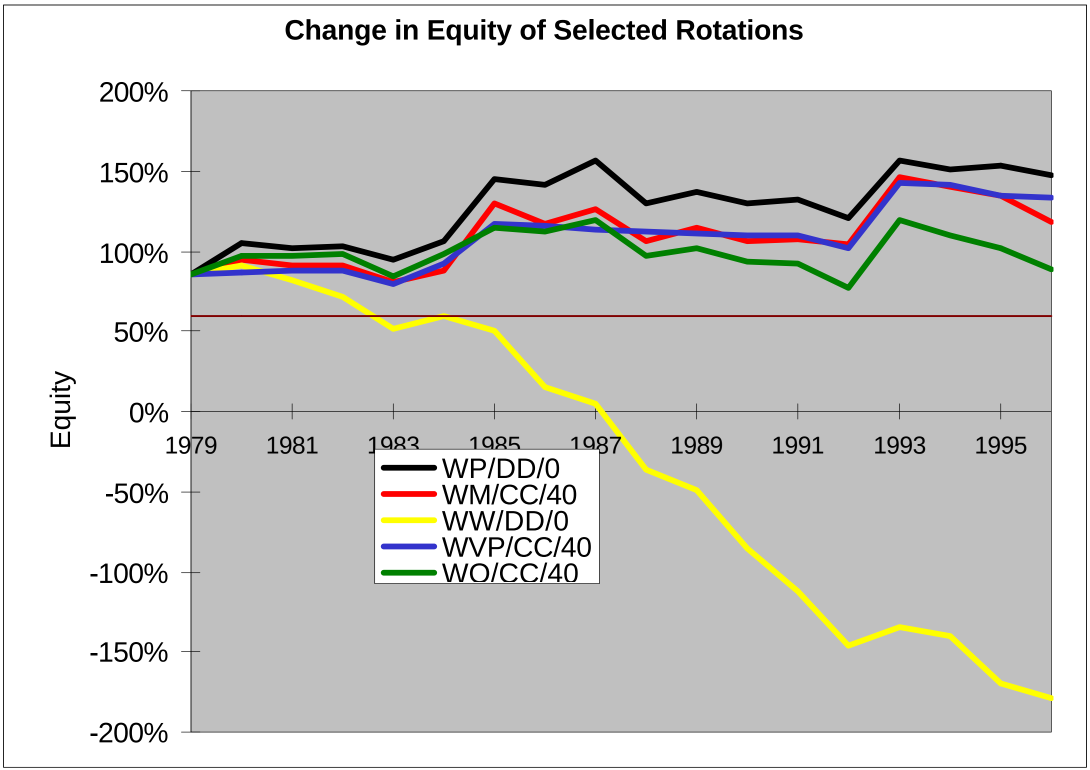


Figure 37 – change in equity of various rotations and tillage treatments.

4.7. HALBURY

4.7.1. BACKGROUND

This trial, commencing in 1984, is located around 100km's due north of Adelaide. The soil is a red-brown earth (Northcote Dr 2.3) with a pH_{CaCl} of 5.2 and an annual rainfall of five hundred millimetres.

Table 61 – Rotational, tillage and nitrogen treatments at the Halbury site.

Rotation	**Tillage**	**Nitrogen**
Wheat-pasture	Conventional tillage	Nil N
Wheat-barley-grain legume	Reduced tillage	63kgs N as urea since 1990
Wheat- pasture-long fallow	Direct drilled	

The trial went through a range of phases in its history. The original trial was set up as a fully replicated, phased experiment. With funding difficulties this was reduced to a two of the phases being represented each year. This has made the modelling of the trial over a farm difficult but an average gross margin of these crops has been overlaid on the cropping area of the farm.

A range of tillage and rotational treatments were used. In the wheat-pasture-long fallow rotation (rotation one - WPLF) only mechanical cultivation was used. Different rates of nitrogen were used as the variable.

In the wheat-pasture rotation (rotation two - WP) nitrogen was also used as a variable. In addition tillage treatments (full tillage with no herbicide usage, reduced tillage with some pre-sowing cultivation, sowing with wide shares and post emergent herbicide use, and no-tillage which used narrow points and only herbicides for weed control) were used

In the continuous cropping scenario (rotation three - WBGL) the same three tillage treatments were tested in addition to a full tillage and stubble retention treatment. Nitrogen was again used as a variable.

4.7.2. RESULTS

Rotation one saw a positive yield response to nitrogen application (3.57t/ha vs 3.21t/ha) but once account of the cost was taken the average gross margins of the two nitrogen treatments were very similar ($96 per hectare versus $98 per hectare). Given that urea costs $330 per tonne, has forty six percent nitrogen and is applied at sixty three kilograms of nitrogen per hectare, 137 kilograms of urea per hectare will cost $43.82 per hectare. To meet this cost of production when wheat brings a net $150 per tonne, an average yield increase of 0.3 tonnes per hectare is needed. Mechanical cultivation was used for all weed control pre-sowing but chemical costs increased over time post-emergence.

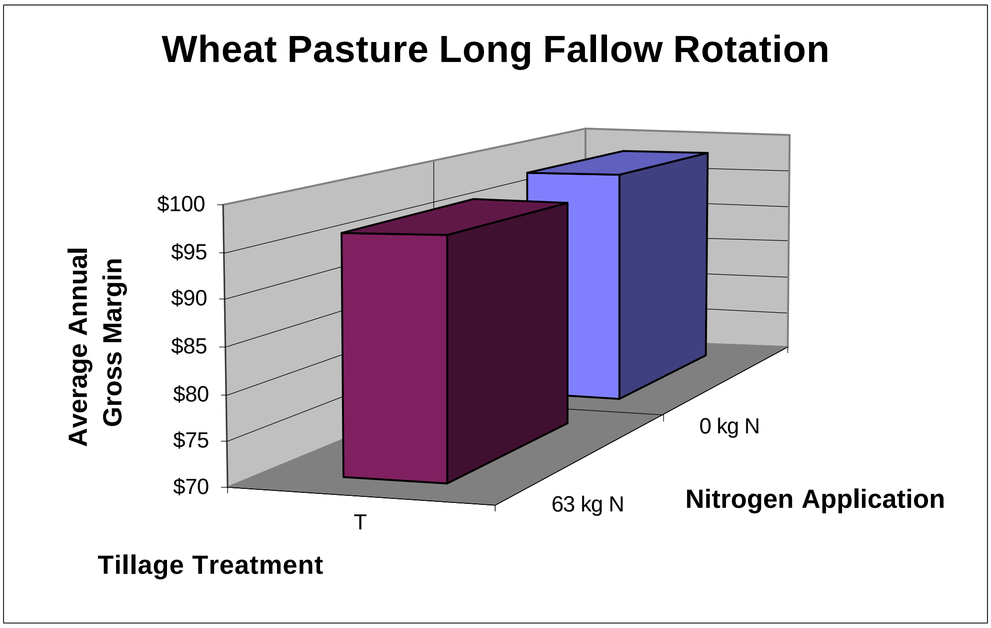


Figure 38 – Average gross margin of rotation 1 (Wheat-pasture-long fallow)

Rotation two saw a similar situation occur with regards to nitrogen. Yields were increased but there was a negative marginal effect with regard to gross margin. Interestingly the impact of nitrogen was greater in the no-till treatment. The use of cultivation would theoretically increase the rate of nitrogen mineralisation, reducing the benefit of N fertiliser application. To supply this N however the organic matter in the soil has to be mineralised. Over time the amount of organic matter in the tilled treatment would be expected to decrease. These measurements are not available but the treatment has responded as expected.

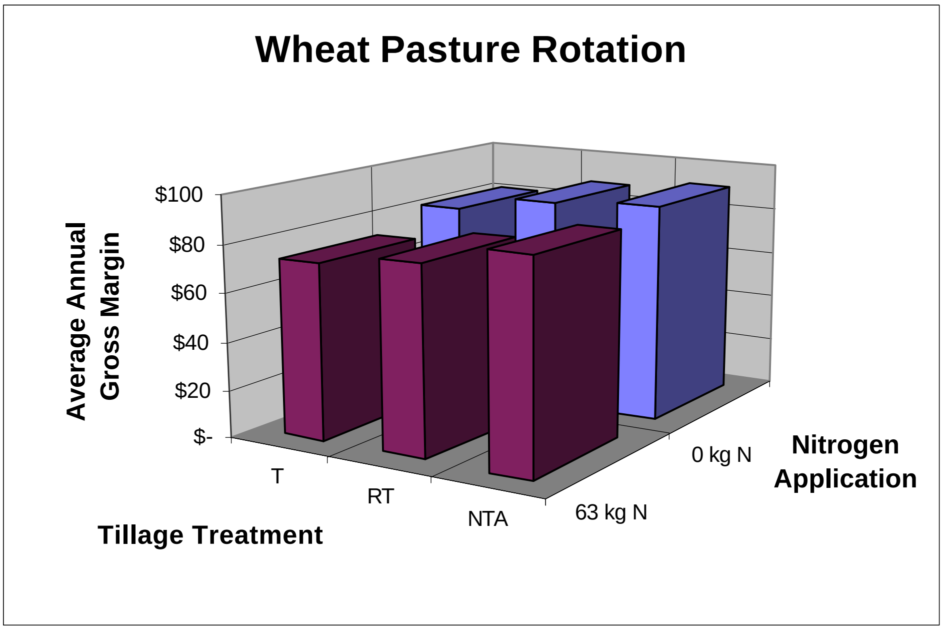


Figure 39 – Average gross margin of rotation one (Wheat-volunteer pasture)

Similar to rotation two the no-till treatments in rotation three responded positively to nitrogen in comparison to the tilled treatments. A positive effect on gross margin was seen in the no-till treatments. This would be expected also in the more intensive cropping regime. The use of a grain legume will supply some nitrogen for the rotation. Average gross margins were very similar in all treatments except for the reduced tillage.

The main point to note from the use of continuous cropping are the much improved average gross margins in comparison to the rotations that include a pasture phase. Roughly twice the average gross margin is received when continuous cropping takes place. This is based on the quoted district average stocking rates of three DSE per hectare in nil nitrogen treatments and four DSE per hectare when nitrogen was applied. At a gross margin of $16.70/DSE, returns are usually much less than cropping.

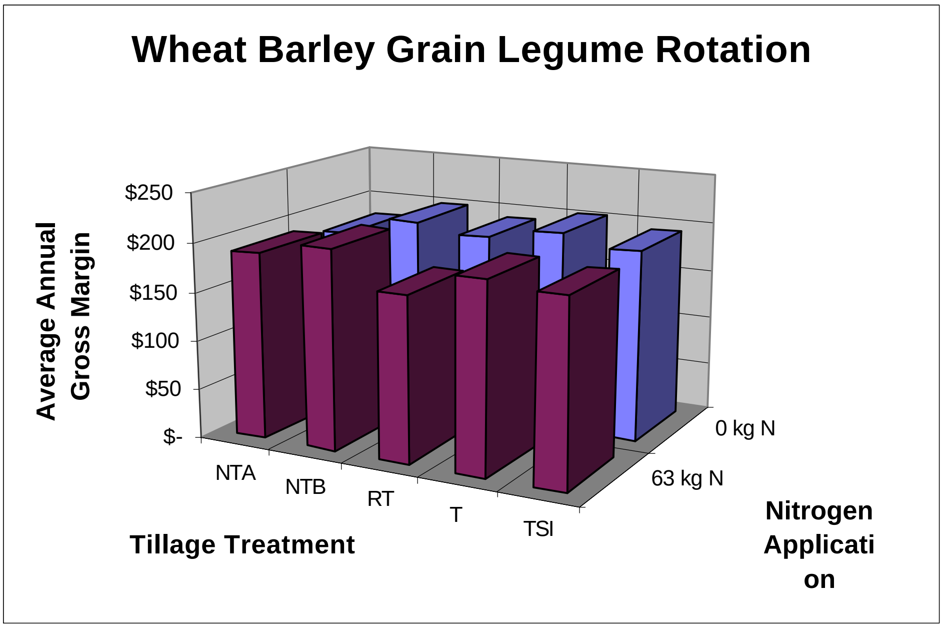


Figure 40 – Average gross margin of rotation one (Wheat-barley-grain legume)

The estimated effects of various treatments, modelled over an 800ha property, can be seen below. In short the scale of the property is nowhere enough to cater for the profitability of the farm in the long term if a pasture phase is used. The trend is clear even given a run of good seasons in the late 1980's and early 1990's.

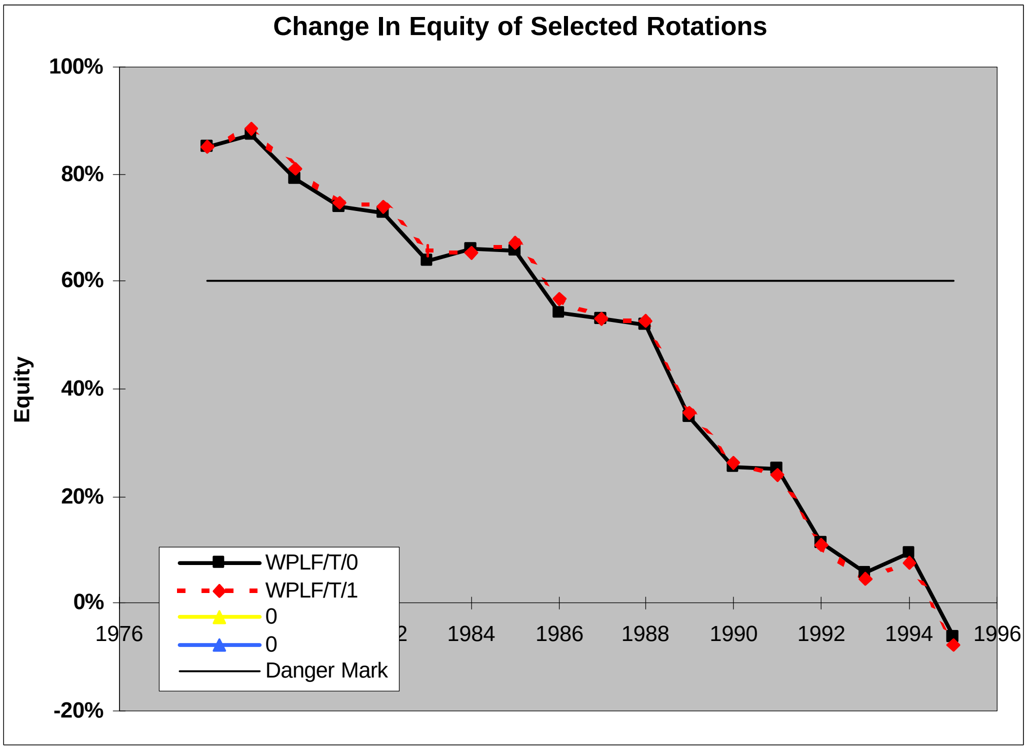


Figure 41 – The effect of nitrogen application on equity in a wheat-pasture-long fallow rotation (rotation one).

The equity of the farm reduced at a slower rate in the wheat-long fallow-pasture rotation compared to the wheat-pasture treatment, illustrated in Figure 42. The application of nitrogen made no difference to the rate of fall however.

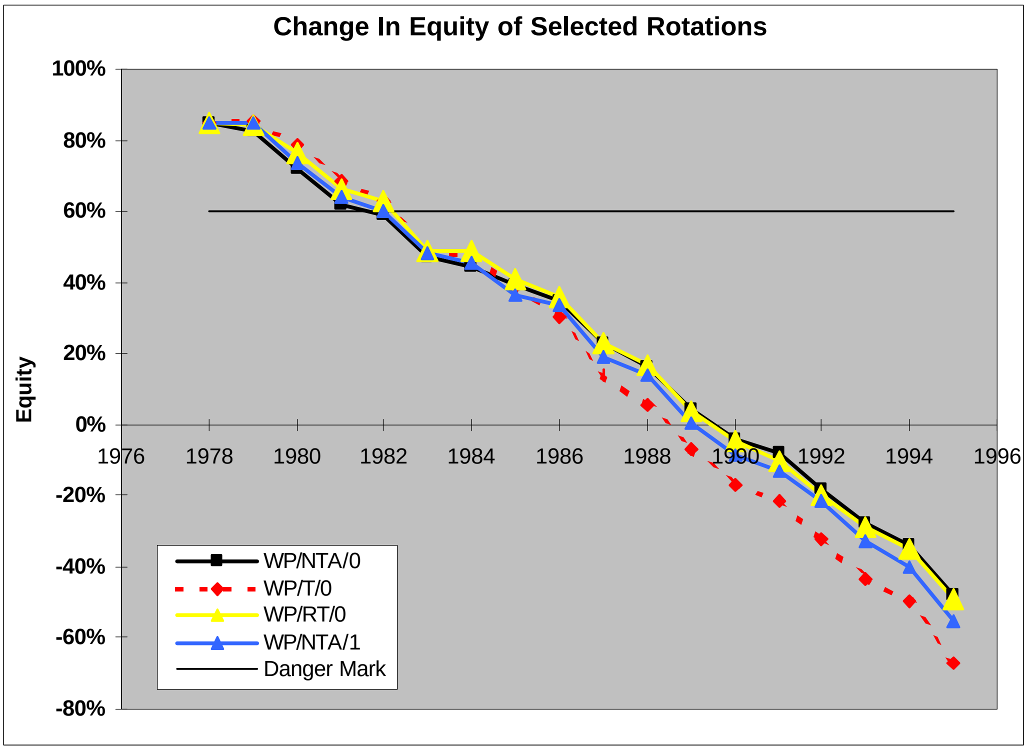


Figure 42 – The effect of tillage and nitrogen on equity in a wheat pasture rotation (rotation two).

When a pasture phase is used the profitibility of the farm diminishes rapidly. The wheat-pasture rotation was seen to be the least profitable of all rotations. The type of tillage and nitrogen application made little difference to the overall decline in equity. However, of the treatments, the no-till,nil N treatment at least slowed the rate of decline in comparision to that of tilled treatments.

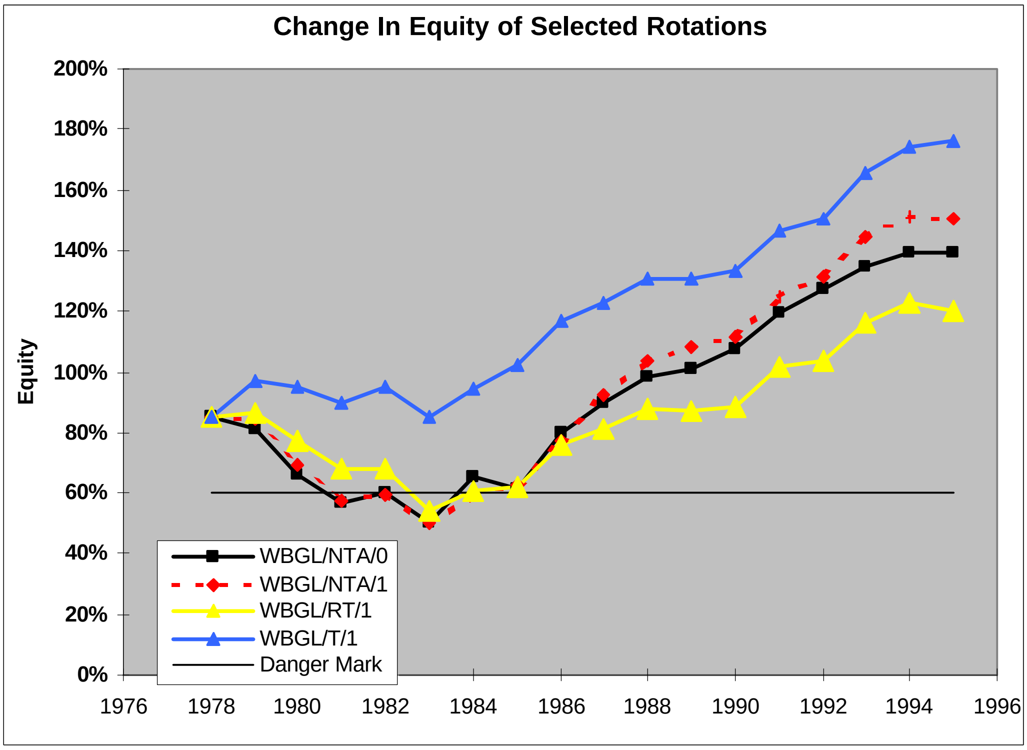


Figure 43 – The effect of tillage and nitrogen on equity in a wheat-barley-grain legume rotation (rotation three).

The tilled treatment was seen to provide greater gross margins in the early years of the experiment. This reduced interest payments on debt and the level of equity is thus greater. The two no-tilled treatments show the positive impact of nitrogen fertiliser over time when tillage is limited.

Figure 43 does show some possible explanation for the poor adoption of conservation cropping. Reduced yield in the early years compared to the tilled experiment may place growers at financial risk. Once the system starts to settle down and/or management improves however the returns are seen to be very similar. Management of the site may have changed over time to reflect greater knowledge of cropping without tillage.

4.7.3. SUMMARY

The greatest impact on equity of the farm was rotation. Tillage and nitrogen application impacted on financial performance to a lesser degree. The experiment has shown that tillage type has a relatively minor effect on the financial operation of the farm over time. Long term damage to soils over time may only affect tilled treatment gross margins at a time after the experiment was wound up. Lower organic carbon measurements were seen in the tilled and nil nitrogen treatments. This may have detrimental long term effects on yield, productivity and financial position.

In the continuously cropped treatment there appeared to be a definite “learning phase” that impacted on the overall equity of the farm. This may reflect the adoption risk on many farms and thus act a major disincentive.

4.8. KAPUNDA

This site is located approximately 80km’s north east of Adelaide on a red-brown earth (Northcote Dr 2.3) with a pH_{CaCl} of 5.2. The elevation of the site in the Mount Lofty ranges confers an annual rainfall of five hundred millimetres. This tillage, rotation and, in later years nitrogen, trial commenced in 1984 and ended in 1995.

Table 62 – Rotation, tillage and nitrogen treatments at Kapunda.

Rotation	Tillage	Nitrogen
Wheat-wheat	Conventional tillage	Nil N
Wheat-lupins	Reduced tillage	80kgs N as urea since 1990
Wheat-volunteer pasture	Direct drilled	

This experiment is set up in similar fashion to that of the Avon and Halbury sites, testing the effect of rotation, tillage and nitrogen on yield. Nitrogen was only added as a variable in 1990. The experiment was fully phased in the early years but again time constraints eliminated phasing post-1987 (Roget, 1999). This may affect the validity of results in the short term but the analysis was carried out with these limitations anyway.

The modelled farm is again of the same value as the other farms in the study. With land in the area valued at around $2000/ha, the farm size was said to be 545 hectares. Overhead costs, machinery investment and starting equity were said to be similar to other sites.

4.8.1. ROTATION ONE - WHEAT-WHEAT

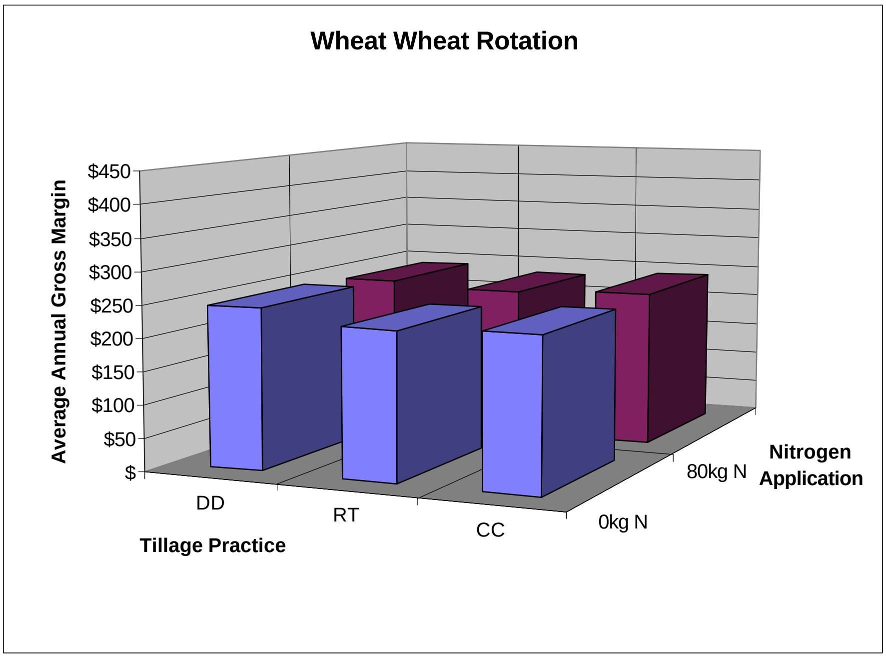


Figure 44 – Average gross margin of rotation 1 (Wheat-wheat)

Table 63– Average gross margins of wheat-wheat rotation ($/ha)

	0kg N	80kg N
DD	246	239
RT	225	231
CC	232	239

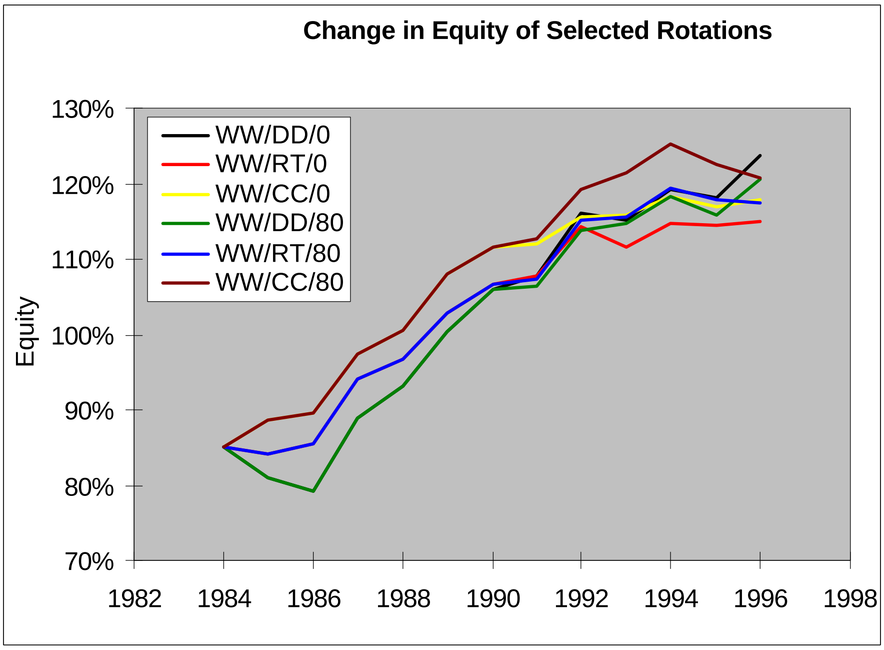


Figure 45 – The effect of tillage and nitrogen on equity in a wheat-wheat rotation (rotation 1).

4.8.2. WHEAT-LUPINS

The wheat-lupin rotation produced the most noticeable effect of the trial.

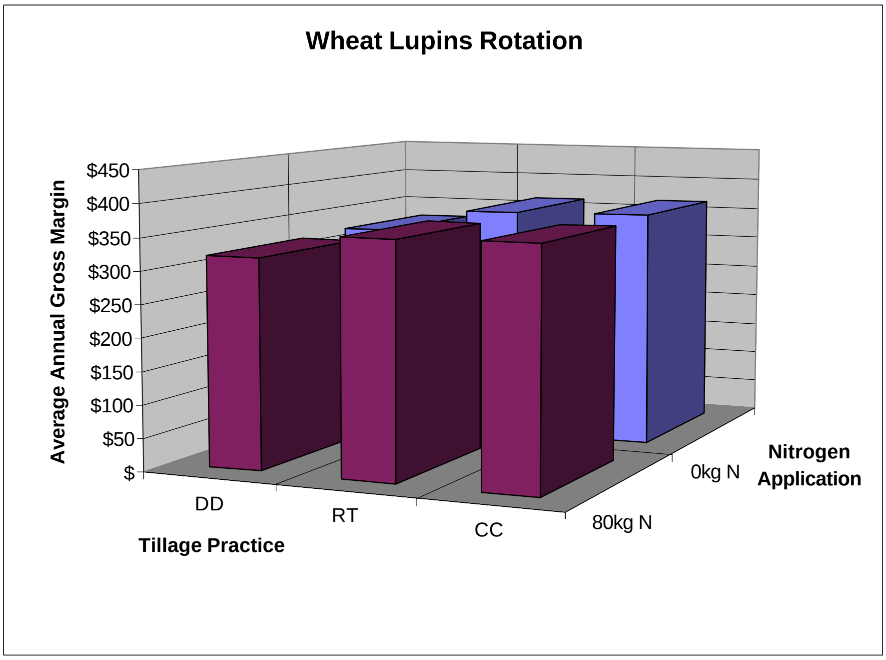


Figure 46– Average gross margin of rotation 2 (Wheat-lupin)

Table 64– Average gross margins of wheat-lupin rotation ($/ha)

	0kg N	80kg N
DD	324	319
RT	360	356
CC	363	359

As Figure 46 shows direct drilling using a wheat-lupin rotation did not favour average gross margin. Reduced tillage and conventional cultivation produced the highest average gross margins. This was reflected in the modelled equity levels over time. Some form of cultivation was seen to be beneficial.

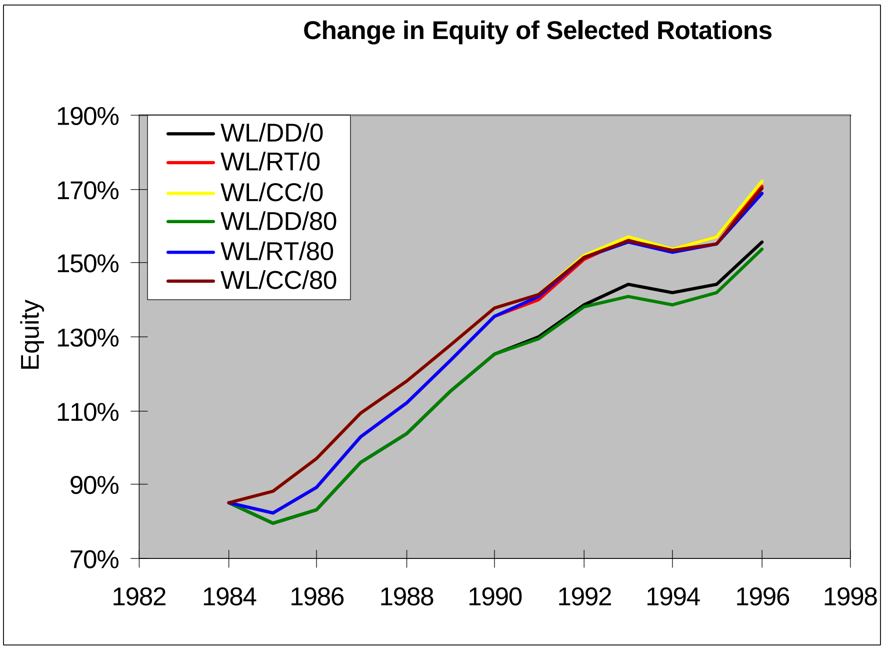


Figure 47– The effect of tillage and nitrogen on equity in a wheat-wheat rotation (rotation 2).

4.8.3. WHEAT-VOLUNTEER PASTURE

The wheat-volunteer pasture rotation saw direct drilling favoured to a small extent in terms of average gross margin.

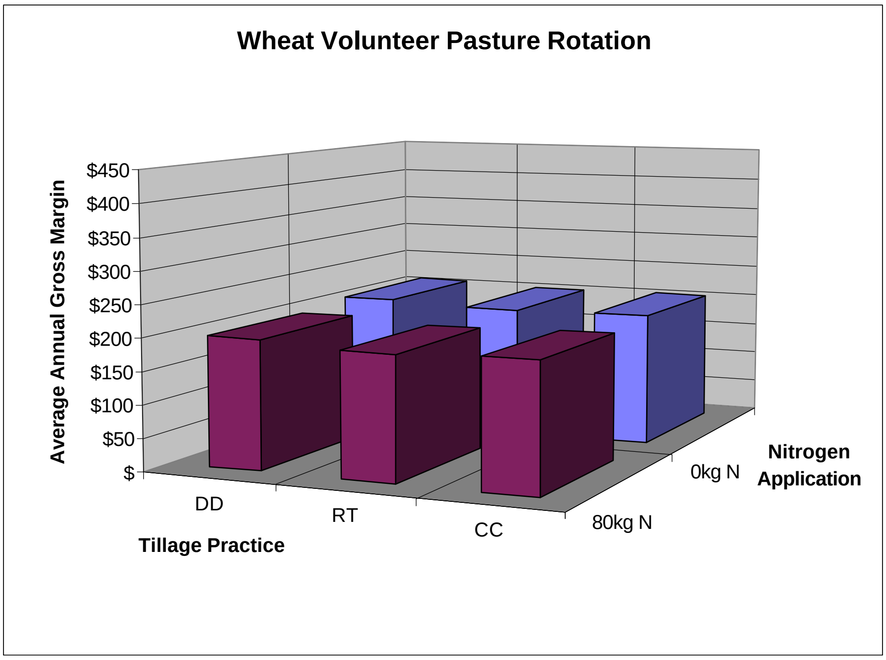


Figure 48 – Average gross margin of rotation 3 (Wheat-volunteer pasture).

Table 65 – Average gross margins of wheat-volunteer pasture rotation

	0kg N	80kg N
DD	208	199

RT	201	190
CC	204	195

As we would imagine the effect on the equity of a modelled farm was negligable regardless of tillage operations.

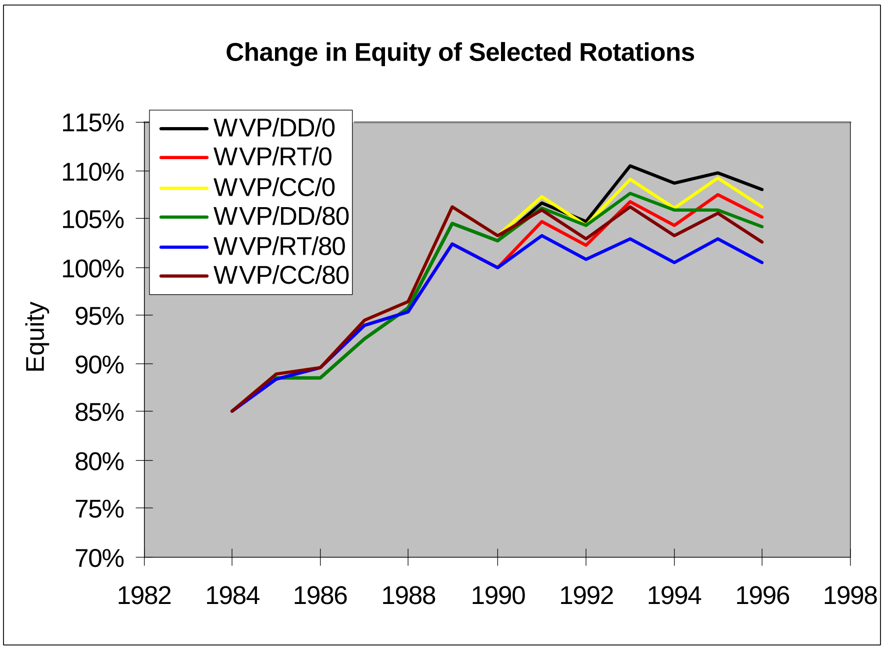


Figure 49 – The effect of tillage and nitrogen on equity in a wheat-volunteer pasture rotation (rotation 2).

Also of interest in the trial was the constant monitoring of soil factors that relate to the tillage trial. Organic carbon levels were measured at four times over the course of the study and were seen to vary according to management.

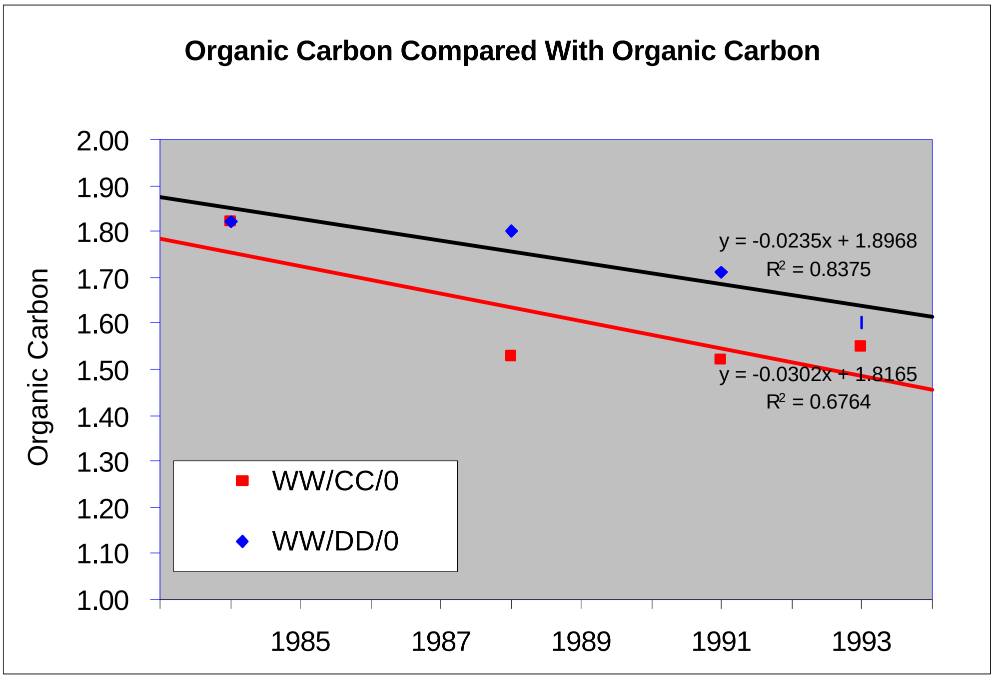


Figure 50 – Organic carbon level change in a wheat-wheat rotation.

Organic carbon levels decreased at a greater rate when conventional cultivation was used. The R^2 co-efficient shows the strength of the explanation of the regression equation. In the case of the cultivated soil, organic carbon was predicted to be decreasing at 0.03 percent per year, compared to 0.23 percent per year in the direct drilled plots. Prior to the last measured year in the wheat-lupin rotation direct drilling showed decreased rates of decline as well. The effect of nitrogen application was not seen due to the late inclusion of nitrogen as a variable. It is likely that nitrogen application would reduce the rate of organic carbon decline due to decreased reliance on mineralisation for plant nutrition.

Table 66 – The effect of tillage and rotation on organic carbon levels

	1984	**1988**	**1991**	**1993**
WL/DD/0	1.82	1.80	1.58	1.30
WL/RT/0	1.82	1.62	1.62	1.46
WL/CC/0	1.82	1.55	1.52	1.46
WVP/DD/0	1.82	1.95	2.00	1.80
WVP/RT/0	1.82	1.73	1.80	1.78
WVP/CC/0	1.82	1.75	1.85	1.80
WW/DD/0	1.82	1.80	1.71	1.60
WW/RT/0	1.82	1.55	1.52	1.53
WW/CC/0	1.82	1.53	1.52	1.55

From Table 66 we can see that most treatments saw an initial maintainence of organic carbon levels with the use of direct drilling but this was reduced over time. This concurs with anecdotal evidence which suggests that initially organic matter mineralisation rates may be reduced in direct drilled treatments due to a lack of aeration and other mineralising factors. Over time the microbial population will increase to an extent that the rates of mineralisation are similar to that of cultivated soils. This may have been the case over time in this trial. Also we can see that only treatment to maintain organic carbon levels was the pasture rotation. Cropping reduced the levels significantly over time regardless of tillage treatment.

Interestingly pH levels were also measured. Rotation was again seen to be the major determinant of trend, but no distinction was made between tillage treatments. The legume rotation maintained higher pH levels than the wheat-wheat and wheat-pasture rotations. Nitrogen application was seen to reduce pH levels but the significance of these figures have not been tested.

Table 67 – The effect of rotation on pH levels at Kapunda.

	1984	1988	1991	1993
WW/0	5.20	4.80	4.60	4.65
WVP/0	5.20	4.90	4.60	4.69
WL/0	5.20	5.20	4.92	4.85
WW/80				4.51
WVP/80				4.64
WL/80				4.82

4.8.4. SUMMARY

This trial has again shown that the use of tillage has been predicted to have only modest effect on the profitability of farms in the Kapunda area, unless a wheat-lupin rotation was used. This result was unexpected when the wheat-pea results from the Avon trial are considered.

Organic carbon levels were not significantly different over time with regard to tillage treatment but reduced levels of breakdown were seen in the early years of a cropping rotation. This may implications for growers using a phased rotation of pasture and cropping. Organic carbon levels may be maintained at present levels in the cropping phase and possibly increased in the pasture phase. Continuous cropping was seen to degrade the carbon resource irrespective of tillage treatment.

Soil pH levels were maintained to a greater extent in the wheat-lupin rotation when compared to the pasture and continuous wheat treatments. This has implications on the profitability of the pasture and cereal rotations. The inclusion of lime as a cost of production for these rotations further reduces their attractiveness to growers and enhances the continuous rotation of legume and cereal.

4.9. TARLEE ROTATION TRIAL

Again this trial is located around 80kms north east of Adelaide. Tarlee is about 12kms north west of Kapunda. , Red-brown earth (Northcote Dr 2.3) with a pH_{CaCl} of 5.2. Annual rainfall is five hundred millimetres. This rotation, nutrition and stubble retention trial commenced in 1983.

Table 68 – Rotation, nitrogen and stubble treatment at Tarlee.

Rotation	Nitrogen	Stubble
Wheat-wheat	Nil N	Burn
Wheat-barley	40kgs N as urea	Retain but incorporated
Wheat-peas	80kgs N as urea since 1990	Retained on surface
Wheat-faba beans		
Wheat-sown pasture		
Wheat-volunteer pasture		
Wheat-fallow		

This trial specifically looked at the effects of stubble treatment on yield rather than tillage-stubble interactions. For this reason not as much attention will be given to the trial. Only average gross margins will be given and discussed.

Table 69 – Average gross margins of wheat-wheat.

	Burn	Incorporate	Retain
0.kg	$21	$10	$33
40.kg	$92	$69	$78
80.kg	$112	$74	$98

Table 70 – Average gross margins of wheat -barley.

	Burn	Incorporate	Retain
0.kg	$73	$71	$68
40.kg	$178	$137	$146
80.kg	$203	$158	$177

Table 71 – Average gross margins of wheat-peas.

	Burn	Incorporate	Retain
0.kg	$162	$136	$149
40.kg	$178	$175	$166
80.kg	$177	$147	$151

Table 72 – Average gross margins of wheat-lupins

	Burn	Incorporate	Retain
0.kg	$140	$127	$177
40.kg	$162	$139	$178
80.kg	$153	$127	$176

Table 73 – Average gross margins of wheat-faba beans.

	Burn	Incorporate	Retain
0.kg	$194	$194	$205
40.kg	$211	$203	$213
80.kg	$202	$195	$209

Table 74 – Average gross margins of wheat-sown pasture.

	Burn	Incorporate	Retain
0.kg	$126	$115	$113
40.kg	$152	$135	$127
80.kg	$143	$121	$127

Table 75 – Average gross margins of wheat-volunteer pasture.

	Burn	Incorporate	Retain
0.kg	$110	$85	$92
40.kg	$145	$100	$112
80.kg	$134	$101	$113

Table 76 – Average gross margins of wheat-fallow.

	Burn	Incorporate	Retain
0.kg	$58	$49	$72
40.kg	$70	$62	$93
80.kg	$71	$53	$94

4.9.1. SUMMARY

As the results testify, in nearly all cases the use of stubble incorporation resulted in depressed returns. Stubble retention saw the highest average gross margins in the wheat-lupin, wheat-faba bean and wheat-fallow rotations. Stubble burning saw the highest returns in the wheat-volunteer pasture, wheat-sown pasture, wheat-peas, wheat-barley and wheat-wheat rotations. Stubble incorporation did not produce the highest gross margins in any of the rotations.

From a rotational point of view the most profitable rotations (classed by average gross margin for all N rates) in order were wheat-faba bean ($203/ha), wheat-peas($160/ha), wheat-lupin($153/ha), wheat-barley($135/ha), wheat-sown pasture($129/ha), wheat-volunteer pasture($110/ha), wheat fallow ($69/ha) and wheat-wheat($65/ha). Large yield responses to nitrogen were seen in the continuous cereal rotations as we would expect. Other rotations saw responses but these were not of the same magnitude. Again the experiment saw that the greatest impact on gross margin was rotation rather than stubble treatment, or tillage as we have seen other experiments. The implication is again that relatively more diverse cereal-legume rotations have generally returned the highest gross margins over time. Of these rotations, direct drilling and stubble retention has often aided yield and hence profit.

4.10. TARLEE TILLAGE TRIAL

The tillage trial at Tarlee aimed to examine the effect of sowing method and stubble treatment on crop yields. No set rotation was kept as the tested variables were stubble and tillage treatments rather rotation. Crops in each year are shown in Table 77 below.

Table 77 – Crop type over the time of the experiment.

Year	1984	1985	1986	1987	1988	1989
Crop	Wheat	Wheat	Peas	Wheat	Barley	Peas
Year	1990	1991	1992	1993	1994	1995
Crop	Wheat	Oats	Beans	Wheat	Barley	Peas

Table 78 – Tillage and stubble treatments.

Tillage treatment	**Treatment type**	**Stubble treatment**	**Treatment type**
T1	Direct drilled with wide points	S0	Stubble removed
T2	No-till with narrow points	S1	Stubble retained
T3	Reduced tillage	S2	Stubble retained and S0's stubble put on
T4	Conventional cultivation		

Nitrogen was applied at rates of 0, 20, 40 and 80kgsN/ha in 1988, 91, 93 and 1994. The simulated farm consists of 606ha valued at $1875/ha.

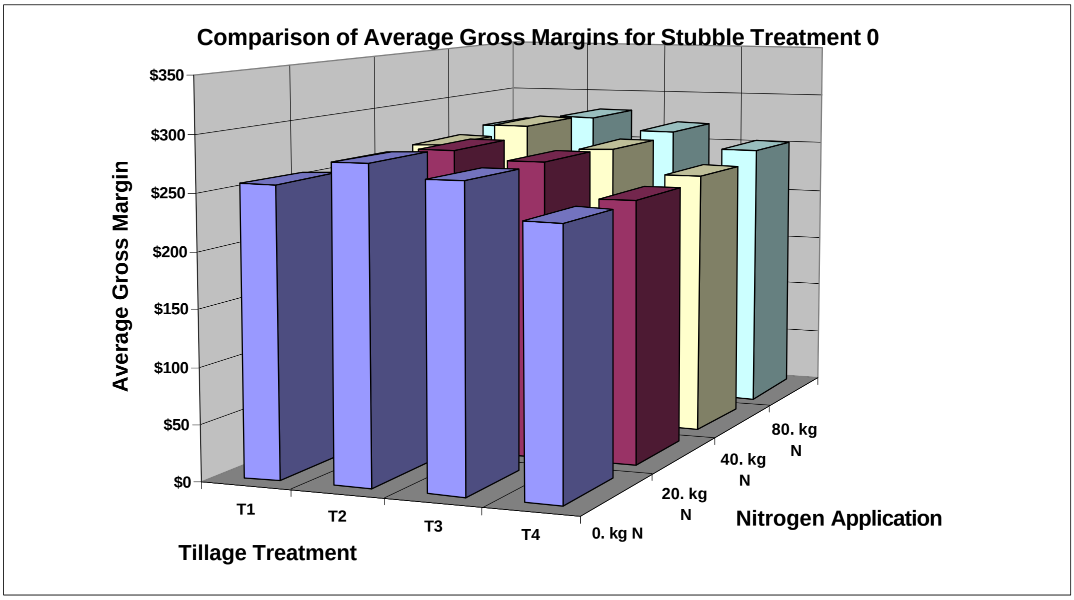


Figure 51– Average gross margin of treatment S0.

Table 79 – Average gross margins of stubble treatment S0.

S0	T1	T2	T3	T4
0. kg N	$256.68	$277.51	$266.48	$235.09
20. kg N	$260.65	$274.63	$267.18	$236.28
40. kg N	$263.06	$284.40	$264.43	$242.02
80. kg N	$269.23	$280.50	$269.19	$252.08

The average gross margin of the stubble-removed treatment was highest when 80kg's of N was applied to a no-till treatment.

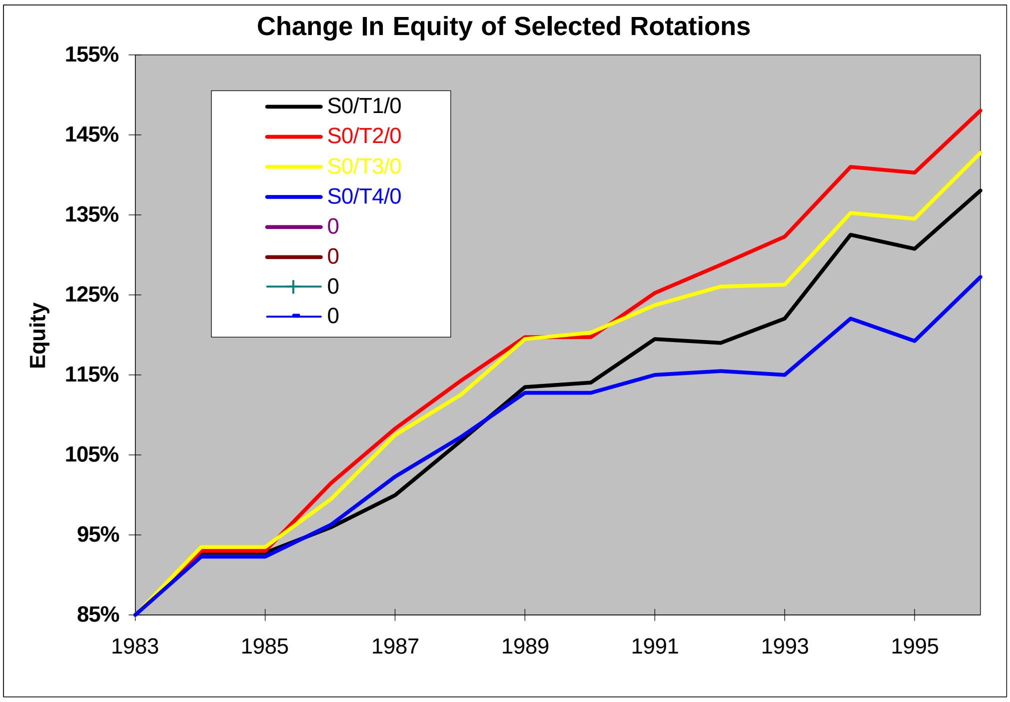


Figure 52– Change in equity of treatment S0 with no N fertiliser applied.

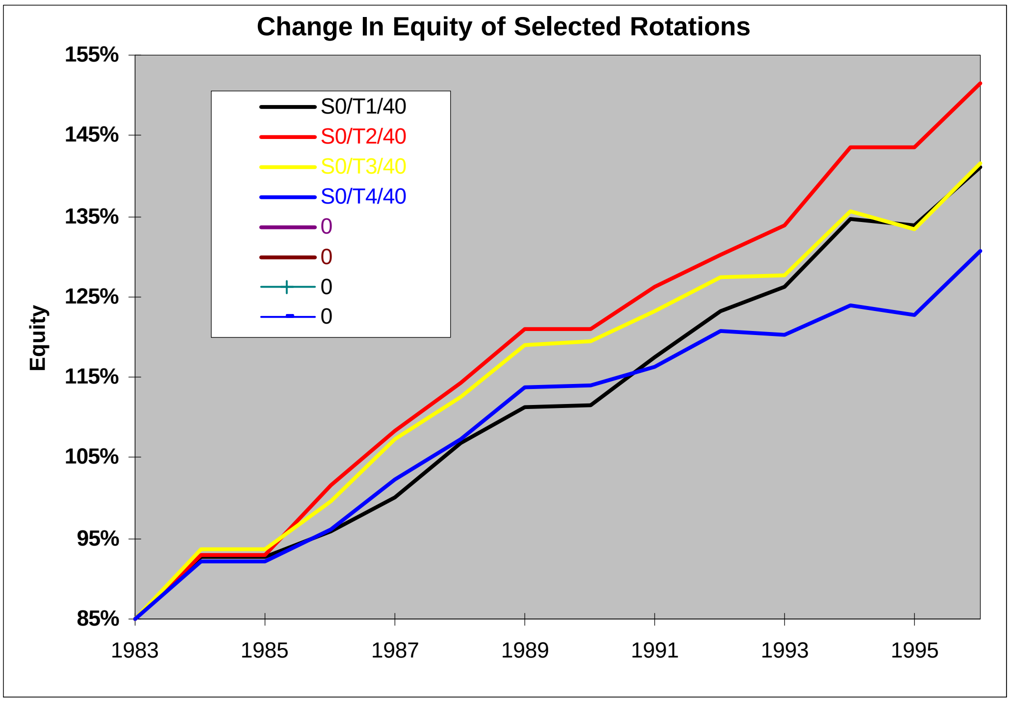


Figure 53 – Change in equity of treatment S0 with four 40kgs of N fertiliser applications.

The higher average gross margin of the the narrow point treatment was also reflected in the analysis of equity on a model farm, in both nil nitrogen and forty kilograms of nitrogen treatments. Conventional cultivation's equity was seen to be significantly lower than other tillage types in both treatments.

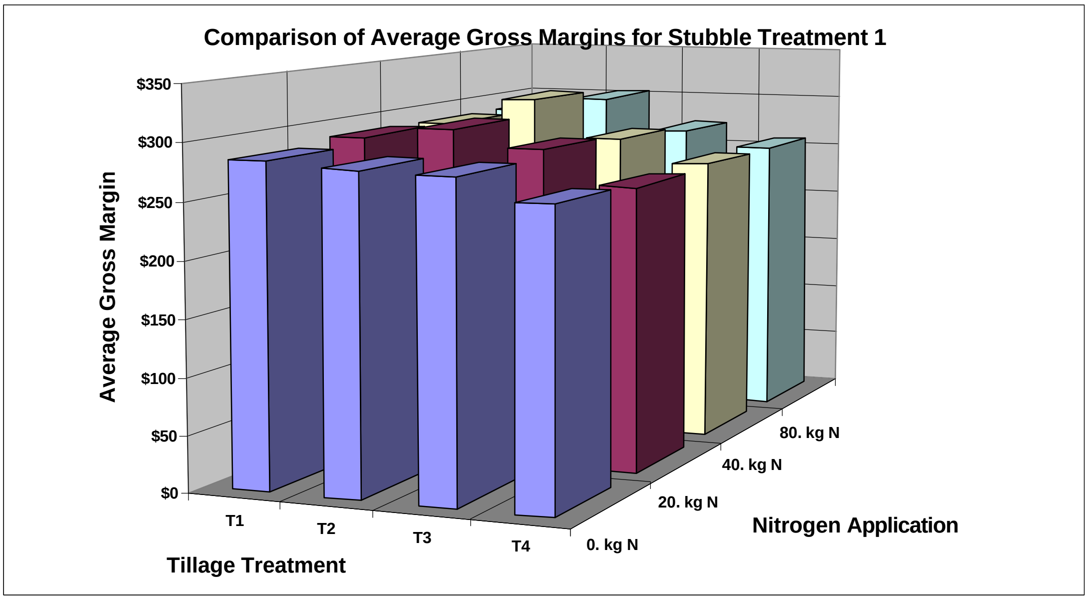


Figure 54 – Average gross margin of treatment S1.

Table 80 – Average gross margins of stubble treatment S1.

S1	T1	T2	T3	T4

0. kg N	$283.76	$279.23	$276.98	$257.81
20. kg N	$289.37	$299.38	$283.56	$253.54
40. kg N	$288.02	$313.37	$278.34	$257.40
80. kg N	$287.55	$302.34	$271.74	$257.13

Again the average gross margin was highest when crops were established with narrow points when stubble was retained. The marginal gains from nitrogen application were limited in all sowing methods.

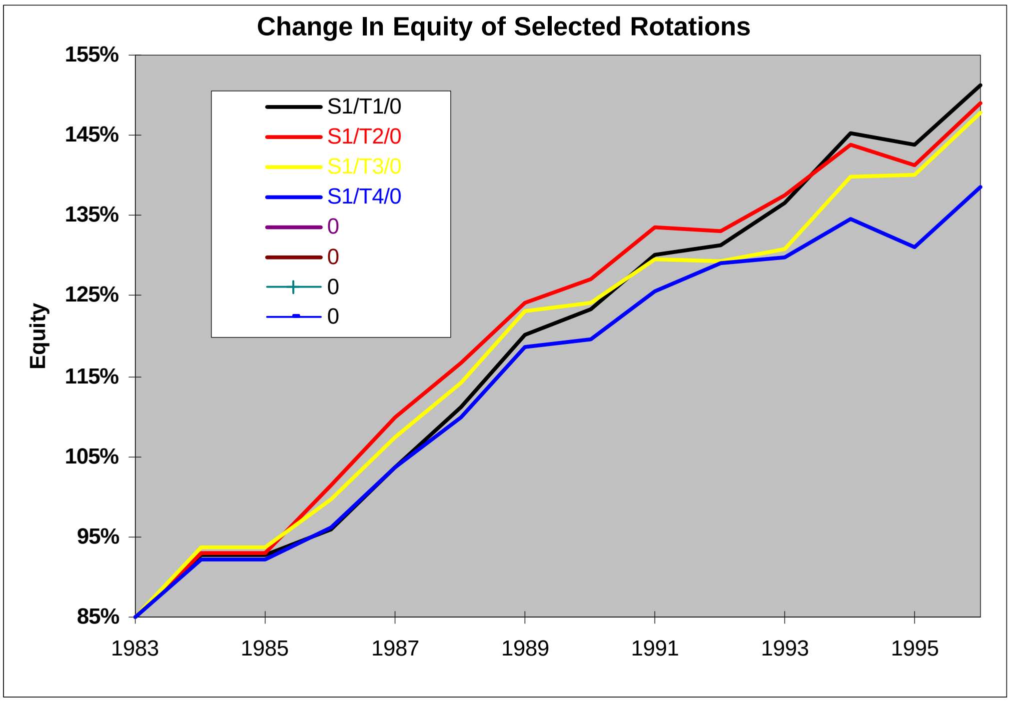


Figure 55 – Change in equity of treatment S1.

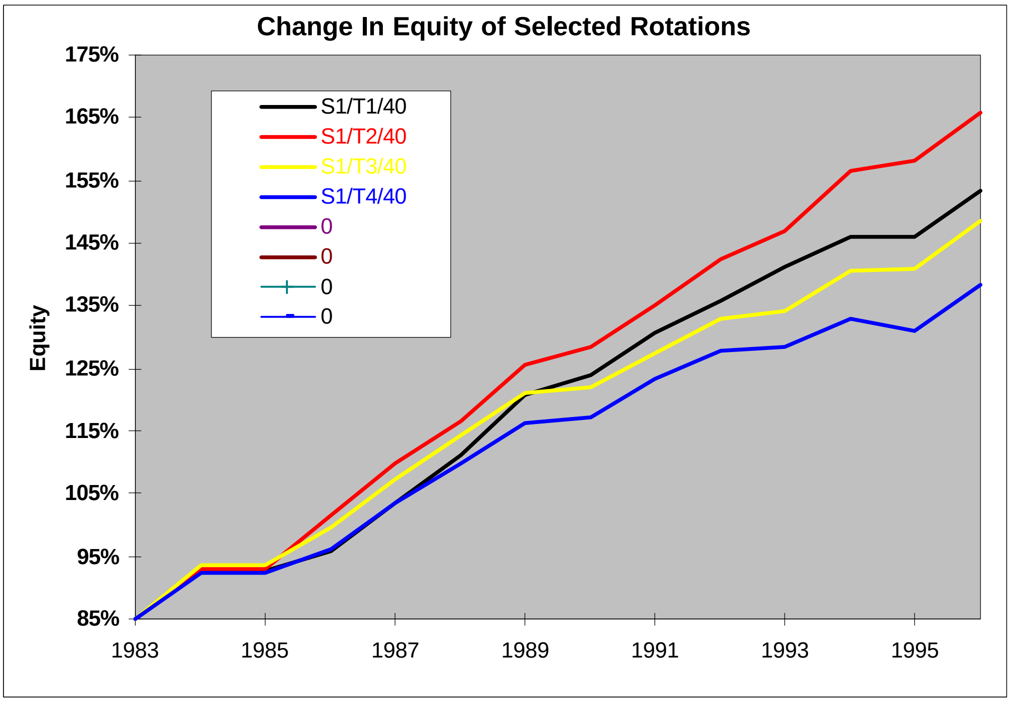


Figure 56 – Change in equity of treatment S1 with four 40kgs of N fertiliser applications.

Again the dominant feature of the analysis of equity is the poorer results from the full cultivation treatment. The three other treatments are very close when no N fertiliser is applied but application of N significantly lifted the yields of the no-till treatment.

The retention of stubble in this trial produced the highest returns of the stubble treatments.

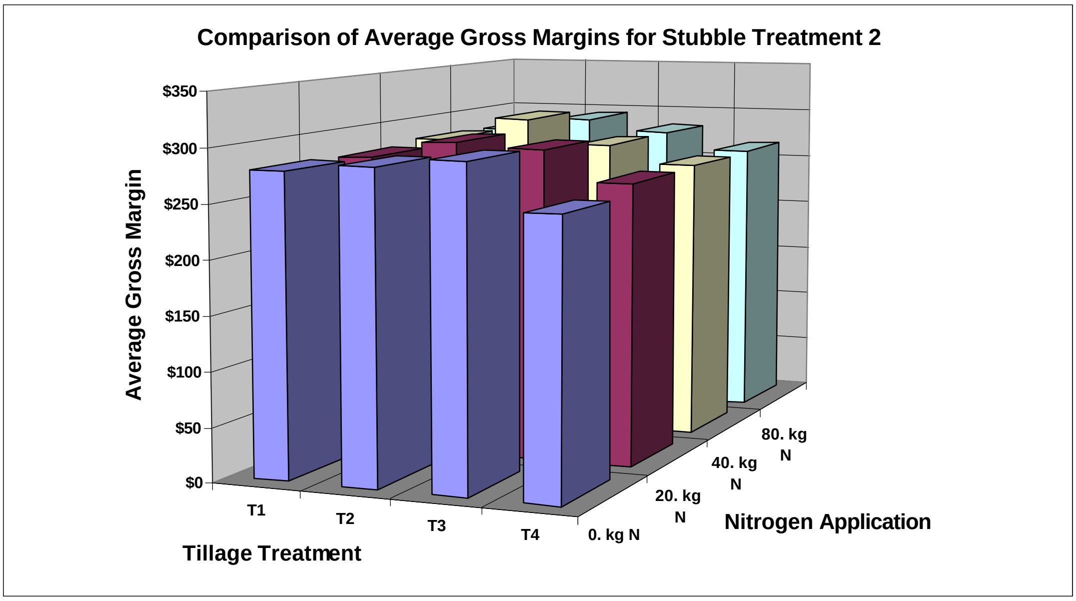


Figure 57 – Average gross margin of treatment S2.

Table 81 – Average gross margins of stubble treatment S2.

S2	T1	T2	T3	T4
0. kg N	$278.88	$285.37	$292.93	$250.86
20. kg N	$277.44	$293.55	$290.33	$261.93
40. kg N	$282.33	$304.88	$281.24	$264.33
80. kg N	$280.69	$293.55	$282.04	$265.37

The placing of stubble removed from S0 onto plots in treatment S2 saw little effect on gross margin. Again the highest average gross margin was seen with the use of narrow points and some form of nitrogen application.

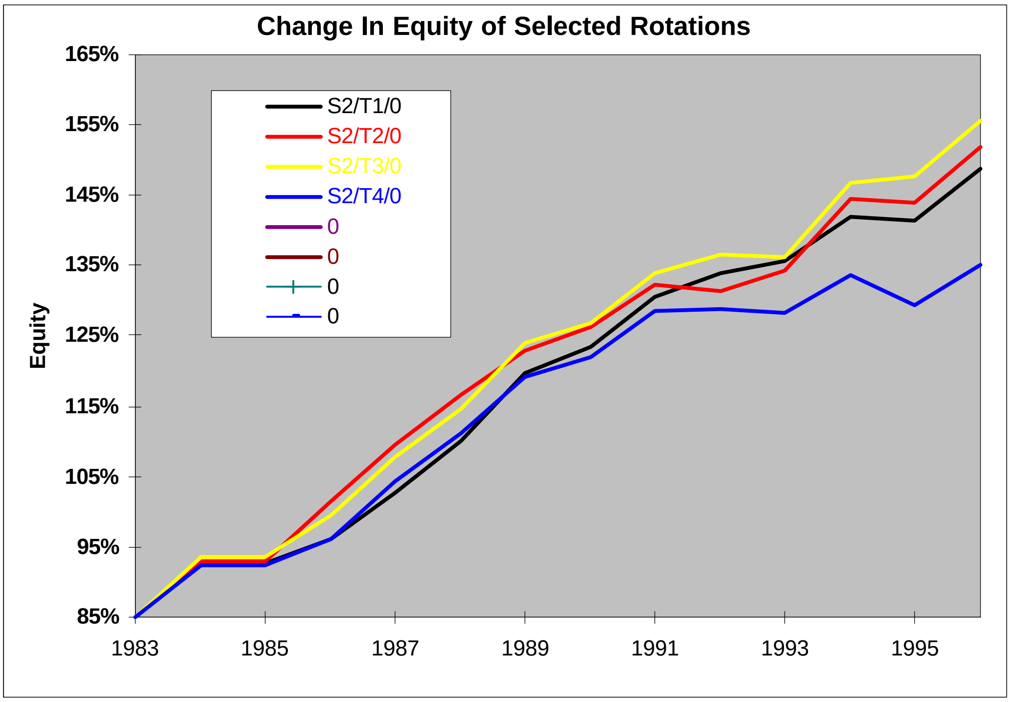


Figure 58 – Change in equity of treatment S2.

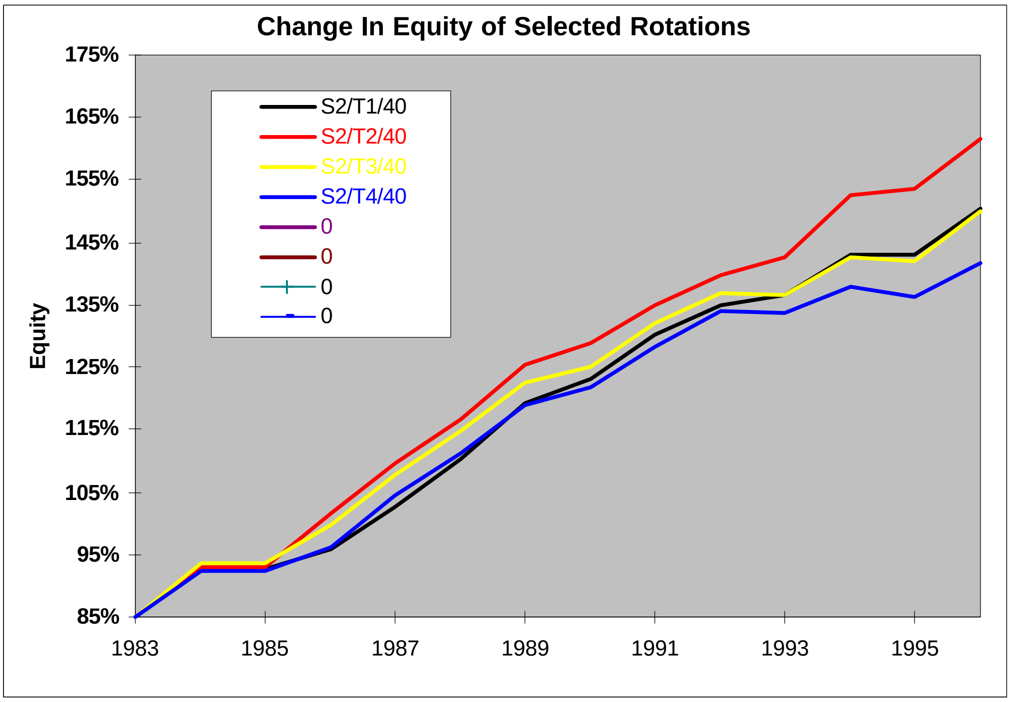


Figure 59 – Change in equity of treatment S2 with four 40kgs of N fertiliser applications.

Both nitrogen treatments saw some interesting factors emerge. In the nil nitrogen treatment the declining returns from conventional cultivation indicates a worsening soil structural or nutritional environment. The returns, in terms of equity, are similar regardless of fertiliser application for the conventional treatment. It is possible that soil factors could be limiting the potential response to fertiliser, but without supporting data this is not known. When fertiliser is applied to the no-till treatments returns lift, clearly separating the benefits of no-till sowing methods.

Stubble addition in S2 saw returns still at levels higher than where stubble was removed but lower than the stubble retention system.

4.10.1. SUMMARY

The trial saw narrow points with a short fallow as being the best way to establish a crop. Conventional cultivation saw diminishing returns over time in some of the treatments but establishment with narrow points consistently produced the best returns of any establishment method.

The application of nitrogen fertiliser lifted returns in nearly all treatments but not to a great extent. No-till treatments saw greater response to nitrogen fertiliser than conventional tillage treatments.

Stubble retention was seen to increase the returns from the crops sown. The application of extra stubble in treatment S2 did not inhibit yield greatly but the retention of stubble was seen to produce the greatest modelled returns. The removal of stubble, as opposed to burning, produced the lowest returns over time. This is possibly to be expected as nutrients are being removed from the site, no sanitation from burning is achieved and the evaporative effects of removal are still present. Hence we would have expected retention systems to offer greater water benefits than the removal treatment.

This trial perhaps gives the most hope to the ongoing promotion of the stubble retention-no-till systems. The results clearly show the complementarity of the system in comparison to other treatments.

4.11. OVERALL SUMMARY

As modelled in a whole farm context the use of conservation cropping methods did affect farm equity in the majority of treatments. In many cases where a good rotation was used, direct drilling consistently outperformed conventionally cultivated plots. Rotation was seen to be major determinant of profitability. Nitrogen application rarely altered the modelled position of the farm.

In some trials there was a clear 'learning phase' with direct drilling; a feature frequently reported by farmers. This affected the overall position of the operation in some cases due to the increased interest costs resulting from lower profits in the early years of the experiment. If the rotation was not profitable the deficit was hard to make up over the period of the trial even if the overall average gross margin was higher than other treatments. These cases clearly demonstrate what is at stake for growers in areas where margins are tight such as in the Mallee region of Victoria. One lower producing year than what could have been achieved with the old technology may set the farm's financial situation back considerably. This may be one of the reasons why adoption of conservation cropping is low in these regions. In the higher rainfall environments seasonal conditions had smaller effects on equity.

The experiments that have been analysed have proved to be important sources of knowledge for finding out what happens to direct drilled crops in the long term. In many cases the experiments have not run long enough to see effects separate sufficiently but many have been important in the adoption of conservation cropping however.

4.12. FARMERS AND CONSERVATION CROPPING: SOME CASE STUDIES

4.12.1. INTRODUCTION

The key question that needs to be asked when selecting analytical methods to investigate conservation cropping is 'how is the research going to best augment what is already known about conservation cropping?' The research aims need to be clearly established, as what the research is trying to discover determines, in part, how best to do it.

Relevant research aims to solve problems. Present day research increasingly draws on knowledge from a range of disciplines. Always research resources are constrained, meaning that invariably a trade-off exists between the number of relevant cases that can be included in a study and the disciplinary depth and breadth that can be brought to bear on each case (Crosthwaite, 1997). Thus making the best use of case study research to answer particular questions often boils down to getting the appropriate balance between breadth of coverage of cases and depth of investigation of cases. As Stake (Stake, 1995) states:

> Case study research is not sampling research. We do not study a case primarily to understand other cases. Our first obligation is to understand the case in point. The first criterion should be to maximise what we can learn. Time and access is often limited, hence picking a case that leads to understandings, to assertions, perhaps even to modification of generalisations is important but selection of cases for production of generalisations should be tempered as traditional comparative studies do this better. However, the case study can increase the confidence in the researcher's assertions.

Stake emphasises understanding the individual case independently of other cases, viz:

> The case is a specific, complex, functioning thing; an integrated system. The parts do not have to be working well, the purposes may be irrational, but it is a system. Thus people and programs clearly are prospective cases. Events and processes fit the definition less well.

This, in essence, is why the case study approach has been used in investigating farmers and conservation cropping. The adoption of conservation cropping is about people and the way in which they make decisions, irrational or otherwise, and how they integrate particular systems of farming on their farm. It is a dynamic process. Detailed study of what crop farmers do and why they do it can shed light on the benefits and costs, real and hoped for, of conservation cropping system of farming.

Case study research can be either intrinsic or instrumental. When given a particular problem relating to a program for example, we are studying the case not necessarily to learn about other cases or a problem but because we need to know about that particular case. In effect, knowing about that case is 'intrinsic' to the solving of the problem (Stake, 1993)

On the other hand we may have a particular question where there is a need for greater understanding. Selection of a case will be an "instrument" for this greater understanding. This is what is termed as instrumental case study analysis.

In this study of conservation cropping we are using instrumental case study analysis. Cases are used to gain insight into a larger question to which understanding a case in isolation can contribute to greater understanding of the overall question to be answered.

Generalising from case studies is an area of concern for most due to doubts about 'representativeness'. To date this has been the main reason for the perception of the method as being a poor substitute for wider survey type methods. This stems from misunderstanding of the method and fundamental differences between generalising to theory (analytical generalisation), which is done by case studies and most experimental methods, and generalising to populations (statistical generalisation), which is the focus of survey and econometric methods. The correct context for generalising beyond the immediate case findings is that of theory development and generalisation to theory (Crosthwaite, 1997). Similar to scientific experiments, valid case study design will ideally be based on a well-grounded theory and set of propositions to be tested by the case. The generalisation is then supported by the degree to which the empirical findings support the proposition.

Stake is cautious about using generalisation however. He states:

> The real business of case study is particularization, not generalization. We take a particular case and come to know it well, not primarily to know how it is different to others but what it is, what it does. There is an emphasis on uniqueness, and that implies knowledge of others that the case is different from, but the first emphasis is on understanding the case itself.

The use of testable theory supports this process by allowing inference on possible reasons for an outcome. In turn this will augment theory development. The use of case methods are hence important in expanding knowledge of theoretical propositions and hypotheses where the context is important and where events can not be manipulated like an experiment (Yin, 1993). The confidence would in turn increase as empirical findings are also found to apply to multiple cases, consistent with the theoretical context from which the first case was drawn (analytical generalisation). This is similar to the use of multiple experiments to confirm and enhance analytical generalisation through replication. The use of multiple cases however should not be confused with increasing the representativeness of "samples" which applies to statistical generalisation.

Case studies are used to allow investigations of process and context that underlie the central questions that are being asked. In essence, the questions being asked are how and why in the context of what background or within which environment decisions are being made. Neither a sample survey or modelling process would capture the essence of management. Case studies can do this, albeit with limited information on many aspects. Cross checking of results by using a range of sources is done to ensure validity.

4.12.2. SELECTING A CASE STUDY

A number of other criteria should also be kept in mind when selecting a case. These include:

maximising learning or understanding, allowing modification of generalisations

being easy to get to and hospitable (willingness to comment on draft material)

supplying balance and variety over the range of case studies.

In short, the overriding theme when selecting cases however should be to increase the opportunity to learn.

Yin (1989) argues that the use of case studies is heavily dependent on design. Ignoring formal methods of design will leave the analysis vulnerable to criticism and limit effectiveness. Selecting the use of case studies and proceeding to collect data without adequately specifying method and design is often done in the belief that case studies are an explanatory tool that precedes some more formal experiment or survey if anything interesting turns up. Such an approach is not very useful. Proper research design for case study research involves the following steps (Stake, 1995):

Presenting a clear and adequate specification of the theoretical issues and, from this, the propositions that underpin the study. *What is the study trying to find out?*

Clearly defining the units of analysis, including possible sub units if warranted. *Are we looking at farm or paddock data?*

Deciding on the appropriate number of cases to explore within the study. *Selection of contradictory (theoretical replication) or supporting (literal replication) cases to augment the findings of the study.*

Clearly specifying the selection criteria of the case studies.

Choosing an appropriate and effective data collection and analysis strategy. *Analyse each case separately and then try cross case conclusions at the end.*

Developing appropriate tests to ensure the validity and reliability of the approach taken in conducting the case study.

Documentation of these points aims to allow a logical process where data is linked to objectives, conclusions to data, thereby allowing the linking of objectives to conclusions. This will be the case for any type of research methodology.

When testing validity of any research design there are essentially four basic tests of logic that might be applied to assess its quality. These are:

Construct validity – appropriate definitions and operational measures for the theoretical propositions being studied. Use of several ways to measure the key variables in the study is needed to overcome possible inaccuracy in any single measure. Multiple sources of information are needed particularly when information is limited.

Internal validity – appropriateness for establishing credible casual relationships. The theory must be consistent internally. This requires careful specification of the units of analysis.

External validity – convincingly specifying the domain to which the findings can be generalised; and

Reliability – ability to repeat the findings if the same methods are applied on different case studies.

In the following case studies social, agronomic and farm management economics perspectives have to be brought to bear on our understanding of the particular situation at hand. Agronomic and social understanding are relatively self-explanatory. The economic analysis however may need some explanation. The standard farm management approach to assessing whether a business is healthy is to calcualte some important measures of performance for the time period in question. The assessment of business health could be for the coming production year, or maybe a 3-4 year planning period, or in some cases it could looking backward to see how, and why, the state of a business health has changed over some time period of interest. Remember, 'healthy' refers to the ability of the business to achieve the goals of the owners of the business. One approach is as follows:

Calculate the state of the balance sheet of the business at start of period of time in question.

Calculate the operating profit for the periods in question

Calculate net farm income for the periods in question

Calculate change in equity over the period in question

Calculate net cash flow before debt servicing commitments over the periods in question

Calculate net cash flow after debt servicing commitments over the periods in question

In assessing the net benefits or otherwise of a crop farming business changing from conventional to conservation tillage practices, the key test of whether it has been worthwhile or not is "Is the business as healthy by all relevant criteria as it would have been if the change had not been made and some other change had been made instead (usually no change is not an option in Australian farming)?'.

The standard criteria for judging business health include annual return on total capital, return on capital over the entire time period, growth in net worth, current and near future debt servicing ability, and most important of all, reorganizational ability. The ability to reorganize is the key to medium-term survival and success in modern, dynamic farming circumstances. The ability to reorganize is dictated in part by the liquidity and borrowing ability of the business, as well as the attitude of the decision-makers. The main 'reorganizations' farm businesses have to undertake are adopting relevant new technology and making it work; increasing control over the major farming asset, land, either by purchase or leasing; and appropriate investment in capital equipment.

In the situation of the case study farms that have been using conservation cropping techniques for many years, the question of interest is how have these business performed over time when judged by the standard criteria for judging the health and prospects of a farm business. The argument is simple – if some crop farm businesses have been able to implement conservation cropping systems and by reasonable farm business management criteria have maintained or even improved business health in ways comparable to, or better than could have been achieved doings things differently or doing different things, then conservation cropping systems can be said to have been sound systems of resource use and business management for the cases in question. A business has to do no more than meet the owners objectives for it to be a successful business – and as those objectives usually include making the best use of resources under the owners control in the light of alternative uses. When this happens, wider societal aims of efficient resource use are also achieved.

Hence, the human, technical, economic, financial and risk performance of the case study farms are judged by looking at key summary measures such as the annual returns on capital achieved by these farms over time, the liquidity of the businesses, the growth in net worth achieved, as well as other measures, some objective, some subjective, such as measures to do with operator satisfaction, soil condition, perceptions about and occurrence of risk related outcomes, stability, and so on.

For the case study farms, as well as annual returns on capital, net cash flows and growth in equity, the profitability and return on capital over the time period in question can also be estimated. That is, the Internal Rate of Return (IRR) on the total capital invested over the time period in question can be estimated, as follows:

Year 1:
Value of land, machinery and stock treated as an investment cost, in nominal Year 1 dollars

Year 1 to current time:

Annual operating profits earnt in nominal dollars

Current year:

All assets salvaged in nominal current year values.

The nominal internal rate of return, which is the nominal discount rate that equates all the annual net cash flows to zero, is calculated. This figure, after allowance for non-measured 'way of life' benefits, can be seen as being able to be compared to earnings of similarly risky alternative investments. The nominal IRR indicates the efficiency of the resources used in these businesses over time. Alternatively, all cash flows over all years can be adjusted to same-year current dollar values and the real return on the capital involved is estimated.

As well, the financial health of the case study firms over time can be estimated by calculating the nominal cumulative net cash flows (NCF) (though not including salvage values of assets in the current year, as these are not 'cashed-in'). The cumulative NCF over time indicates the change in business liquidity over time, and indicates the state of the business in terms of potential for reorganization for growth and survival. The state of the cumulative NCF for these business after a time of running conservation cropping systems can be assessed in terms of where these business are likely to have been if they had run some other cropping system, or, if it was a realistic possibility, in some other use altogether.

In farming, average returns to investment often do not equate to off-farm investments. Thus the conclusion that 'Over time, this farm business has done as well as it would have if it had been run in some alternative way, and the resources did not earn as much measurable return as they could have if employed in an off-farm use' is not uncommon, and is likely to hold true for conservation cropping options as well.

4.12.3. RISK

Fundamentally here are two angles to the risk question in the context of conservation cropping. First, there is risk associated with what is not known about the most likely performance of a conservation cropping system on any particular paddock and whole farm.

Second, there is the way in which the risks associated with the operation of a conservation cropping system in terms of yield variability in most likely, poor and good seasons compares with the yield variability of another cropping system under the same seasonal conditions. Neither of these risk angles are able to be explored explicitly in the backward-looking case study farm analyses reported here – but the long run performance of these businesses encompasses the firms' experience of, and adaptations to, both of these types of risk. Ultimately, all of the effects of both of these types of risk are encapsulated in the after-the-event assessment of business performance and health over the time period in question. Businesses that survive and grow, at rates coparable to others in the same industry, have managed to manage the risks.

4.12.4. ECONOMIC AND FINANCIAL MANAGEMENT

The end result from any farming operation has to be that farm family goals continue to be met, including the financial survival of the business and the preservation and growth of the family farm assets. The growth in equity of the business is a primary reason for the farm operating - rather than just being a way of life.

Analysis of changes in cropping cultural practices in crop farm systems, from a farm management perspective, involves investigation of the operation of the whole farm system - covering human, technical, economic, financial, risk and beyond-the-farm-gate considerations. In this research, several approaches are brought to bear on the question of the net benefits or otherwise of conservation cropping compared to alternative cropping systems. The approach in analysing changes to complex systems such as farming systems, where often the relevant counter-factual case is unknown and unknowable, is to generate new information about the question from a number of different angles. Thus, in this investigation, conservation cropping as a change to crop-farming methods is analysed in the following terms:

analysis of all technical aspects of the effects of changes in crop cultural practices;

analysis of the gross margin per rotation hectare that would have resulted from the technical outcomes of several crop rotation trials and experimental results conducted over a number of years and covering a range of crop rotations and tillage treatments;

investigation of the whole farm human, technical, economic, financial, risk and beyond-the-farm-gate aspects of non-conventional cropping systems.

The first approach to finding out about technical effects of conservation cropping systems on farming systems is relatively straight-forward, lending itself to methods of standard scientific inquiry.

The second approach, analysing rotation gross margins of a crop sequence over time provides some comparison of differences in yields and variable costs associated with different cropping systems. To the extent that overhead costs were similar, differences in total rotation gross margin over the sequence of crops would amount to differences in farm operating profits. However, different cropping systems usually have significantly different overhead costs. Of interest with this approach is whether yield are significantly different between rotations. If they are, or if they are not. Both cases are interesting because it is shown either that one cropping system consistently has achieved greater yields than another – or it has not done so. If it has not done so and it is expected that it would do so, then such a finding is extremely illuminating and useful to know in the situation where there are other, non-yield benefits that may be achievable.

The third approach used is that of the whole farm analysis, which is complex because the performance of changed whole farm systems does not always lend itself to straight-forward comparisons. There are several key reasons why analysing the change from conventional to conservation cropping systems is quite a complex and subtle procedure:

Conventional cropping to conservation cropping covers a continuum of cropping practices, elements of which can be found on most farms, in some paddocks, in some years. That is, in terms of innovation and adoption theory, the change is not a simple change but a complex change involving degrees of adoption of elements of various possible ‘packages’, and involving much learning and management adaptation and development over time.

The counter-factual case – after a change has been made, what would have happened if the ‘old’ system was not replaced with the ‘new’ (and evolving) systems emphasising conservation cropping approaches is unknowable. The traditional benefit-cost approach of comparing ‘outcomes with the change’ with ‘outcomes without the change’ is the correct perspective – just ‘without the change’ scenario cannot be known for certain, and proxy or indicative measures need to be used. Probabilistic measures about wheat might have otherwise happened are useful here..

Some of the net benefits of changes in cropping systems are not easily measureable in monetary terms

Some of the net benefits of changes to farming systems may be gains in that worse outcomes are avoided. That is, without a change in cultural practices, a cost would have been incurred, such as future soil degradation, the extent of which in terms of timing and magnitude is quite uncertain. Again measureable or not, this gain is real and has to be taken into consideration.

The approach taken in this inquiry into conservation cropping at the level of the whole farm system has been to carry out some whole farm case studies into the operation of farm businesses that use conservation cropping techniques in different areas of the southern cropping zone. In these case studies, all relevant aspects of the whole farm system are taken into consideration. The economic and financial performance of these farm businesses over time are analysed using conventional farm business management measures of business health such as operating profit, return on total capital, growth in net worth, net cash flow after debt servicing ability. For reasons discussed above, the farm management economic analysis does not assess precisely whether these farms have performed better in terms of these measures of business performance than they would have done if they had continued to practice conventional cultivation, because how they would have performed under the same management but using conventional cultivation methods, is not able to be known – though estimates of likely alternative performance can be made. Thus the criteria to apply in this situation is as follows:

Using standard farm business management measures of business performance, have the resources of land, labour, capital and management of the case study farms using conservation cropping techniques achieved results that can be considered as being reasonably likely to be commensurate with levels of performance that could be expected to have been earnt in alternative uses open to those resources, such as

could be expected to be earnt in non-conservation cropping systems on the same farms using similar resources,

could be expected to be earnt in alternative farming systems on the same farms using similar resources,

could be expected to be earnt in investment in alternative farms elsewhere using similar quantities of total esources,

could be expected to be earnt in non-farm uses of these resources (with due allowance for the value of non-economic benefits attached to farming by the case study farmers)

One yard-stick by which to compare the types of net returns available in alternative farming systems are the net returns that are able to be achieved by similar businesses in the industry that do not practice conservation cropping techniques?

4.13. CASE STUDY 1 - BURRUMBUTTOCK, SOUTHERN N.S.W.

4.13.1. INTRODUCTION

The main farm of the family is situated around eight kilometres east of Brocklesby and five kilometres west of Burrumbuttock on undulating red brown earths. A second property is situated west of Walbundrie, approximately 25 kilometes west of the main farm. Sharefarming of other farms in the district is also carried out by the farmers. The family has been farming in the area since the early 1970's. Expansion has occurred since this time as outlined in Table 82. The main operation is cropping but a substantial Merino/first cross lamb enterprise also exists. The farm is operated by three brothers aged from thirty to forty five years. All are married and live on the properties. Originally from a dairying background, the farm was formerly run by their parents who have recently retired, but they still have active interest in the farm.

These farmers grow crops using conservation cropping methods. One of the key factors in the adoption of conservation cropping on the farm was the prior experience acquired on the dairy farm, where sod seeding feed oats into pasture was a practice carried out for many years prior to them coming to the mixed cropping farm. The farmers believe that their background in dairying created an openness to new ideas that was not always evident with some longer established farmers in their industry. This openness to change, combined with the advent of conservation cropping methods, resulted in the family becoming co-operators with Department of Agriculture conservation cropping trials in 1976. The reasons and thinking for the adoption of the methods back then was one that continues to apply today. Quotes from the growers in an ICI publication in the early 1980's best sums up the thinking that encouraged a move into the cropping methods that they continue to use today:

We are not looking for increased yields from direct drilling. Because of the feed advantages, wider management options and lower inputs we're in front so long as the yields stay about the same as we'd get from conventional crops.

This case study documents the development a modern cropping operation in southern NSW. The integration of new technology, attention to detail and application of business management planning sees this family business well situated to tackle problems of farming in the future.

4.13.2. GENERAL CROPPING ENVIRONMENT - SOILS

The soils of the farm are typical of the southern Riverina mixed farming zone. Red brown earths predominate; characterised by hard setting, acidic topsoil and generally a heavier, neutral to alkaline subsoil.

Red Brown Earths are important arable soils on which agriculture first became established in Australia (Pratley, 1988). The reason for their extensive early cultivation was related to the ease of cultivation for horse drawn implements, initial fertility levels which gave reasonable yields, and ease of clearing associated with the virgin savanah woodland. They are distributed through most of the wheatbelt but reach their greatest extent in southern NSW (the Riverina), the northern Victorian plains , north of Adelaide in South Australia and in the Liverpool plains region of Northern NSW.

The red brown earth is duplex in nature, characterised by the distinct texture contrast between a hard setting A and pedal clayey B horizon. Alkaline soil reactions are exhibited down the profile, which can result in a pale or bleached A2 horizon. In the Riverina the soils are developed on gently sloping plain formed from sediments of stream and aeolian origin. This results in a range of textures in the surface horizons of the soil. Total profile depth varies from 0.75 to 1.3m. The A horizon can be up to 0.5m in depth with texture varying from loamy sand to clay loam. Thicker A horizons are associated with sandier textures. Structure of this horizon varies from weakly massive when the texture is sandy through to weak blocky to a more developed sub angular blocky structure when the texture is a loam or clay loam. These conditions are more developed under grassland but when cultivated the structure deteriorates so that the surface becomes hard setting. Surface sealing can occur after rainfall.

The topsoils on this farm vary from pH 4.5 to 5.1 (CaCl). For the reason, the family has embarked on an extensive program of liming and gypsum application. The lime increases pH of the topsoil, while gypsum alters the cation exchange capacity (CEC) of the soil and increases water infiltration rates. Gypsum also supplies sulphur to canola crops grown on the farm.

Red Brown Earths are generally considered to have inherently low to moderate fertility. Organic matter and nitrogen levels are low and are depleted rapidly by cultivation. Soil aggregation and general structural decline have been reported widely with cultivation. This is not exclusively due to loss of organic matter but also the pulverising action of cultivation and dispersion of soil surfaces by rain events. The combination of factors reduces soil porosity, which in turn may reduce the establishment of the seedlings in crops. Cation exchange capacity of the soil varies with the organic matter content and the amount and type of clay mineral (Illite-kaolinite). Moderately high values are the norm however (30meq/100g). Calcium and magnesium are the dominant cations and sodium can reach 10-15% of total bases in the B horizon. High values of exchangeable sodium and salt can result in poor structure and salting problems if management is poor. Phosphorous deficiency is present in almost all red brown earth and the soils respond well to applications. Potassium deficiencies rarely occur on these soils but molybdenum, zinc and sulphur deficiencies have been reported. The hard setting characteristics which develop after cultivation influence water storage capabilities of the soil and predispose the soils to erosion in many cases. Waterlogging occurs on types that have a massive or strongly prismatic structure in the B horizon which reduces permeability and aeration.

4.13.3. RAINFALL

Broadly, the farms are in a six hundred millimetre rainfall area (twenty-four inches). The property at Rand experiences a little less, on average, at around twenty inches. As with almost all other areas of crop production in Australia, rainfall can be extremely variable, as seen in Figure 60.

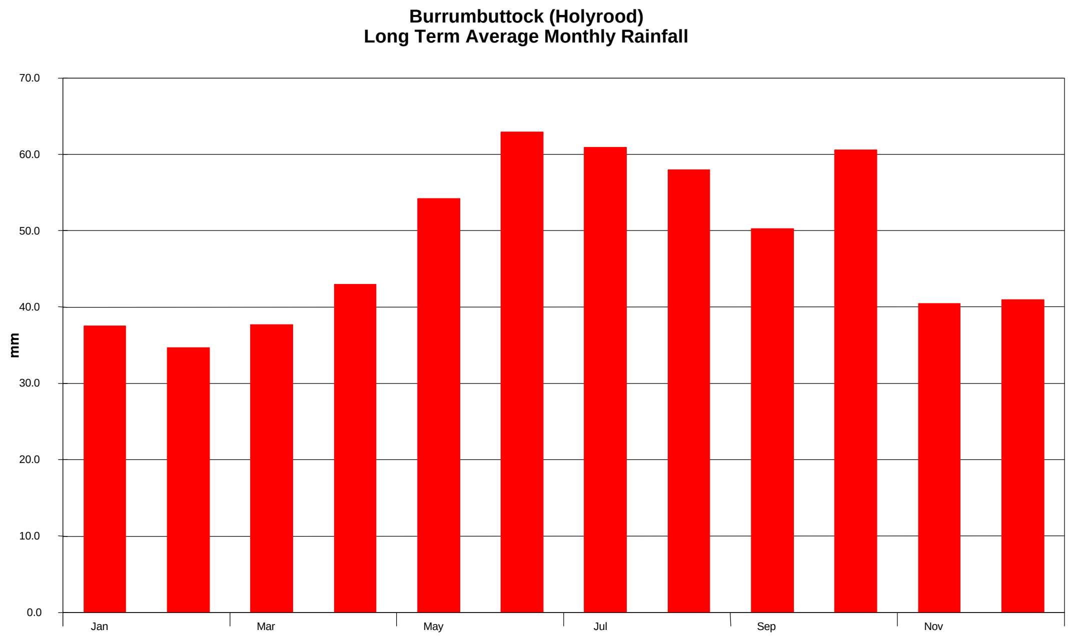


Figure 60 – Average monthly rainfall at Burrumbuttock

Figure 60 shows the variability of the rainfall but patterns are generally winter dominant as occurs in a semi-Mediterranean environment. Southern N.S.W is generally regarded as an area of higher rainfall for a cropping region. The seasons are also relatively 'safe' in comparison to other areas of South-Eastern Australia.

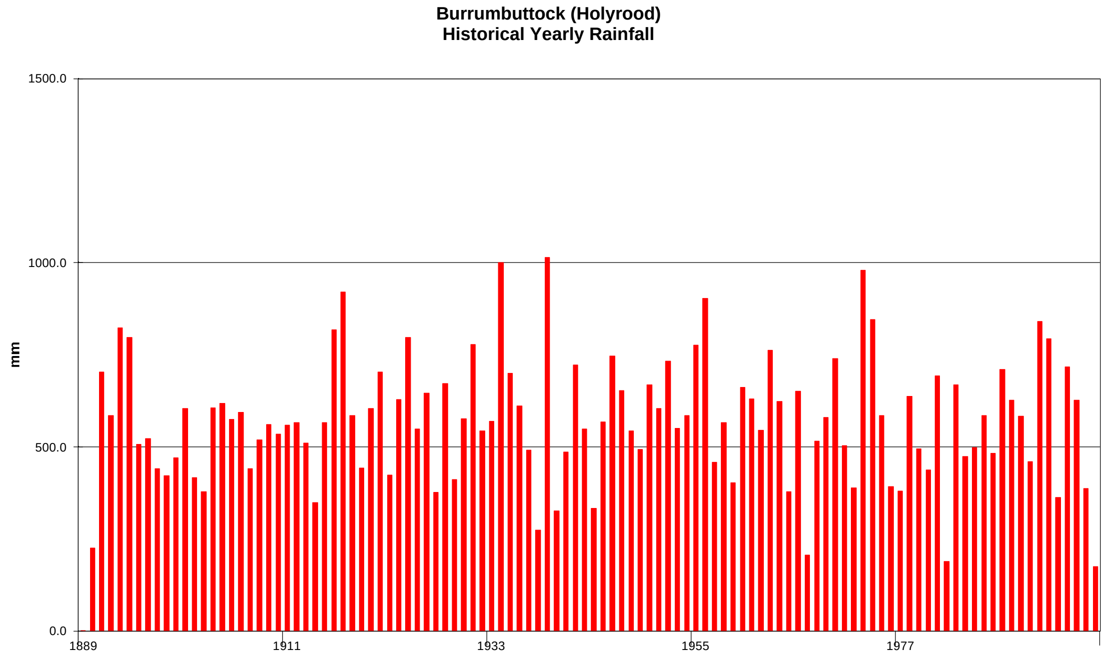


Figure 61 - Historical rainfall over the last one hundred and ten years.

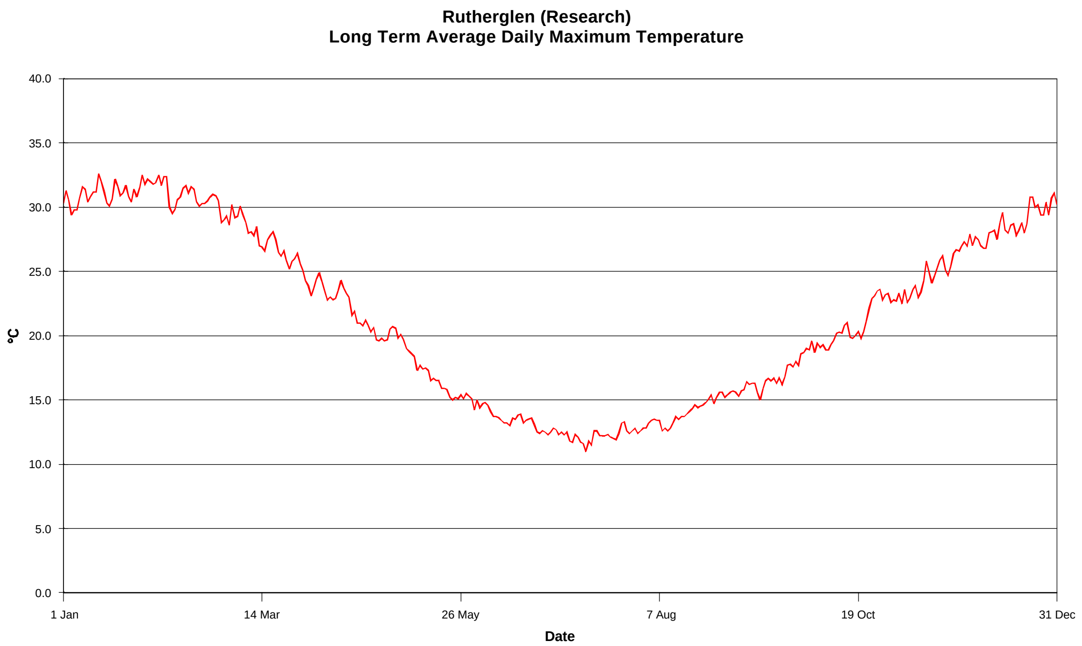


Figure 62 – Average daily temperature at Rutherglen.

Using French and Schultz's equation of water use efficiency of 20kg of grain/ha per millimetre of growing season rainfall, if rainfall was the limiting factor, and all rainfall was available to plants, then the long term average yields on the property could be at the upper end of yields in Australian environments (French, 1984). Given that there has been on average around three hundred and ninety millimetres in the growing season, potential wheat yields chould be in the region of (390-110)*20 = 5.6t/ha if the rainfall was the limiting factor. One hundred and ten millimetres of water is estimated to be lost to evaporation in the growing season on average. The potential yield equation is relevant to the farm in question more than other perhaps due to the lack of waterlogging on the undulating country that constitutes most of the cropping country.

In addition to the total growing season rainfall, the timing of the break is vital to the yield prospects of the crop and the likely feed supply for the season. A late break will mean slower crop and pasture growth due to the colder temperatures of autumn and winter, reducing available feed in the winter and leaving crops more susceptible to the problems of waterlogging, post-anthesis drought and poor yield. The timing of the break, defined as receiving more than twenty-five millimetres in any given week after the first of April, is illustrated below.

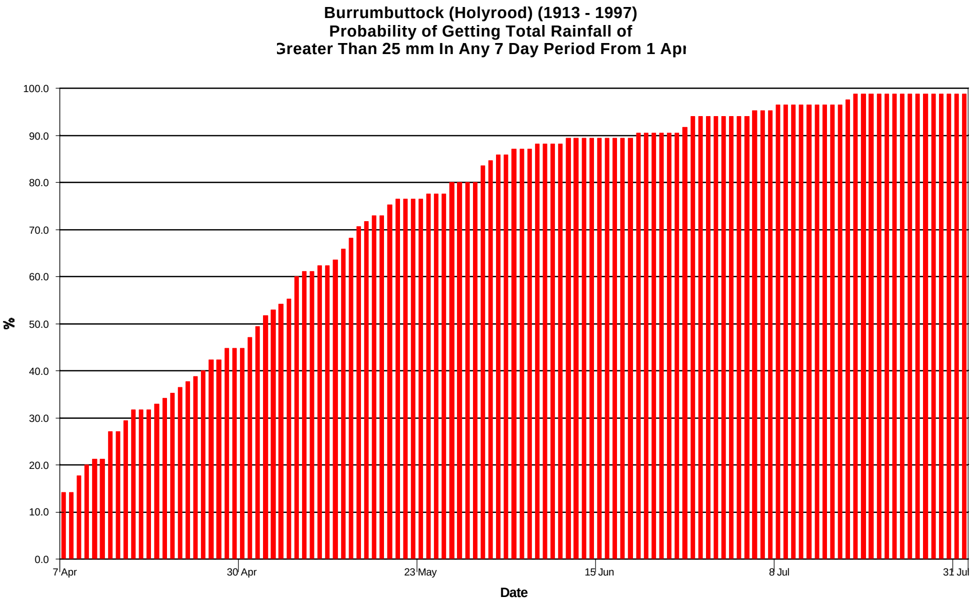


Figure 63 – Cumulative probability of receiving greater than 25mm of rain in a 7 day period.

The break in the season has around a fifty percent chance of occurring by the end of April. This allows the sowing of longer season varieties and is one of the reasons why crops in the area generally attain high yield. The earliness of the break and smaller farm sizes in the area, in comparison to some other areas, perhaps also offer reasons for the limited uptake of conservation cropping. Farmers with smaller areas to farm are able to cultivate their crop areas and still have time to sow in what would be considered to be near optimal timing for the various crop varieties.

4.13.4. CROPPING EXPANSION, MACHINERY AND MANAGEMENT PRACTICES

We're steadily increasing the area under crop and we want to put money into property - not machinery.

This quote from the owners in the early 1980's has probably explained some of the success of the operation overall. Initially direct drilling reduced the required investment in machinery per hectare to farm the large crop area in comparison to other growers using conventional cultivation. In recent times however the machinery investment per hectare has increased with the purchase of larger capacity harvesting and seeding machinery. The dramatically increased crop area and importance of timely sowing and harvesting has facilitated this move.

In recent years global positioning systems (GPS) equipment has been trialled and installed on the harvesting equipment. The GPS equipment has allowed detailed analysis of the cropping program to take place. A range of factors have been identified for analysis, with the focus thus far being the effect of soil acidity on crop growth. Paddocks have been tested on 100 metre grids to see the correlations between yield and acidity with the hope of identifying areas for lime applications. Areas of higher pH were expected to yield more so that future lime applications could be on the lower pH areas. The outcome was that higher wheat yields were found to occur in areas of higher pH. However in the following year, yields of triticale, which is more acid tolerant, were higher in the areas of lower pH due to residual water and nutrient from the previous season's crop. The introduction of large areas of canola into the rotation has the potential to change the situation considerably because of the greater sensitivity of canola to acidity. Still, the main factor, correlating to yield variation is soil type.

The high level of technology presently used on the farm has been incorporated over time. Expansion of the farming operation, as shown in Table 82, has been relatively rapid.

Table 82 – Expansion of the families operations since farming in the region.

Year of change	Aquired area (ha) and new area farmed (ha)	Owned Area (ha)	Farmed Area (ha)
1968	Bought Long Gully 311ha @ $120/ha which was run with dairy.	311 + dairy	311
1974	Sold dairy and piggery and bought Yaralla 512 ha WIWO ha @ $475/ha.	823	823
1982	Bought 317 ha Wandaloo at Rand @ $1250/ha.	1140	1140
1987	Bought 240 ha Wandilla at Rand @ $1225/ha.	1380	1380
1996	Bought 226 ha Wandilla at Rand @ $1025/ha.	1606	1606
1996	Began sharefarming Everitt's (168 ha) and Klinberg (140 ha)		1914
1996	Began leasing Heinjus (228 ha) and St Clair (235 ha)		2377
1999	Began sharefarming 640 ha at Rand		3017

The amount of land put toward cropping enterprises has dramatically increased over time. Cropping intensity, defined as the percentage of total farm area sown to crop, is now 86 per cent. The inclusion of canola has allowed rotations to be extended and weed control to be integrated. Increased machinery capacity and adequate labour availability has also meant the operation has the ability to further increase area cropped.

The family moved to the area in the early seventies. The original holding was around 800 hectares. This was added to in the early eighties with another property that brought the area farmed up to 1140 hectares. At this point the operation underwent perhaps the biggest change to occur on the farm since the family took over. The move from primarily being a grazing operation to one that earnt most of its income from cropping fundamentally changed the farm business. The area sown to crop has progressively increased since the use of direct drilling commenced in 1976, when around 200 hectares of crop was sown, to 1983, where 730 of the expanded 1140 hectare property was cropped. This constituted around two-thirds of the total land holding, with additional land cropped on a share agreement. This area of crop was cropped with two tractors (sixty-five horsepower and ninety horsepower), an eighteen metre boomspray, a twenty four run combine and one truck. The move to bulk handling at sowing was also some time away due to cost. Put simply, the increase in acreage without the move to direct drilling would not have been possible if conventional cropping had taken place. The restrictions of cost, labour and plant requirements to do a similar job conventionally would have significantly reduced the area able to be cropped.

The red-brown earths of the home farm allow direct drilling to be done successfully but the purchase of the new farmland, which had granite-based soils, meant that conventional cultivation was needed in the first year coming out of the pasture phase. In the drought of 1982 the value of conservation tillage was evident, with first year, conventionally cultivated crops by far being the worst crops on the property.

The cropping expansion continued until machinery improvement became necessary. The purchase of a 120 horsepower tractor and 24-run Napier combine allowed this to occur. By 1987 eight hundred and sixty hectares of the again expanded 1400 hectare holding was cropped. The new combine was hitched in tandem to the old, a set-up that continued until 1998, with modifications where necessary.

The 1999 cropping season has seen a major changeover of machinery on the property with the purchase of a Flexicoil® cultivating bar and three bin airseeder for complete one-pass sowing and fertiliser placement. An Agco-White two hundred and fifty horsepower tractor was also purchased to cater for the increased machinery draft. The 12.2 metre seeder reduces the need to spread fertiliser later in the season, provides more accurate seed placement and greater sowing capacity. The value of the machine was evident in the 1999 season. Good early rains in February and March saw good soil moisture levels going into April. No rain fell in April and the cropping paddocks dried out quickly. Sowing began regardless, with the knowledge that the deep penetration of the knife-points would bring up stored moisture in the seeding row for germination. Meanwhile other growers in the region were waiting for rain or sowing into dry soil, which is always a risky option.

Figure 64 – New farm seeding equipment for the 1999 season.

The airseeder and bar are equipped with narrow superseeder points and trailing press wheels. The boot configuration provides deep fertiliser placement, followed by a closer plate to cover this fertiliser and then the seed tube following to place seed. This is illustrated in figure x. Press wheels following provide increased seed to soil contact to increase germination and early growth.

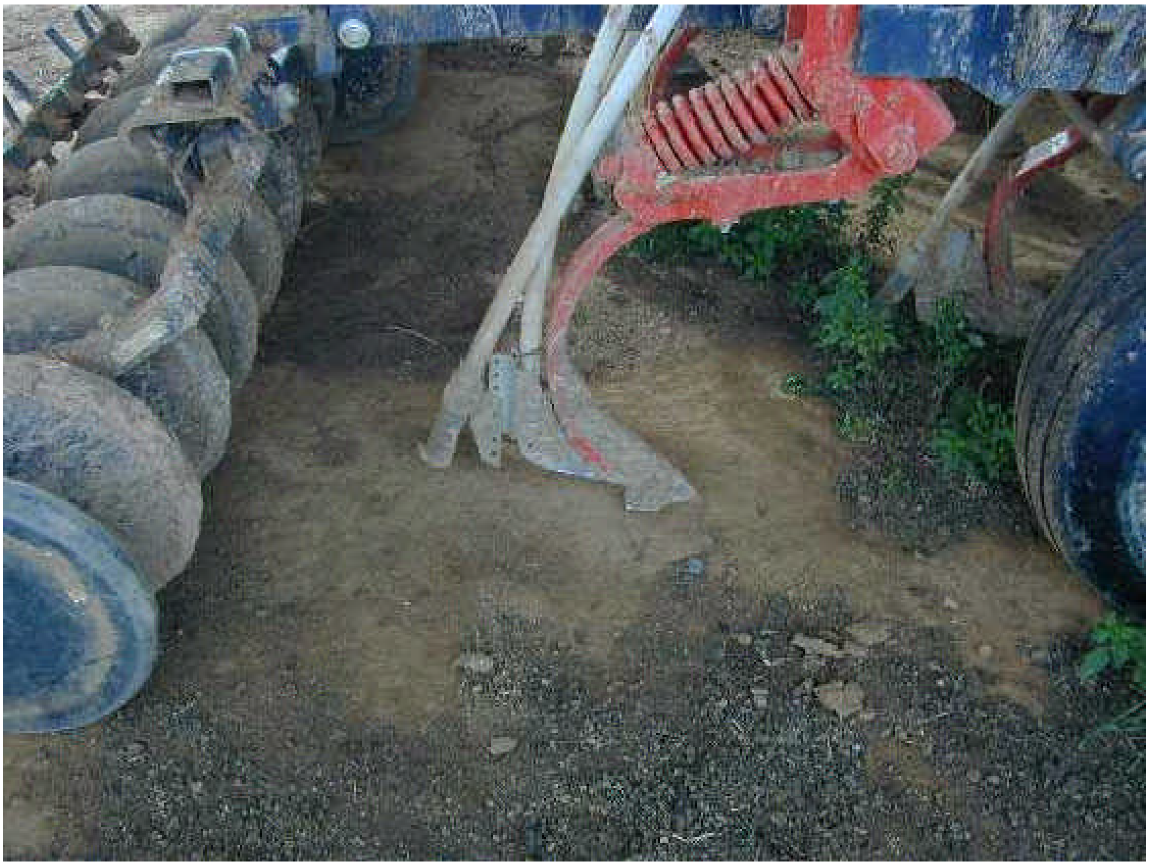


Figure 65 – Superseeder boot and press wheels.

Figure 66 – Gently undulating country in the Burrumbuttock area.

Table 83 - Average yields (t/ha) and area (ha) of crops over time.

Year	Growing Season Rainfall	Wheat	Triticale	Canola	Lupins	Barley	Oats	Total tonnes	Crop ha	Cropping intensity
1999*		4.0	3.5	1.8	1.7			7250	2582	86%
1998		3.3	2.9	1.5	1.6	3.9		5010	1863	79%
1997		3.2	2.4	0.9	1.1			3705	1795	76%
1996		4.2	3.4	1.3	2.2		3.8	4025	1302	69%
1995		5.4	5.1		2.5			4188	921	66%
1994		1.6	1.5	0.2	0.1			888	876	66%
1993		4.5	3.6		2.2			3067	879	66%
1992		5.2	4.8		2.3			3202	783	
1991		4.7	2.7	1.8	1.6			2248	774	
1990		4.1	4.9		1.8		1.9	2454	760	
1989		3.3			2.2		1.4	1933	718	
1988		4.2			1.9		1.9	1898	632	
1987		3.9			2.1			1905	599	
1986		3.7			1.8		3.3	1876	624	
1985		3.6			2.1	1.8	1.4	2047	666	
1984		3.4			1.8	3.1		2027	673	
1983		3.7			1.4	2.5	1.9	2378	858	
1982		1.0			0.6			558	616	
1981		2.3			0.7	2.0		1058	541	
1980		2.4			1.4	2.3		673	309	
1979		3.7				3.2		1051	307	
1978		4.7			1.9	2.5		1092	312	
1977		2.0			1.3	2.3		275	208	
1976		3.2			1.2	2.7		294	207	
1975		2.5			1.0	2.5		240	209	
1974		1.9			1.7	1.5		217	155	

*Nb. 1999 are budgeted figures only

Table 82 gives a graphic illustration of the rapid expansion of the operation. A move from 150 hectares of cropping in 1974, to the near 2600 hectares that will be undertaken in 1999, is a massive increase. Not all of this land is owned, with large portions being leased and sharefarmed. The increase in area is in part a result of realising the potential efficiency gains of a conservation cropping system.

4.13.5. ROTATION

The farm has undergone many changes in the last ten years with a large program undertaken to maintain and improve productivity. Concern for soil condition, and the management advantages of conservation cropping lead the family to the technique, but the management regime extends beyond this limited field. Lime and gypsum applications to reduce acidity and sodicity problems respectively, sowing of lucerne pasture, weed management techniques and application of precision farming methods, have all been aimed at increasing long term productive capability.

The move toward establishment of lucerne on the non-cropped part of the farm is seen as one of the main factors in an overall improvement of medium to longer term prospects of the farm business. The pasture phase previously relied on a clover-ley rotating with the cropping phase. The establishment of lucerne is designed to increase soil nitrogen levels for the cropping phase while allowing summer feed reserves to be available for the spring lambing flock, factors that were not as effective or are lacking with clover pastures. The increase in the area sown to canola has also played a part in the development of the lucerne phase. The application of lime to increase soil pH for canola (the crop prefers soil pH to be in above 5 in CaCl) has also opened up options for growers including lucerne, which also does not like very acid conditions.

In recent times the move to intensive crop production has required that a range of limitations to production have had to be tackled so the cropping rotation could be extended. These issues are covered below.

In general the crop rotation consists of canola-wheat-triticale-lupins. The introduction of canola into the rotation has meant that some reshuffling of the mix has had to be done. More recently cereal rye has also been grown.

The rotation is reasonably flexible which allows responses to price and varietal changes. Rotations have to be flexible, both in a whole farm and an individual paddock context. Ideally, crop is grown continuously for about seven years and followed by similar length of pasture to allow an effective disease break and nitrogen build-up. This aim has been severely compromised in recent times with the continued poor profitability of sheep. The pasture phase has thus been reduced to around three years in length. A move to continuous cropping of some paddocks is now imminent for the operators as their management skill increases and they become more comfortable with high intensity cropping. The need to increase cash flow has also forced the hand of the operators to some extent.

4.13.6. HERBICIDES AND WEED CONTROL

Weed management on the property begins in the year prior to cropping with winter cleaning of many pastures, which reduces grass weeds, especially silver grass. Prior to sowing, the paddocks receive a knockdown chemical, usually Roundup®. These are then sown without any prior cultivation. Post-sowing pre-emergent chemicals are applied if necessary. A recent development in the program has been the trialling of Treflan® (trifluralin) and Yield® (trifluralin and oryzalin) in a direct drill situation. Usually incorporation into a fine seedbed is required to prevent volatilisation of the chemical. Crop damage is also seen regularly with the use of this chemical. Thickening of the coleoptile is symptomatic, inhibiting seedling germination and potentially causing large losses given the already short coleoptile length in semi dwarf varieties. As a result the move to conservation cropping was seen to be at odds with the use of Treflan®.

No-till seeding with narrow points has altered this situation. Limited soil movement and the application of higher rates of the product dramatically increase chemical effectiveness and crop safety in conservation cropping systems. Application prior to sowing means that the chemical and soil is moved from the sowing row to the inter-row area where the weeds will grow. The presence of the chemical on the soil surface means that if the implement throws soil from the sowing row to cover the next crop row, damage will occur. Moving to wider row spacing improves crop safety in this situation. The operation presently uses 25 centimetre row spacings, compared to the conventional 18 centimetre spacing of rows. Product volatilisation will occur due to reduced amount of soil incorporation but higher rates compensate for this. Soil thrown from the seeding operation and its friability will affect the amount of chemical coverage and hence also losses.

The use of the chemical reduces the pressure placed on in-crop selective chemicals and the risk of resistance developing, as trifluralin is part of the lower risk group D chemicals. Additionally the resistance risks of chemicals used in-crop are lowered because weed populations are lower and less chemicals are required at seeding.

The continual application of selective herbicides to cropping paddocks had the result that chemical resistance is extensive on the property. Testing of suspected resistant seed has been carried out at Charles Sturt University's testing laboratories, where suspicions were confirmed. A range of strategies have been employed to overcome some of the problems. Possibly the most unique strategy has been the incorporation of a seed collection unit into the harvesting operation. The aim of this machinery is to catch ryegrass seed that usually passes out the back of the harvesting unit. Chaff and seeds are blown from the sieves into a tow behind cart. When sufficient material has been collected it is dumped in heaps in the paddock. These dumps are then burnt prior to the next seeding. Research suggests that around sixty percent of ryegrass seed in the paddock at harvest is collected by the unit. This move has dramatically reduced weed pressure, chemical costs and resistance risks. The different timing of weed control is particularly beneficial. The operators are convinced of the effectiveness of this tactic, despite some drawbacks. The harvesting capacity of the header is reduced significantly due to the need to drive the blower fan. Sieves can overload also, causing harvesting problems.

Figure 67 – Seed collection unit dumping seeds and residue from harvest in paddock.

Figure 68 – Complete harvesting setup with header blowing residue from sieves into collection cart

Additionally, at harvest, canola seed is graded to exclude radish seeds. The use of integrated weed management techniques has decreased the weed burden over time.

Chemical weed control is one of the main costs on the farm, even considering the use of the collection unit and modification of seeding and chemical practices. Chemical costs regularly run at around fifty dollars per hectare. The main weeds of the area are annual ryegrass *(Lolium Rigidum. P)*, wild radish *(Brassica Raphinatrum L)*, wild oats *(Avenae fatua)* barley grass *(Hordeum)* toad rush and silver grass *(Vulpia spp)*. The wide range of weed types mean that a broad range of chemicals are needed to control weed populations. A brief summary of the chemical use is given in table x below. This is just one paddock consisting thirty hectares but it gives a good example of the cropping operation on the property. The marked crosses represent chemicals applied over time. Frequent use of chemical infers greater risk of resistance developing. In recent times the range of chemicals has been broadened to reduce these risks.

Crop topping of legume crops has also been incorporated into the legume phase to reduce ryegrass seed set. Application of glyphosate or paraquat to kill ryegrass prior to seed development can impact on crop yield if timing is sub-optimal. The long-term benefits of the method may outweigh the costs of lost production however.

Rotation of chemical groups is also carefully practiced. Careful monitoring of what chemicals have been applied in which paddocks aims to reduce the risk of resistance development.

Table 84 – Chemical weed management, cost and resistance groups over time.

Year	Crop	Chemical application	Cost/ha	Resistance groups									
				A fop	A dim	B	C	D	F	G	I	L	M
1990	Wheat	Glean, Sprayseed, MCPA	$35			X					X	X	
1991	Lupins	Sprayseed, Simazine	$40				X					X	
1992	Wheat	Roundup, Glean, Amber Post	$24			X							X
1993	Triticale	Sprayseed, Puma, Goal, Tigrex	$56	X					X	X		X	
1994	Lupins	Sprayseed, Simazine, Verdict	$59	X			X					X	
1995	Wheat	Roundup, Tigrex, Garlon	$29						X		X		X
1996	Triticale	Roundup, Hoegrass, Ally, Buctril, Glean, Tigrex	$83	X		X	X		X				X
1997	Canola	Simazine, Atrazine, Select	$39		X	X	X						
1998	Wheat	Roundup, Goal, Yield, Tigrex, Glean	$53			X		X	X	X			X

4.13.7. STUBBLE MANAGEMENT AND NUTRIENT MANAGEMENT

Stubble is generally burnt on the property to reduce disease problems and to reduce the large trash load. This is usually carried out in late summer to autumn. Stubble burning is also practiced to reduce the bank of weed seeds. The purchase of new seeding machinery may cause this situation change however. A move to stubble retention has been mooted, but the machinery requirements may prevent this happening in the near future.

The incorporation of an extensive lime application program into the operation of the farm has made possible the use of a range of options for running the farm. Increasing soil pH allows lucerne to be used as a pasture plant. Lucerne has a higher potential to fix nitrogen in the soil than traditional annual clover based systems due to its perennial habit. An extensive root network and high dry matter production also auger well for improved productivity in the cropping phase. This has perhaps been the major change in the fertiliser program.

Fertiliser application rates in-crop have increased in keeping with the increased yields that have been attained in recent years. In general, a range of fertiliser rates are used on crops. This is illustrated by the history of the application of fertilisers on one paddock shown in Table 85.

Table 85 – Application of fertiliser on paddock on home block

Year	Crop	Fertiliser applied	Cost ($/ha)	N	P	K	S
1990	Wheat	120 (kgs/ha) Urea, 100 Double super	$81	55	17		4
1991	Lupins	100 Double super	$33		17		4
1992	Wheat	140 Triple super, 90 Urea	$84	41	28		1
1993	Triticale	120 MAP, 95 Urea	$90	51	26		2
1994	Lupins	100 Triple super	$34		20		1
1995	Wheat	120 Starterfos, 80 Urea	$82	51	26		3
1996	Triticale	110 Starterfos, 100 Urea	$84	57	24		3
1997	Canola	110 Starterfos, 80 Urea, 1200 Lime	$154	48	24		3
1998	Wheat	110 Starterfos, 100 Urea	$84	57	24		3
Nutrient balance (kgs/ha)				-195	133	-128	-31

From the yields that have been achieved on this paddock the net export and import of nutrients in the paddock can be estimated. These are indicated in the last row of Table 85. As shown the farm is generally a net exporter of nutrients. In other words the nutrient pool in the soil is gradually being run down and needs to be replenished regularly via the use of a pasture phase or some other method.

A move to higher inputs of nitrogen has occurred over time. The move to deep banding of fertiliser is aimed to increase the efficiency of nitrogen application. Incorporation of canola has also increased the need for nitrogen. Premiums for high protein wheat have also increased the incentive for increased nitrogen application.

4.13.8. MARKETING

The business usually has a large crop to market each year. Price risk is a major factor in the continued profitable operation of the farm. Some of the crop is sold forward each year to local end users for milling, feed and oil products. A move to more sophisticated price risk management techniques is planned by the farmers as contracts that offer greater flexibility are becoming available. In recent times a group of growers have formed a discussion group with the aim of increasing information available about reducing price risk and marketing. A move into futures trading and use of optional pricing contracts is likely.

4.13.9. ECONOMIC AND FINANCIAL SITUATION OF THE FARM.

The economic (Table 86) and financial history (Table 87) of the business is shown in below.

Table 86 - Operating profit over time

	Financial Year	198	198	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	199
	Annual Rainfall (mm)		##	580	458	841	792	361	716	628	386	498	
	Growing season rainfall		##	495	332	548	399	141	496	373	260	381	
Operating Profit													
1	Income - Wheat	#	#	$ 145,416	$ 161,950	$ 193,930	$ 152,431	$ 98,345	$ 402,032	$ 257,756	$ 266,708	$ 307,051	#
2	Triticale	#	#	$ -	$ -	$ -	$ -	$ 113,566	$ 162,091	$ 136,488	$ 148,340	$ 161,016	#
3	Lupins	#	#	$ 81,175	$ 66,929	$ 108,270	$ 93,929	$ -	$ 41,127	$ 215,794	$ 124,346	$ 39,561	#
4	Canola	#	#	$ -	$ -	$ -	$ -	$ 3,122	$ -	$ 75,100	$ 81,876	$ 185,488	#
5	Livestock	#	#	$ 9,259	$ 6,500	$ 20,260	$ 35,485	$ 28,910	$ 53,048	$ 42,770	$ 36,821	$ 50,611	#
6	Wool	#	#	$ 125,875	$ 107,539	$ 25,382	$ 191,431	$ 120,247	$ 108,468	$ 121,336	$ 115,535	$ 90,502	#
9	**Gross Income**	**#**	**#**	**$ 361,725**	**$ 342,918**	**$ 347,842**	**$ 473,276**	**$ 364,190**	**$ 766,766**	**$ 849,244**	**$ 773,626**	**$ 834,229**	**#**
10	Chemicals	#	#	$ 33,438	$ 57,947	$ 43,771	$ 69,823	$ 75,614	$ 95,999	$ 118,239	$ 113,426	$ 141,598	#
11	Fertilisers	#	#	$ 34,127	$ 65,805	$ 54,035	$ 88,370	$ 53,109	$ 124,729	$ 145,005	$ 174,268	$ 211,795	#
12	Fuel	#	#	$ 7,493	$ 7,244	$ 9,914	$ 8,680	$ 24,707	$ 25,688	$ 36,991	$ 17,877	$ 19,000	#
12a	Seed and Freight	#	#	$ 6,416	$ 12,602	$ 7,296	$ 11,018	$ 8,165	$ 20,863	$ 22,441	$ 27,861	$ 52,896	#
13	Livestock costs	#	#	$ 27,964	$ 21,193	$ 28,509	$ 34,713	$ 28,450	$ 47,731	$ 54,572	$ 20,214	$ 20,985	#
14	Other	#	#	$ -	$ -	$ -	$ -	$ -	$ 20,251	$ 18,868	$ -	$ -	#
15	**Total variable costs**	**#**	**#**	**$ 109,438**	**$ 164,791**	**$ 143,525**	**$ 212,604**	**$ 190,045**	**$ 335,261**	**$ 396,116**	**$ 353,646**	**$ 446,274**	**#**
16	**Farm Gross Margin**	**#**	**#**	**$ 252,287**	**$ 178,127**	**$ 204,317**	**$ 260,672**	**$ 174,145**	**$ 431,505**	**$ 453,128**	**$ 419,980**	**$ 387,955**	**#**

Cash overhead costs

Accountancy/agronomist fees	#	#	$ 2,640	$ 2,675	$ 2,675	$ 11,658	$ 17,623	$ 11,021	$ 8,169	$ 6,291	$ 13,420	#
Casual labour	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ 100	$ 800	$ -	#
Computer supplies	#	#	$ -	$ 1,095	$ -	$ -	$ -	$ -	$ -	$ 1,003	$ -	#
Contractors	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,914	$ 7,791	$ 8,540	#
Dogs	#	#	$ 729	$ 690	$ 806	$ 735	$ -	$ -	$ -	$ 660	$ 583	#
Electricity (70%)	#	#	$ 1,358	$ 2,485	$ 2,494	$ 3,050	$ 4,599	$ 3,269	$ 4,080	$ 5,389	$ 1,200	#
Private electricity	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	#
Farm advisory fees	#	#	$ 1,910	$ 895	$ 860	$ 152	$ -	$ -	$ -	$ -	$ -	#
Insurance	#	#	$ 5,760	$ 2,763	$ 5,481	$ 5,869	$ 4,113	$ 6,245	$ 13,062	$ 12,305	$ 12,451	#
Legal	#	#	$ 3,629	$ -	$ -	$ -	$ -	$ -	$ 3,448	$ 1,783	$ 342	#
Licences & registrations	#	#	$ 96	$ -	$ 130	$ 95	$ -	$ -	$ -	$ 80	$ -	#
Livestock purchases	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,500	$ 2,500	$ -	#
Machinery R&M	#	#	$ 7,250	$ 335	$ 19,462	$ -	$ 6,646	$ 16,104	$ 35,229	$ -	$ -	#
Motor vehicle expenses	#	#	$ 37,750	$ 31,210	$ 35,332	$ 31,810	$ -	$ 16,613	$ -	$ 48,159	$ 35,354	#
Other R+M	#	#	$ -	$ -	$ 152	$ -	$ -	$ 2,402	$ 6,158	$ 6,470	$ -	#
Pest Control	#	#	$ -	$ -	$ -	$ -	$ -	$ 381	$ 967	$ 422	$ -	#
Plant hire	#	#	$ 365	$ 635	$ -	$ -	$ 1,480	$ -	$ 30	$ 413	$ -	#
Postage & stationary	#	#	$ 160	$ 252	$ 58	$ 15	$ -	$ -	$ -	$ 481	$ 500	#
Private non deductable	#	#	$ -	$ -	$ -	$ -	$ 24,837	$ 19,322	$ 10,224	$ -	$ -	#
Protective clothing	#	#	$ 217	$ 396	$ 193	$ 636	$ -	$ -	$ -	$ 151	$ -	#
Rates	#	#	$ 9,819	$ 9,372	$ 9,174	$ 5,127	$ 12,692	$ 2,501	$ 10,678	$ 7,571	$ 10,700	#
Rent	#	#	$ 5,343	$ 5,486	$ 4,608	$ 5,507	$ -	$ -	$ -	$ 5,376	$ 5,389	#
Repairs and general maintenance	#	#	$ 10,752	$ 21,594	$ -	$ 19,376	$ 11,744	$ -	$ -	$ 21,461	$ 18,662	#
Subscriptions	#	#	$ 1,234	$ 2,015	$ 2,854	$ 2,377	$ -	$ -	$ -	$ 2,807	$ 2,880	#
Superannuation	#	#	$ -	$ -	$ 322	$ -	$ -	$ -	$ -	$ 2,823	$ -	#
Telephone (90%)	#	#	$ 1,658	$ 2,470	$ 2,764	$ 3,496	$ 8,396	$ 7,659	$ 7,763	$ 4,904	$ 4,700	#
Telephone private	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	#
Travelling expenses	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	#
Wages	#	#	$ -	$ -	$ -	$ -	$ -	$ 60	$ 55,568	$ -	$ -	#
Workers comp.	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,146	$ -	#
Total Cash overhead costs	**#**	**#**	**$ 90,670**	**$ 84,368**	**$ 87,365**	**$ 89,903**	**$ 92,130**	**$ 85,577**	**$ 161,890**	**$ 141,786**	**$ 114,721**	**#**
27 Depreciation#	#	#	$ 25,940	$ 25,074	$ 23,814	$ 20,460	$ 19,512	$ 68,643	$ 69,662	$ 59,720	$ 85,827	#

Drawings	#	#	$ 83,600	$ 85,000	$ 85,000	$ 85,000	$ 59,818	$ 101,500	$ 91,537	$ 89,119	$ 85,000	#
30 Operators allowance	#	#	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	#
Operators allowance in excess of drawings	#	#	-$ 6,400	-$ 5,000	-$ 5,000	-$ 5,000	-$ 30,182	$ 11,500	$ 1,537	-$ 881	-$ 5,000	#
28 Operating profit	##	##	**$45,677**	**$21,315**	**$3,138**	**$60,309**	**$27,497**	**$187,285**	**$131,576**	**$128,474**	**$97,407**	##
Interest to creditors	#	#	$ 86,609	$ 69,905	$ 47,999	$ 64,396	$ 44,510	$ 38,812	$ 138,751	$ 87,190	$ 83,744	#
Land leasing	#	#	$ -	$ -	$ -	$ -	$ -	$ 10,500	$ 38,500	$ 38,500	$ 39,265	#
Net Farm Income	##	##	**-$40,932**	**-$91,220**	**-$44,861**	**-$4,087**	**-$72,007**	**$137,973**	**-$45,675**	**$2,784**	**-$25,602**	##

Table 87 - Net Cash Flow over time

Net Cash Flow												
Sources - Cash in												
Sales	#	#	$ 361,725	$ 342,918	$ 347,842	$ 473,276	$ 364,190	$ 766,766	$ 849,244	$ 773,626	$ 834,229	#
8 Asset sales							$ 144,652					
7 Other*	#	#	$ 9,188	$ 5,397	$ 1,261	$ 25,723	$ 622	$ 8,855	$ 152,864	$ 78,932	$ 28,455	#
New borrowings						$ -	$ 150,000	$ 140,000	$ 139,041		$ 160,000	
Total	**#**	**#**	**$ 370,913**	**$ 348,315**	**$ 349,103**	**$ 498,999**	**$ 659,464**	**$ 915,621**	**$ 1,141,149**	**$ 852,558**	**$ 1,022,684**	**#**
Uses - Cash out												
Variable costs	#	#	$ 109,438	$ 164,791	$ 143,525	$ 212,604	$ 190,045	$ 335,261	$ 396,116	$ 353,646	$ 446,274	#
Cash overheads	#	#	$ 90,670	$ 84,368	$ 87,365	$ 89,903	$ 92,130	$ 85,577	$ 161,890	$ 141,786	$ 114,721	#
19 Income tax	#	#	$ -	$ -	$ -	$ 23,104	$ 42,175	$ 15,480	$ 66,919	$ 19,614	$ 15,000	#
Consumption	#	#	$ 83,600	$ 85,000	$ 85,000	$ 85,000	$ 59,818	$ 101,500	$ 91,537	$ 89,119	$ 85,000	#
Interest	#	#	$ 86,609	$ 69,905	$ 47,999	$ 64,396	$ 44,510	$ 38,812	$ 138,751	$ 87,190	$ 83,744	#
Principal	#	#	$ -	$ -	$ -	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	#
Land improvement	#	#	$ -	$ 2,675	$ 7,576	$ -	$ 3,467	$ 7,500	$ 5,495	$ 1,725	$ -	#
Machinery replacement	#	#	$ -	$ 17,030	$ 26,713	$ 1,650	$ 20,050	$ 310,550	$ 101,120	$ 12,000	$ 281,304	##
Land leasing	#	#	$ -	$ -	$ -	$ -	$ -	$ 10,500	$ 38,500	$ 38,500	$ 39,265	#
Investment	#	#	$ -	$ -	$ 322	$ -	$ -	$ -	$ -	$ 2,823	$ -	#
Total	**#**	**#**	**$ 370,317**	**$ 423,769**	**$ 398,500**	**$ 486,657**	**$ 462,195**	**$ 915,180**	**$ 1,010,328**	**$ 756,403**	**$ 1,075,308**	**#**
26 **Net Cash Flow**	##	##	**$596**	**$75,454**	**$49,397**	**$12,342**	**$197,269**	**$441**	**$130,821**	**$96,155**	**$52,624**	##

Table 88 - Calculation of equity, return on equity and growth over time

Change in equity

Reduced machinery value	#	#	$ 25,940	$ 25,074	$ 23,814	$ 20,460	$ 19,512	$ 68,643	$ 69,662	$ 59,720	$ 85,827	#
Increased machinery value	#	#	$ -	$ 17,030	$ 26,713	$ 1,650	$ 20,050	$ 310,550	$ 101,120	$ 12,000	$ 281,304	##
land improvement	#	#	$ -	$ 2,675	$ 7,576	$ -	$ 3,467	$ 7,500	$ 5,495	$ 1,725	$ -	#
Reduced debt	#	#	$ -	$ -	$ -	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	#
Increased cash	##	##	-$ 98,592	-$ 153,821	-$ 113,623	-$ 101,731	-$ 167,955	$ 82,636	-$ 111,464	-$ 19,454	-$ 10,510	#
Investment	#	#	$ -	$ -	$ 322	$ -	$ -	$ -	$ -	$ 2,823	$ -	#
Assets –Land	#	#	$ 1,522,755	$ 2,034,045	$ 2,034,045	$ 2,034,045	$ 2,034,045	$ 2,313,155	$ 2,313,155	$ 2,313,155	$ 2,313,155	
Assets - Machinery	#	#	$ 169,544	$ 161,500	$ 164,399	$ 145,589	$ 146,127	$ 388,035	$ 419,493	$ 371,772	$ 567,249	
Assets - Stock	#	#	$ 11,873	$ 14,300	$ 14,133	$ 14,230	$ 14,300	$ 14,300	$ 10,320	$ 11,071	$ 12,532	
Assets - Other	#	#	$ -	$ -	$ 47,972	$ 30,418	$ -	$ -	$ -	$ -	$ 32,792	
Total Assets	#	#	$ 1,704,172	$ 2,209,845	$ 2,260,549	$ 2,224,282	$ 2,194,472	$ 2,715,490	$ 2,742,968	$ 2,695,998	$ 2,925,728	
Liabilities – overdraft	#	#	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 34,000	
Long term loans and other	##	#	$ 389,438	$ 389,438	$ 389,438	$ 290,241	$ 137,678	$ 414,550	$ 684,550	$ 834,550	$ 906,979	
Total liabilities	##	#	$ 389,438	$ 389,438	$ 389,438	$ 290,241	$ 137,678	$ 414,550	$ 684,550	$ 834,550	$ 940,979	
Equity ($)	##	#	$ 1,314,734	$ 1,820,407	$ 1,871,111	$ 1,934,041	$ 2,056,794	$ 2,300,940	$ 2,058,418	$ 1,861,448	$ 1,984,749	
Equity (%)	##	##	77.1	82.4	82.8	87.0	93.7	84.7	75.0	69.0	67.8	

Table 89 - Operating profit, investment analysis and annual return on equity

	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Annual Operating Profit	$45,677	$21,315	$3,138	$60,309	$27,497	$187,285	$131,576	$128,474	$97,407
Asset value	$ 1,704,172								$ 2,892,936
Investment cash flow	$1,658,495	$21,315	$3,138	$60,309	$27,497	$187,285	$131,576	$128,474	$2,990,343
Internal Rate of Return	10.02%								
Annual return on Equity	2.68%	-0.96%	0.14%	2.75%	-1.25%	6.90%	4.80%	4.77%	3.37%

The expanded cropping area, a result of land purchase, leasing and sharefarming, has significantly increased the business gross income in recent times. The average annual farm gross income over the period 1990-1 to 1998-99 was $568,202. Since the early 1990s the farm has consistently been generating high farm total gross margins. The high input nature of cropping in southern NSW creates structure with high variable costs per hectare, high returns per hectare, compared to the Mallee for example, where inputs per hectare are less. The average annual whole farm variable cost over the period 1990-1 to 1998-99 was $261,300, creating an average annual total farm gross margin of $306,902. The good total farm gross margins have been offset by the high overhead cost structure of the farm. The average annual overhead costs totalled $117,623. The addition of new machinery has increased depreciation costs on the farm. Operators allowances are also high due to the number of operators. Both factors have reduced the potential for high operating profits. Operating losses have been incurred in two of the nine years investigated.

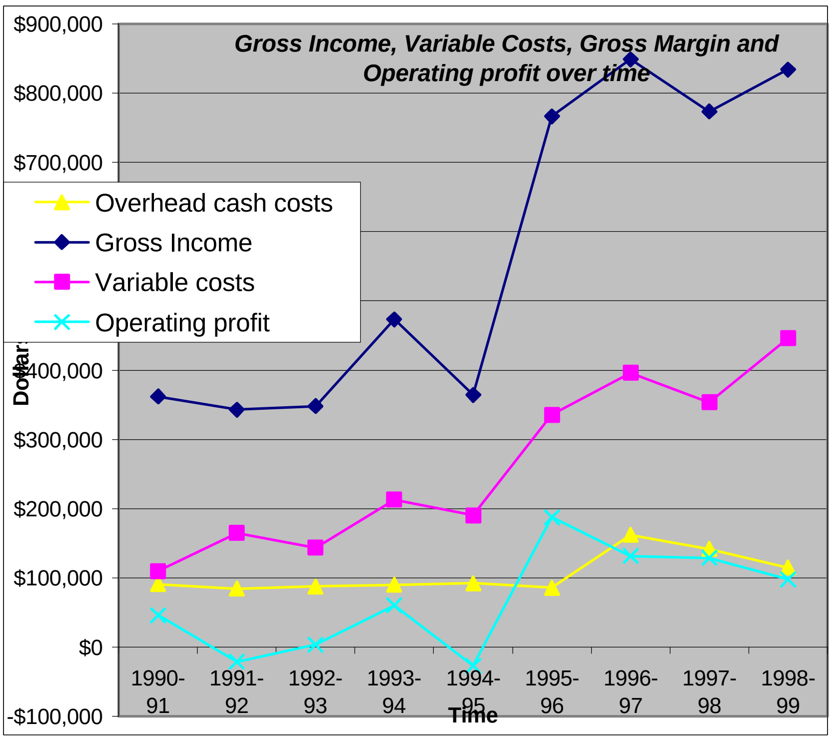


Figure 69 – Farm performance over time

Using rationale explained earlier, an analysis of performance has been undertaken. Using total asset value of the farm at the beginning of the period (1990-91) as an initial cost, nominal operating profits in each year as income from the investment, and closing asset value in 1998-99 as the salvage value of the investment, the farm has generated an annual internal rate of return of 10 per cent. This indicates the efficiency of the use of those total assets over that time, and can be compared to returns that may be available on the amount of total capital involved if it was used in another way. Given that the consumer price index over that time averaged 3.28 per cent, real internal rate of return averaged 6.74 per cent. This figure is dependent on changes in land prices over time to some degree. Increases in land value stated above are used in the calculation. This return is commensurate with returns on capital in agriculture in general, though generally less than was achievable from alternative, non-agricultural forms of investment.

The average annual return to capital in this operation was found to be 2.58 per cent. This figure is somewhat less than what could have been achieved in other non-agricultural forms of investment. We should conclude that much of the internal rate of return is produced by increased asset value at the end of the investment period.

In this time the business has managed to achieve an increase in owners equity over the past ten years. Nominal equity has increased from an estimated $1.1m in 1990-91 to almost $2.0m in 1998-99.

Reasonable farm performance in terms of operating profits and return on total capital over time (Table 89) has not necessarily translated into high net farm income because large debts being carried by the farm have meant large interest costs. The average annual interest paid by the business over the period was $73,546, and with the addition of land leasing costs, negative net farm incomes (running down equity) occurred in four of the eight years. Average annual net farm income since 1990-91 has been –$20,403. It should be kept in mind that high non-cash costs associated with depreciation, especially in recent years, are incorporated into this analysis. A nominal operators allowance will also tend to blur the cash position of the farm. Even so, new borrowing has been needed in some years to meet cash deficits.

Cash flows have been under pressure however because of the purchase of land and equipment over time. Borrowing has overcome these shortfalls in the short-term. The purchase of land and machinery has increased owners net worth but has also resulted in losses of equity and increased debt in some years. Increased interest costs have ensued. The expanded cropping area and use of conservation cropping methods have increased the reliance on short-term working capital. This has also increased the interest costs. Increased long-term financial viability for all of the families on the farm is the aim of the recent expansion. Recent dry years, depressed prices and the frost of 1998 have placed significant pressure on the business.

The cumulative cash flow over time reveals a build-up of cash over time, largely financed through borrowing.

Table 90 – Cumulative cash flow over time.

Year	Cumulative cash flow
1990-91	596
1991-92	-74,598
1992-93	-124,255
1993-94	-111,913
1994-95	85,356
1995-96	85,797
1996-97	216,618
1997-98	312,773
1998-9	260,149

The financial and economic health of a complex business such as this is often difficult to assess. The analysis is backward looking and is not simple to compare with how the business would have progressed under a cultivated cropping system. Still, some conclusions about the performance of the resources in this crop farming system can be made. In practical terms, the cropping operation, available labour and equipment previously owned, would not have allowed a move into extensive cultivated cropping. Conservation cropping has increased the annual working capital requirements of the business, but at the same time medium to longer term capital requirements per hectare cropped have been reduced. Thus capacity to crop a larger area with the same capital became possible – a possibility that was realised by leasing more land to crop has offered flexibility for the business expansion. The need to generate increasing income and equity for three farming families has necessitated expansion and some risk-taking. Given a run of reasonable seasons and prices much of the debt can be reduced and business equity increased.

The overall stability of the farming system in terms of annual total cropping gross margin over time is illustrated in Figure 70. The amount of growing season rainfall has not altered greatly the annual farm total gross margin of the business over time. Reasons for this may include waterlogging effects, the presence of a significant sheep enterprise and the prices of grain increasing in years of poor yield.

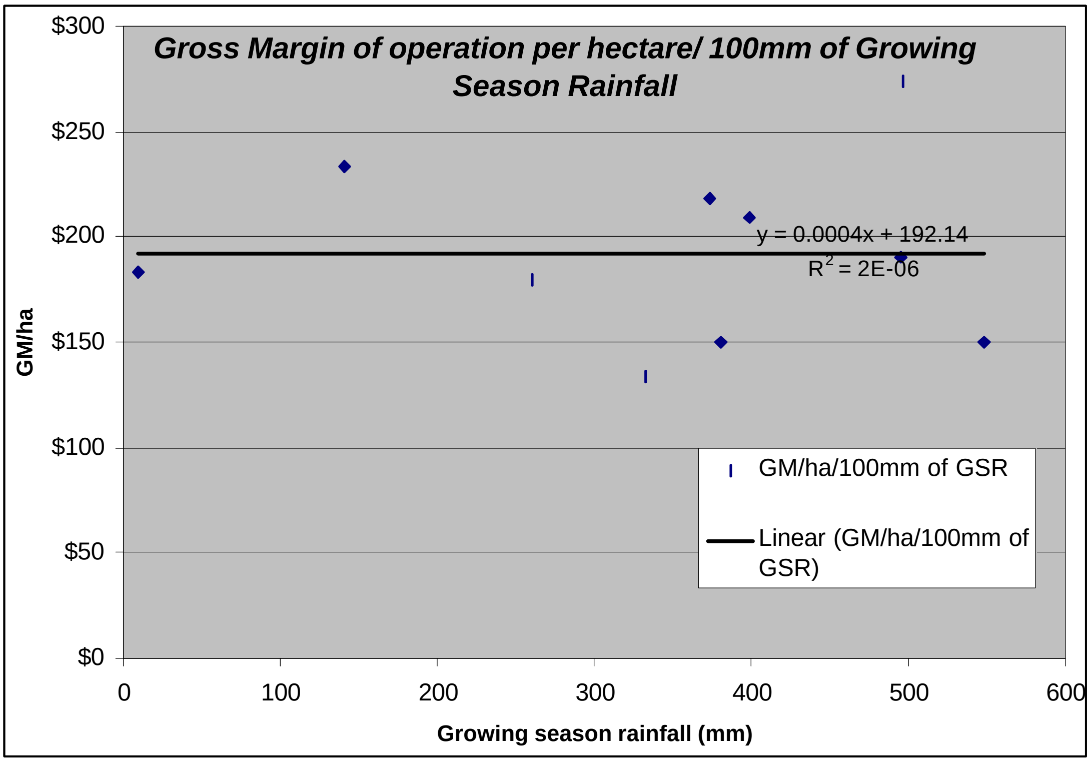


Figure 70 – Annual total farm gross margin per hectare per 100 millimetres of growing season rainfall.

The annual cash requirements of the farming operation have increased markedly over time. The variable costs of cropping are large, particular in intensive conservation cropping situations, while the hidden costs of depreciation linked to machinery investment in conventional systems are reduced. Increased variable costs means that losses associated with crop failure are larger than otherwise would be the case, and returns in good years are larger than would otherwise be the case. Intensification can increase both the mean and variance of net profits.

The gross margin figures supply some vital information as to the profitability of the farm in recent times. The very profitable 1995 season has been a fillip for the expansion of the operation over the last couple of years. That year, high world cereal prices along with impressive yields provided huge returns on a per hectare basis. This was translated into strong operating profits.

The equity of the business has increased in the analysed period in nominal terms from an estimated $1.31m to $1.98m. In percentage terms however, the operators hold a 68 per cent stake in the total asset value of the business. This places the business at some risk if variables such as grain prices, interest rates, climate and/or costs move against the business.

4.13.10. WHOLE FARM MANAGEMENT

The role of management in any farming operation can not be understated. As stated by Malcolm:

> The importance of the human condition in business success cannot be overstated. Ultimately, it is the personal qualities of individuals involved in conducting the business which determines the results. Often the vital aspect of management is the task of getting the most from each person according to each person's ability. Communication is at the core of the management of labour (Malcolm, 1993).

The main management functions of a farm operator are planning and deciding, organizing resources and putting decisions into practice and controlling the operation of the business and reappraising actions (Malcolm, 1993).

The task of management is combining the complex soil, plant, animal and human interrelationships into a cohesive unit that produces a profit – even though running a farm is more than a profit making exercise:

> Once we called farming a way of life. Then it became a business. It is both (Malcolm, 1993).

These farming brothers had obviously thought a lot about how conservation farming was to fit into the operation of farm as a whole. Initially the decision was made easier by the fact that their sheep flock lambed in spring. The increased feed over the summer period from conservation cropping similar stock numbers to be carried whilst being able to crop more land. If spring lambing was not used then winter feed would be a major issue and possibly not as much land would be able to be cropped. Quotes from the owners in the early 1980's spell the issues out.

> It let's us carry the maximum number of stock through to May. We can use the stubbles through the autumn. Last year (1981), for instance, about half our area was crop and the other half stocked. We had about 160ha of lupin stubble and that was very handy when things started to go wrong this year (1982).

As time progressed the ability to sow crops on time and over greater areas lead these farmers to continue to refine their knowledge of conservation cropping. As they looked to lease and share land, the use of conventional cultivation methods would have significantly affected the scope and timing of operations, and profitability. The use of conservation cropping has been adopted to such an extent that these farmers feel they are better off applying chemicals in all situations rather than using cultivation.

4.14. CASE STUDY 2 – WALBUNDRIE SOUTHERN N.S.W.

4.14.1. INTRODUCTION

This case study involves a no-till crop production system. In a traditionally mixed farming area of southern NSW, this grower has converted his operation to a continuous crop no-till farm. Financial circumstances played their part in this move, but investigation of the adoption process and management system reveal the complex relationships involved in a high management input regime such as this one.

The farm is situated about ten kilometres north of the southern NSW town of Walbundrie (Latitude 35° 42'S, Longitude 146° 43'E) and approximately sixty kilometres north-west of Albury. The farm is owner-operated with some assistance from the operator's father throughout the year and also from employed labour during the sowing and harvesting periods. The owner is around 45 years of age. The farm consists of around eight hundred and eighty hectares with another three hundred and sixty hectares of leased land at nearby Alma Park, 20 kilometres from the home farm. In 1999 another 360 hectares was leased to the west of the property toward Rand. This brings the total area cropped to around twelve hundred hectares – a large area for one person to manage.

The defining feature of the operation is its use of continuous cropping. It is perhaps the only farm in a traditional mixed farming area where this is the case. Sheep were forsaken in the early 1990's to alleviate some financial difficulties. The farm mirrors the trend to cropping in mixed farming areas over the last ten to fifteen years - a direct result of the declining profitability of livestock activities.

4.14.2. GENERAL CROPPING ENVIRONMENT - SOILS

The soils of the home block are primarily red-brown earths (Gc 2.31). On the leased country to the east of Walbundrie the ground is somewhat heavier with grey clays in patches, but the soils are still predominantly red-brown earths with higher clay/loam contents. The soils on the home block are generally free draining, reducing potential water logging problems. These soils however do present their own problems such as hard setting and compaction.

The home block is situated on gently undulating country. The potential for water erosion is apparent in years such as 1999, where high intensity summer storms have caused problems on many problems; a factor indicated by Figure 71. Wind has been a problem in dry years. These problems have been greatly reduced with the introduction of stubble retention and no-till methods.

Figure 71 – The effect of cultivation on a red-brown earth.

The effect of cultivation on these soils can be seen from the illustration above with this neighbouring property's cultivated land setting hard. This photograph was taken in March 1999; the soil surface has sealed following rain. Infiltration of rain into the soil following cultivation has been negligible compared to infiltration on uncultivated land.

The operators belief is that no-till and stubble retention has improved the nature of the soil and reduced some of the problems associated with sealing, compaction and general soil health. Compared to the land shown in the photograph above, the soil where stubble was retained was easily penetrable after good rains over summer in the area.

Figure 72 – stubble retained on soil surface of case study farm.

Note the wide row spacings of twenty five centimetres in Figure 72, and the height at which the stubble was cut at harvest to allow easier sowing conditions in autumn of the following year. Also note the shape of the furrow in which the plant is growing. Seed is sitting under a depression in the soil resulting from the use of press wheels. This allows any water that does pond on the surface to infiltrate to where the plant is situated, in effect harvesting the water. The use of press wheels also increase seed-soil contact at sowing, increasing germination.

Another important factor to note is the evenly distributed crop residue. A chaff cutter and straw spreader spread residue over the width of the header front to reduce the potential for blockage of the seeder. The effect of poor spreading can be seen in Figure 73 below where uneven spreading has resulted in a concentrated area of weed and canola seeds germinating following summer rains. This photo was taken on a farm within a kilometre of the main farm. Areas such as this may require higher than normal rates of herbicide to reduce the burden. This has the potential to increase the selection pressure on the weed population, hastening the onset of resistance. Differing views on the subject exist however (Gressell, 1990).

Figure 73 – Poor distribution of chaff and straw following harvest leading to dense weed patches.

4.14.3. RAINFALL

The main farm receives 450 millimetres per year on average. Average rainfall at Walbundrie, south of the property, is 520 millimetres. The leased land is in a 550 millimetre area. Rainfall is spread reasonably evenly over the course of the year as illustrated below.

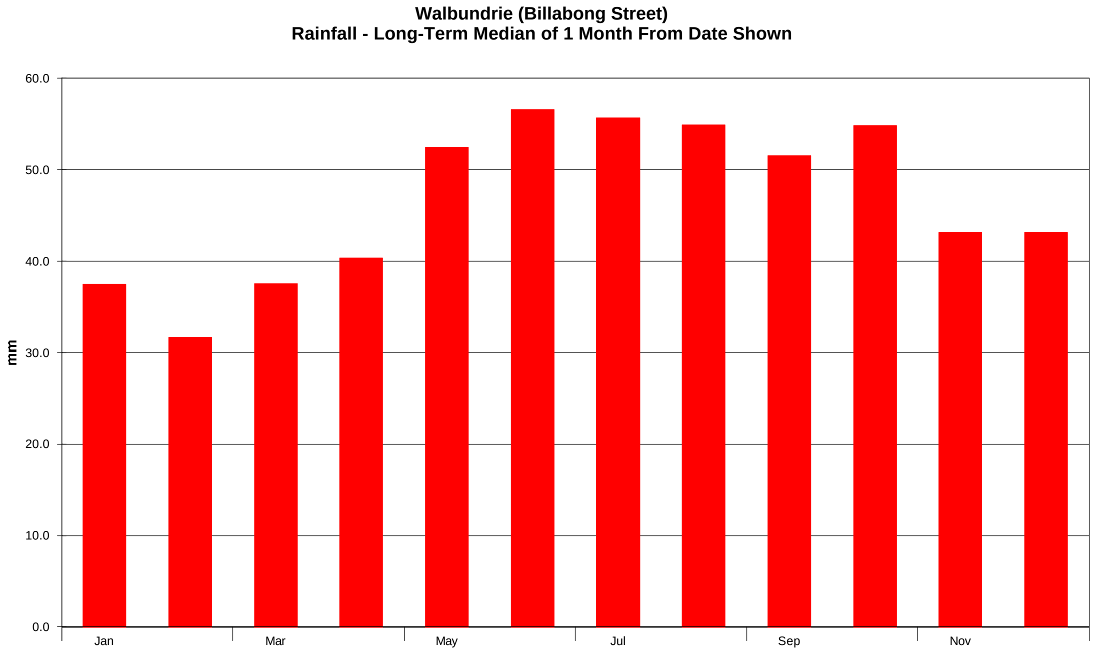


Figure 74 – Monthly distribution of rainfall at Walbundrie

The variability in rainfall has a large effect on the management of the farm. Variation over the last thirty years can be seen below in Figure 75. The graph highlights the wet years of the mid 1970's and the run of what would appear to be reasonable years in the mid 1980's to early 1990's.

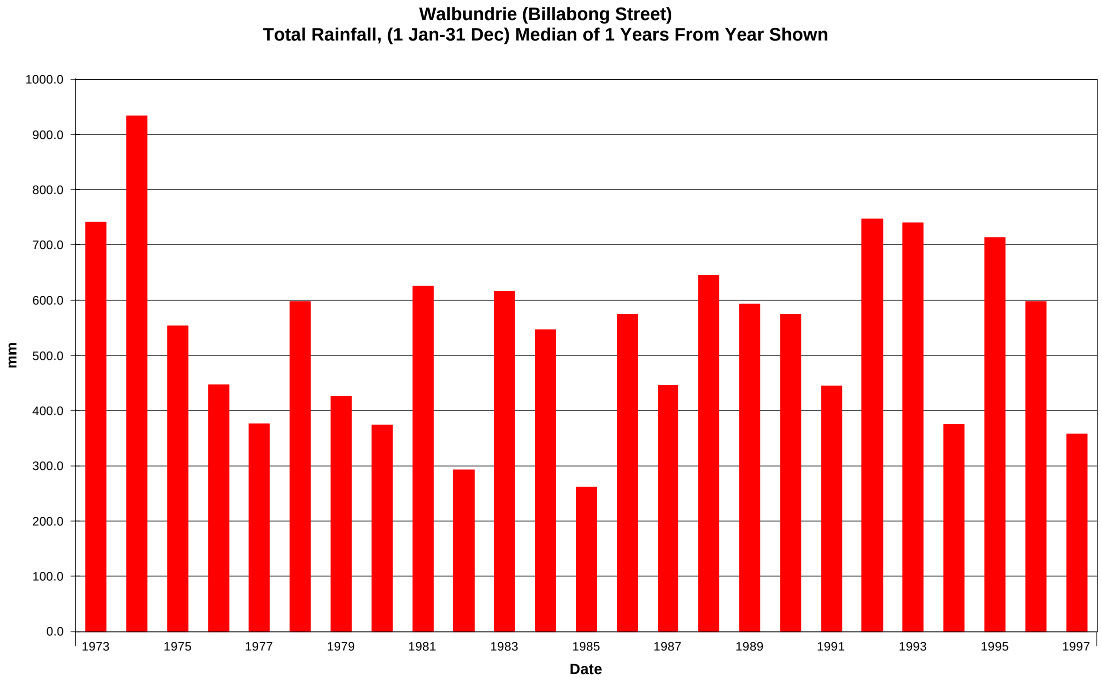


Figure 75 – Rainfall at Walbundrie 1973 – mid 1998.

Variation in growing season rainfall seems more erratic than annual rainfall. This confers a large variation in yield potential for the growers of the region, as is the case for most of the Australian wheatbelt areas. As the other case studies will reveal however the rainfall in this region is much more assured than areas to the west of this region. The probability of various amounts of growing season rainfall falling at Walbundrie is seen below in Figure 76.

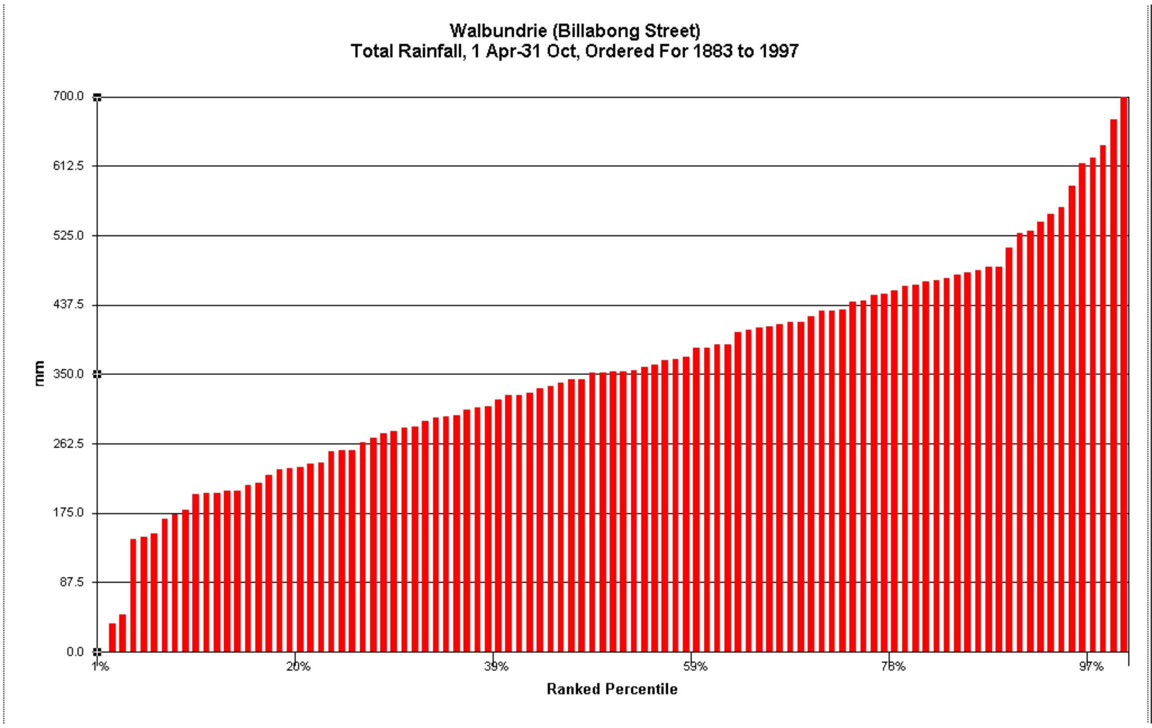


Figure 76 – probability of growing season rainfall totals.

The probability of rainfall indicates a fifty percent chance of more than three hundred and fifteen millimetres falling over the course of the growing season (1998). If this is the average growing season rainfall then the average potential unconstrained yield could be (315-110)*20 = 4.3t/ha. This level of water use efficiency is rarely achieved however but it does indicate the theoretical unconstrained potential of the area.

4.14.4. CROPPING EXPANSION, MACHINERY AND MANAGEMENT PRACTICES

The amount of land, both owned and sharefarmed, used for cropping enterprises has increased markedly in recent years with the addition of two leased blocks to the cropping program.

Table 91 - Expansion of operation over time.

Year	Land owned (ha)	Land leased/sharefarm (ha)	Total area cropped
1973	800		
1978	1130		
1987	1400		
1998			

The move to different seeding equipment has been integral to the move to the new, expanded system. The seeding plant sets up the soil condition at the start of the cropping season and has the potential to affect the soil physically, biologically and chemically for years to come.

The timeliness of seeding operations in a one-man operation is paramount to the success of the system. As a result seeding is completed in a one-pass system on the farm to reduce labour input and for a range of other management reasons.

If summer rains are sufficient to germinate weeds, spraying will occur to conserve moisture and nitrogen for the following crop. Wet summers are important for the cropping operation as the use of stubble retention and no-till has altered the soil structure sufficiently to allow high proportions of incident rainfall to enter the soil. This has the potential to provide sowing moisture.

Following the autumn break, knockdown sprays (Roundup® or Sprayseed®) are applied prior to seeding to kill any existing germinated weeds. After this the seeding implement is the only tool used to put the crop in. On the front of the seeding bar spray nozzles have been attached to allow the application of chemicals that are in turn incorporated by the sowing operation.

Figure 77 – Seeder with chemical application tanks fixed to frame. Orange indicates trifluralin use.

Treflan® (trifluralin) application on cereals has been part of the integration of weed management methods in recent years. This group D chemical reduces the risk of resistance problems emerging while controlling ryegrass numbers. The altered use of the chemical is a key to the success of the no-till system on this and many other farms. Twenty years ago Treflan® users incorporated the chemical into a finely powdered seedbed, with associated effects on soil structure. Today Treflan® is credited with preventing herbicide resistance and a return to cultivation in no-till soils. An increase in applied rates has allowed limited incorporation to occur (ie. sowing operation only) and as it is relatively inexpensive, use of it has increased greatly, particularly in Western Australia. After the chemical application, a coulter follows, slicing through soil and stubble to allow the sowing tyne to pass unimpeded. All stubbles are retained on the farm but some burning of canola residues will occur in 1999 to offset the risks of blackleg infection in neighbouring and following canola crops. In this relatively high yielding area the seeding bar would quickly block with stubble from the previous crop if coulters were not employed. Coulters are coupled in front of the narrow knife-points (12mm) that only minimally disturb the soil. Figure x below shows a rippled coulter in front of the tine. The farmer uses a straight edge, which reduces soil movement.

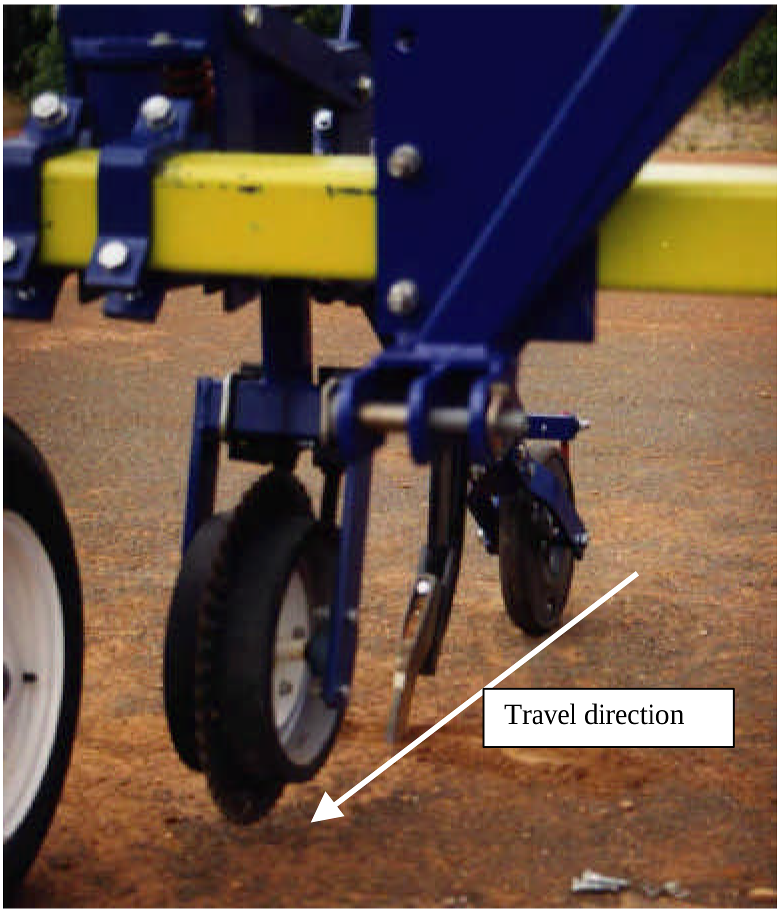


Figure 78 – Tine assembly to be used on the farm in future. Note the coulter at the front to cut stubble, followed by a deep cultivating tine, fertiliser tube for deep banding and then a seed hose follows (seeding kit and hoses not visible).

Figure 79 – Seeding equipment on present airseeder. Note seed tube and soil closer plate following deep knife point and fertiliser tube.

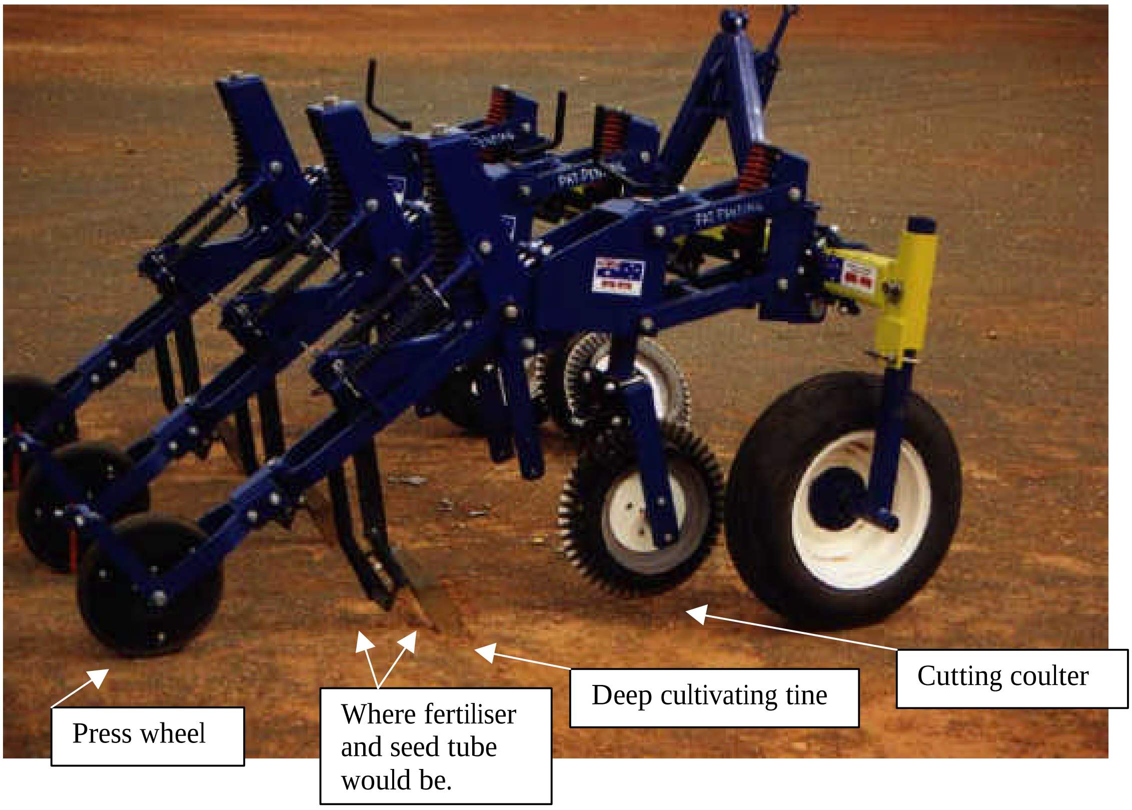


Figure 80 – tine assembly seeding equipment, minus seed and fertiliser hoses.

The soil is cultivated to a depth of around eight centimetres in order to enhance root growth, which is sometimes retarded by soil strength or pathogens when cultivation is minimal. Between the bottom of the furrow created by the knife point and the seed, fertiliser is placed. A soil closer plate then scrapes soil into the bottom of the furrow creating the seedbed. The seed is then dropped onto this soil, at a depth of around two to three centimetres below the surface. The seeding depth is altered by the use of a parallelogram system which links the press wheel to the seed distribution system. Another plate then covers soil over the seed. This is then followed by a press wheel, which firms the soil around the seed. This aims to improve soil-seed contact, which generally increases the success of germination; a product of increased water transmission into the seed coat. The grower's press wheel configuration allows him to press the side of the seeding walls if desired rather than straight down on the seed furrow. This is done by having two press wheels whose angles can be changed depending on conditions. The breakout strength of the tine and press wheels can also be altered by changing the length of the tine and spring pressures. A shorter tine will confer greater breakout strength due to a decreased leverage effect by the ground on the implement.

The aim of the seeding operation is to put the seed at the right depth to allow maximum emergence. The system that is employed by the grower is based on a Primary Sales® seeding kit. The breakout pressure of the spring tines is around two hundred and fifty kilograms, which is considered to be at the upper end of breakout requirements. The producer considers that higher pressures are not required due to the softening up of the soil over the six to seven years of no-till and stubble retention. The coil tynes also allow lateral movement of the tyne in stony situations that are encountered on the leased property.

Row spacing for cereals is set at twenty five centimetres, considered to be wide for the area where eighteen centimetre spacings are the norm. The result is that the ground in between the knife points receives no soil disturbance. Soil is generally thrown over this area from the tine however. This is important, as coverage of Treflan® is needed to stop volatilisation. The layer of Treflan® forms a barrier to the germination of ryegrass seedlings from the inter-row however the area on the walls and around the seeding furrow generally has no Treflan® left to control ryegrass. The end result is that some weed germination may occur in and around the furrow but the inter-row area generally has much reduced emergence. The lack of cultivation over much of the paddock means that weed seeds, and all surface applied agents for that matter, are kept at the surface. The result is that germination of seeds is generally less staggered and weed mortality is increased due to the greater exposure to wetting and drying cycles, insect predation, stubble breakdown and lack of moisture to germinate.

The retention of stubbles is regarded by the farmer as an important mechanism to manage weeds. The leaching of acids from the stubble reduces the emergence and growth of ryegrass in a number of trials recently (Wu, 1998). While this effect is specific to varieties, the grower has observed this phenomenon in a range of varieties and crop types.

The use of deep-banding, or profiling, of fertiliser was a key part of crop management. Placing the fertiliser where the crop roots can get direct access to the exclusion of weed roots is important in the fight against weeds and beneficial to the general agronomy of the crop. All fertiliser was placed below the seed, and none with it. The notion is that for the first ten days of the crop's growth after planting the seedling survives off the nutrients that are stored in the grain. After this period the roots of the plant will be in the zone where the fertiliser is placed. This practice also significantly reduces the risk of seedling nitrogen toxicity however recent research has highlighted a need for phosphorous placement with the seed (Rainbow, 1999).

4.14.5. ROTATIONS

As in most cropping operations, the rotation on the farm is not set rigidly but certain general agronomic principles are applied in most situations. In general the rotation is something like canola-barley-wheat-lupin-triticale with this sequence being repeated. The use of barley is currently being questioned because of perceived inconsistencies of pricing and grading in the malting barley market. Canola acreage was likely to increase, as it is profitable. On the leased block a canola-wheat rotation was going to be grown to a high return quickly. The threat of blackleg damage is large but the potential gains were seen to outweigh the risk. The farmer was also on the lookout for any other crop that had the potential to be profitable. This was in part a result of the tight financial situation, but also the aim is to stabilise the farming system overall.

4.14.6. HERBICIDES AND WEED CONTROL

Weed management is a potential problem area on the property at present. The threat of herbicide resistance looms large as a result of the history of relying on chemical options and lack of measures such as burning and seed collection. Crop topping is employed on legume crops to reduce ryegrass seedset. So far, the operator believes this has proved to be effective. The use of deep-banding has also been seen to reduce the emergence of weeds over time. Late sowing, either by choice or circumstance also reduces the weed burden as it allows greater proportions of the emerging weeds to be killed by knockdown chemicals.

4.14.7. STUBBLE MANAGEMENT AND NUTRIENT SUPPLY

The continuous cropping of the farm and low use of legumes means that a high proportion of nutrient supply to the crop has to come from applied fertilisers. Deep-banding of nitrogen fertiliser improves the efficiency of applications and preferentially feeds the crop instead of weed populations. The farmer believes that deep-banding of nitrogen has been a key to the attainment of high yields.

Using no-till and stubble retention has altered the soil environment. The friability of the soil has improved, as evidenced by the reduction in energy requirements for sowing over time. At the beginning of the use of continuous cropping the one hundred and sixty horsepower tractor was struggling to pull the seeding unit at eight kilometres per hour. Last year it pulled the same seeder at eleven kilometres per hour.

Use of moisture monitors over the farm has also shown the impact of the changed cropping practices on the soil. Waterlogging is rarely a problem these days, where once it was a problem. The increased infiltration has meant that rainfall goes through the soil profile very easily.

Increased levels of moisture have increased the level of microbial activity in the soil. Stubble regularly breaks down over the summer period. This would usually take much longer in cultivated paddocks.

An interesting feature on the property is a block of land that has been continually sown to triticale over the last seven years. The first couple of years demonstrated the deleterious effects that disease can have on crop yields in a monocultural cropping situation. After a period of time however the classic disease treatment effect was seen, with yields increasing as the incidence of disease decreased. Similar to the classic Dutch example of Take-all on reclaimed sea land, crops were initially high yielding, followed by low yields as disease took over, and finally returning to reasonable yields as disease pathogens were suppressed by other microbial predators as the populations reached equilibrium. A similar situation exists in the crop stubbles. After a few years in the system breakdown of stubbles in the field occurred more rapidly than previously. The operator is now unwilling to use stubble burning to tackle any other problems such as weed control.

4.14.8. HARVEST

Harvest is carried out with a Russian-made Don header. A eight metre front makes timely harvest possible. Residues are spread at harvest to alleviate blockages at seeding and promote even weed germination in the following year. Stubbles are cut relatively low to reduce seeding problems also. For two years the header was fitted with a yield monitor and GPS technology.

This yielded some interesting information but the unit was disposed of recently as the grower could see little evidence of profit being increased as a result of information from the monitor. The high initial cost and continual problems with the technology led the grower decide yield monitoring was more trouble that it was worth.

4.14.9. MARKETING

The marketing of produce from the farm has been done in a range of ways over time. Usually some of the crop is forward sold through the season. The introduction of canola to the farm has made the grower more comfortable with using forward selling methods and this has led to forward selling some of the cereal production.

4.14.10. ECONOMIC AND FINANCIAL SITUATION OF THE FARM

The economic and financial performance of the business is shown in Figure 81.

The expanded cropping area, attributable to leasing and sharefarming, has significantly increased the gross income of the business in recent times. The average annual farm gross income in nominal dollars over the period 1991-2 to 1997-8 was $179,032. Gross income has greatly increased with the larger cropping area in recent years. Dry years in 1994 and 1997 contributed to lower gross incomes in nominal dollars. The high input nature of cropping in southern NSW meant average annual variable costs over the period 1991-2 to 1997-8 of $63,225. Average annual farm total gross margin was thus $115,807. Total annual gross margins have been higher in more recent years of the analysis due to the increased cropping area.

Farm total gross margin is used to to pay the overhead costs of the farm. Annual cash overhead costs averaged $35,355 in the period analysed. Neither depreciation costs or operator allowances are particularly high on the farm. After deducting these items average annual operating profit was $37,081. The economic performance of the farm over time can be seen in Figure 81.

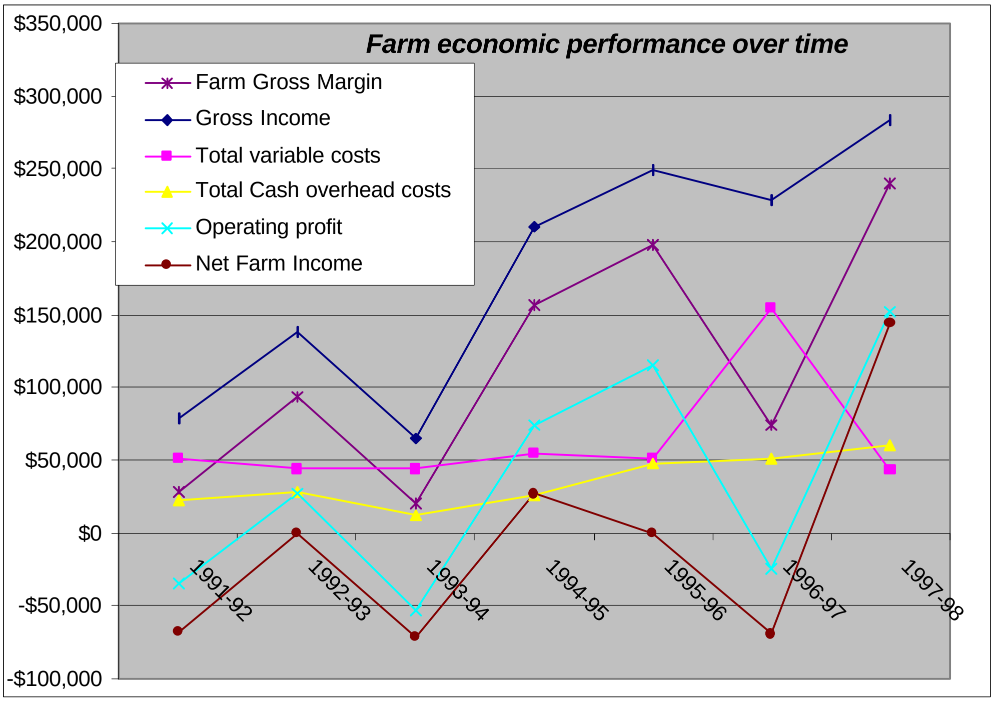


Figure 81 – Farm performance over time

As with case study one, farm earnings are compared with other forms of investment using internal rates of return based on nominal operating profits over time. If we treat the business as an investment, assuming total asset value in year one as an initial cost, operating profits over time as investment income, and estimated total asset value at the end of the recorded period as the salvage value, an internal rate of return (IRR) can be calculated. Over the period 1991-2 to 1997-8 the farm generated a nominal internal rate of return of 10.19 per cent. Given that inflation averaged 3.1 per cent, real internal rate of return averaged 7.09 per cent. This return is comparable to returns that could have been achieved in alternative, non-agricultural forms of investment. As with the previous case, some of this return is generated from increased land value but resource use has been efficient in this operation using conservation cropping.

The average annual return to capital in this operation was found to be 4.81 per cent. Again, this is comparable to other non-agricultural forms of investment. This also indicates that a large proportion of the investment growth of the business has been generated by profit rather than increased asset value.

Net farm income is constrained to a large degree by the amount of debt being carried by the farm. In the period 1991-2 to 1997-8 the average annual interest cost was $42,077. The result is that net farm income has been negative in all but two of the seven analysed years. Average annual net farm income was -$4,995.

The farm has been under financial pressure from the inconsistent farm incomes. Borrowing has been undertaken to cover shortfalls. Net cash flow has predominantly been negative in recent years. The high variable cost of continuous cropping over an increased area has stretched credit facilities to their limits. New borrowings have been used to overcome cash shortages.

The negative annual cash flows have contributed to decreased farm equity. Nominal equity dropped from an estimated $552,000 in 1991-2 to almost $453,000 in 1997-8. This calculation is based on a nominal land price of $975 per hectare in 1991-2, which was assumed to have increased to $1190 per hectare in 1997-8. Land prices have increased in recent years with the introduction of canola and more intensive cropping rotations. Even despite this gain, equity has fallen. In percentage terms the farm was operating at equity of around 56 per cent at the end of 1997-98. This has dropped even further following the financial losses due to frost in 1998-99.

4.14.11. SUMMARY

The move to continuous cropping has not been without some problems but in the end the operator has always stuck by what he originally thought –

> There were plenty knockers but we looked through the research and saw that the system should work. In the end we didn’t really have a choice but to go to continuous cropping anyway. We would be further in debt now if we had stuck to sheep.

Given the financial state of the farm in the early 1990’s it was probably as big a risk to stay doing the same thing as to go to a new production system. The farmer has put every effort into making the system work, and relies on a wide range of information and advice to shore up agronomy and management skills. As the operator said: “it is a full-on system – you have to get it right”.

It is likely that the increase in management skills is the greatest impediment to the adoption of a system such as this in the southern NSW area. Whilst no-till cropping is done in many other areas, in this area advice from locals with experience in the system is hard to find because the system is relatively rare.

The newer system is providing lifestyle benefits for the operators. The smoothing out of the workload and lower labour requirements per unit of gross return compared to sheep have been major benefits for the operation and the farmer. He said - “My social life has never been better than at present.” A key to this has been ensuring that all machinery is in good working order prior to its operation. The operator is a qualified mechanic and part time engineer who ensures that all machinery is in order prior to operation.

In a technical sense the farm is presently well situated to take advantage of improvements in the cropping industry. The owner has equipped himself with a broad knowledge and skill base that puts him good stead to improve the financial position of the farm. However the operation is constrained by the lack of labour in some instances, and a lack of cash resources. The debt situation of the farm is constantly draining cash reserves and reduces the flexibility of the farm in the short term. Pressure to produce profit and cash to repay debt and pay interest constantly restricts the operation and development of the farm, as it does many other farms in the cropping zone. This has been demonstrated again prior to the 1999 cropping season. The grower aims to lease more land this year in order to improve the financial situation of the farm. The severe frost of October 1998 dramatically decreased the yield of many crops and hence the gross income of the farm. Estimates of loss are around 70 per cent in terms of yield and around 80 per cent in terms of income and profit due to the poor quality of the harvested grain. When applying for additional overdraft facilities to finance the inputs for this years crop the bank was reluctant to agree. The high debt situation of the farm has put the business in difficult situation. The farm needs the extra area combined with a good season and prices to relieve financial problems.

Table 92 - Operating profit over time.

Financial Year	1988-(	1989-(	1990-(	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999/2(
Annual Rainfall (mm)		623	580	458	841	792	361	716	628	386	498	
Growing season rainfall		451	495	332	548	399	141	496	373	260	381	
Operating Profit												
Income - Wheat	##	##	##	$ 24,284	$ 79,316	$ 11,495	$ 70,869	$ 104,568	$ 97,001	$ 115,042	$ -	$ -
Triticale	##	##	##	$ -	$ -	$ 12,400	$ 11,313	$ 40,482	$ 10,860	$ 60,433	$ -	$ -
Lupins	##	##	##	$ -	$ 21,590	$ 30,386	$ 67,500	$ 39,204	$ 37,600	$ 30,326	$ -	$ -
Canola	##	##	##	$ -	$ -	$ -	$ -	$ -	$ 21,459	$ 32,122	$ -	$ -
Livestock	##	##	##	$ 768	$ 1,530	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Wool	##	##	##	$ 25,845	$ 8,522	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Other*	##	##	##	$ 27,821	$ 26,742	$ 10,530	$ 61,126	$ 64,960	$ 61,416	$ 45,711	$ -	$ -
Asset sales												
Gross Income	**##**	**##**	**##**	**$ 78,718**	**$ 137,700**	**$ 64,811**	**$ 210,808**	**$ 249,214**	**$ 228,336**	**$ 283,634**	**$ -**	**$ -**
Chemicals	##	##	##	$ 8,394	$ 11,781	$ 12,300	$ 27,365	$ 29,945	$ 44,426	$ 22,116	$ -	$ -
Fertilisers	##	##	##	$ 24,445	$ 11,945	$ 22,000	$ 16,642	$ 10,344	$ 80,315	$ 3,725	$ -	$ -
Fuel	##	##	##	$ 7,213	$ 12,046	$ 4,050	$ 8,594	$ 9,069	$ 15,890	$ 4,742	$ -	$ -
Seed and Freight	##	##	##	$ 5,716	$ 4,694	$ 6,289	$ -	$ -	$ 13,726	$ 12,422	$ -	$ -
Livestock costs	##	##	##	$ 5,128	$ 3,653	$ -	$ 1,800	$ 1,800	$ -	$ -	$ -	$ -
Other		##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total variable cos	**##**	**##**	**##**	**$ 50,896**	**$ 44,119**	**$ 44,639**	**$ 54,401**	**$ 51,158**	**$ 154,357**	**$ 43,005**	**$ -**	**$ -**
Farm Gro #####	**##**	**##**	**##**	**$ 27,822**	**$ 93,581**	**$ 20,172**	**#######**	**#######**	**$ 73,979**	**#######**	**$ -**	**$-**

Cash overhead costs

Accountancy/agro	##	##	##	$ 1,715	$ 1,515	$ -	$ 2,652	$ 3,812	$ 2,560	$ 1,425	$ -	$ -
Casual labour	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Computer supplies	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Contractors	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Dogs	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Drawings	##	##	##	$ -	$ -	$ -	$ -	$ 16,502	$ -	$ 16,336	$ -	$ -
Electricity (70%)	##	##	##	$ 1,652	$ 931	$ 463	$ 1,493	$ 470	$ 1,680	$ 1,021	$ -	$ -
Private electricity	##	##	##	$ -	$ -	$ -	$ -	$ 840	$ -	$ -	$ -	$ -
Farm advisory fee	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Insurance	##	##	##	$ 2,837	$ 2,929	$ 1,818	$ 3,110	$ 4,110	$ 4,351	$ 7,376	$ -	$ -
Legal	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Licences & registr	##	##	##	$ 311	$ 36	$ 1,230	$ 2,620	$ 2,770	$ 246	$ -	$ -	$ -
Livestock purchas	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Machinery R&M	##	##	##	$ 2,357	$ 993	$ -	$ 5,715	$ -	$ -	$ -	$ -	$ -
Motor vehicle exp	##	##	##	$ 3,164	$ 2,554	$ 100	$ 1,476	$ 1,476	$ 2,190	$ 1,638	$ -	$ -
Other R+M	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Pest Control	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Plant hire	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Postage & station	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Private non deduct	##	##	##	$ 150	$ 453	$ -	$ 336	$ 836	$ 9,681	$ 2,976	$ -	$ -
Protective clothing	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Rates	##	##	##	$ 1,821	$ 5,431	$ 1,358	$ 2,498	$ 2,613	$ 2,455	$ 1,940	$ -	$ -
Rent	##	##	##	$ 100	$ 244	$ -	$ 195	$ 195	$ 140	$ 15,210	$ -	$ -
Repairs and gene	##	##	##	$ 584	$ 1,741	$ 7,000	$ 5,079	$ 5,766	$ 7,957	$ 9,690	$ -	$ -
Subscriptions	##	##	##	$ -	$ 89	$ -	$ 22	$ 506	$ 579	$ 469	$ -	$ -
Superannuation	##	##	##	$ 445	$ 653	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Telephone (90%)	##	##	##	$ 383	$ 531	$ 200	$ 1,035	$ 1,144	$ 986	$ 724	$ -	$ -
Telephone private	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Travelling expens	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Wages	##	##	##	$ 7,200	$ 9,620	$ -	$ -	$ 7,125	$ 17,755	$ 1,099	$ -	$ -
Workers comp.	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Cash overhe	**##**	**##**	**##**	**$ 22,719**	**$ 27,720**	**$ 12,169**	**$ 26,231**	**$ 48,165**	**$ 50,580**	**$ 59,904**	**$ -**	**$-**
Depreciation#	###	###	###	$ 9,300	$ 8,370	$ 31,533	$ 25,980	$ 21,462	$ 17,780	$ 14,773	$ 12,313	####
Operators allowanc	###	###	###	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 13,498	$ 30,000	$ 13,664	$ 30,000	####
Operating profit	**####**	**####**	**####**	**-$34,197**	**$27,491**	**-$53,530**	**$74,196**	**$114,931**	**-$24,381**	**$152,288**	**-$42,313**	**#####**
Land leasing	##	##	##	$ -	$ -	$ -	$ -	$ -	$ 5,000	$ -	$ -	$ -
Interest to creditors	##	##	##	$ 33,930	$ 28,305	$ 17,393	$ 46,657	$ 115,338	$ 45,029	$ 7,886	$ -	$ -
Net Farm Income	**####**	**####**	**####**	**-$68,127**	**-$814**	**-$70,923**	**$27,539**	**-$407**	**-$69,410**	**$144,402**	**-$42,313**	**#####**

Table 93 - Net Cash Flow over time.

Net Cash Flow												
Sources												
Cash in												
Sales	##	##	##	$ 78,718	$ 137,700	$ 64,811	$ 210,808	$ 249,214	$ 228,336	$ 283,634	$ -	$ -
New borrowings												
Total	**##**	**##**	**##**	**$ 78,718**	**$ 137,700**	**$ 64,811**	**$ 210,808**	**$ 249,214**	**$ 228,336**	**$ 283,634**	**$ -**	**$ -**
Cash out												
Variable costs	##	##	##	$ 50,896	$ 44,119	$ 44,639	$ 54,401	$ 51,158	$ 154,357	$ 43,005	$ -	$ -
Cash overheads	##	##	##	$ 22,719	$ 27,720	$ 12,169	$ 26,231	$ 48,165	$ 50,580	$ 59,904	$ -	$ -
Income tax	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Consumption	###	###	###	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 13,498	$ 30,000	$ 13,664	$ 30,000	####
Interest	##	##	##	$ 33,930	$ 28,305	$ 17,393	$ 46,657	$ 115,338	$ 45,029	$ 7,886	$ -	$ -
Principal	##	##	##	$ -	$ -	$ 9,000	$ -	$ 71,000	$ 33,300	$ 58,106	$ -	$ -
Land improvement	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Machinery replacei	##	##	##	$ -	$ -	$ 31,043	$ -	$ -	$ 21,851	$ 106	$ -	$ -
Land leasing	##	##	##	$ -	$ -	$ -	$ -	$ -	$ 5,000	$ -	$ -	$ -
Investment												
Total	**###**	**###**	**###**	**$ 137,545**	**$ 130,144**	**$ 144,244**	**$ 157,289**	**$ 299,159**	**$ 340,117**	**$ 182,671**	**$ 30,000**	**####**
Net Cash Flow	**####**	**####**	**####**	**$58,827**	**$7,556**	**$79,433**	**$53,519**	**$49,945**	**$111,781**	**$100,963**	**$30,000**	**#####**

Table 94 - Growth, equity and return on capital over time.

Change in equity													
Reduced machiner	###	###	###	$ 9,300	$ 8,370	$ 31,533	$ 25,980	$ 21,462	$ 17,780	$ 14,773	$ 12,313	####	
Increased machine	##	##	##	$ -	$ -	$ 31,043	$ -	$ -	$ 21,851	$ 106	$ -	$ -	
land improvement	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
Reduced debt	##	##	##	$ -	$ -	$ 9,000	$ -	$ 71,000	$ 33,300	$ 58,106	$ -	$ -	
Increased cash	####	####	####	-$ 58,827	$ 7,556	-$ 48,390	$ 53,519	-$ 49,945	-$ 84,930	$ 101,069	-$ 30,000	#####	
Investment	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
Change in equity	**####**	**####**	**####**	**-$ 68,127**	**-$ 814**	**-$ 39,880**	**$ 27,539**	**-$ 407**	**-$ 47,559**	**$ 144,508**	**-$ 42,313**	**#####**	
Assets –Land	###	###	###	$ 468,559	$ 635,902	$ 635,902	$ 635,902	$ 635,902	$ 635,902	$ 635,902	$ 635,902	####	$ 635,902
Assets - Machinery	###	###	###	$ 83,702	$ 75,332	$ 163,799	$ 137,819	$ 116,357	$ 98,577	$ 83,804	$ 71,492	####	$ 52,561
Assets - Stock	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Assets - Other	##	##	##	$ -	$ -	$ -	$ -	$ -	$ -	$ 81,000	$ 81,000	$ -	$ -
Total Assets	###	###	###	$ 552,261	$ 711,233	$ 799,700	$ 773,720	$ 752,258	$ 734,479	$ 800,706	$ 788,393	####	$ 688,462
Liabilities – overdra	##	##	##	$ -	$ -	-$ 3,973	$ 19,541	$ 5,515	-$ 19,465	$ 40,374	$ -	$ -	$ -
Long term loans an	##	##	##	$ -	$ -	$ 305,000	$ 303,333	$ 271,833	$ 225,250	$ 306,500	$ 264,800	$ -	$ -
Total liabilities	##	##	##	$ -	$ -	$ 301,027	$ 322,874	$ 277,349	$ 205,785	$ 346,874	$ 264,800	$ -	0
Equity ($)	###	###	###	$ 552,261	$ 711,233	$ 498,673	$ 450,846	$ 474,910	$ 528,693	$ 453,832	$ 523,593	####	$ 688,462
Equity (%)	100.0	100.0	100.0	100.0	100.0	62.4	58.3	63.1	72.0	56.7	66.4	100.0	100.0
Return on equity	5.7	5.6	5.5	12.3	0.1	14.2	6.1	0.1	13.1	31.8	8.1	5.8	0.8

Table 95 - Growth, equity and return on capital over time.

	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Annual Operating Profit	-$34,197	$27,491	-$53,530	$74,196	$114,931	-$24,381	$152,288	
Asset value	$ 552,261						$ 719,706	
Investment cash flow	-$586,458	$27,491	-$53,530	$74,196	$114,931	-$24,381	$871,994	
Internal Rate of Return	10.19%							
Annual Return on Capital	-6.19%	3.87%	-6.69%	9.59%	15.28%	-3.32%	21.16%	

4.15. CASE STUDY 3 - DOOEN, THE WIMMERA

4.15.1. INTRODUCTION.

The farm is situated north of the township of Dooen (Latitude 36°40'S Longitude 142°18' E), north of Horsham in the Victorian Wimmera. The farm is completely devoted to crop production, although sheep are agisted irregularly on stubbles after harvest until the next sowing period.

Two brothers operate the farm. One is married, while the other lives on the property. The parents of the brothers also still reside on the property. The family has been farming in the Dooen area for many years. This has been expanded in various stages to the present size of 2111 hectares. This expansion is seen in Table 96 below.

Table 96– Summary of events and expansion of operation over time.

Year of change	Aquired area (ha) and new area farmed (ha)	Farm Area (ha)
1870	First European settlers selected land in Wimmera.	
1872	Current property selected for £1 an acre by first settlers.	
1917	Descendants of present family purchased 320 acres (130ha) at Dooen.	130
1923	Family moved to Warracknabeal.	
1936	Moved back to Dooen from Warracknabeal with the purchase of 680 acres (275ha).	275
1946-60	Sharefarmed adjoining 320 acres.	
1961	Purchased 380 acres (154ha).	429
1965	Purchased 280 acres (114ha) @ 53 pound an acre.	543
1973	Purchased 730 acres (296ha) @ $215/acre.	839
1981	Purchase of 4WD tractor large capacity harvester.	
1983	Purchased 930 acres (376ha) @ $535/acre.	1215
1984	Built the first of the 500t grain storages on farm and first pea sowings.	
1985	Purchase of airseeder.	
1987	Purchased 970 acres(392ha) @ $405/acre.	1607
1991	First sowing of chickpeas.	
1993	First sowing of canola.	
1994	Purchased 62 acres nearby (25ha) @ $1000/acre.	1632
1995	Purchased 760 acres (307ha) @ $875/acre.	1939
1999	Purchased 590 acres (239ha) @ $920/acre.	2178

The holdings of the family are spread over three properties in close proximity. The farm operates as a company. In the last ten years the operation has expanded significantly. Since 1983 the farm size has almost tripled in size from 839ha to 2178ha. This has greatly enhanced the potential earnings of the company and sees the brothers well-positioned to endure the commodity cycles.

The move into continuous cropping has seen the cropped area, and hence production, greatly increase since the farm was a mixed farming operation. The farmers believer that the move into conservation cropping facilitated some of the expansion. If conventional cultivation was still practiced over such a large area, timing of operations or machinery capacity would become constraints: with conventional cropping cropping operations would not be able to be completed with sufficient timeliness without substantial increases in machinery investment. In judging a cropping system it is difficult to partition the effects of conservation cropping and other factors. There are complex interactions and relationships in the crop production systems. Further, the way conservation cropping advantages the operation of a farm system will be different in each case. Many of the benefits will be pecuniary in nature; many others will not. The most useful way to judge a system is by how the system as a whole operates. If the operation is successful financially, and meets goals and criteria in other important ways, then the system as a whole can be judged to be of benefit to the operator.

4.15.2. GENERAL CROPPING ENVIRONMENT - SOILS

The soils are typical of the Wimmera, particularly the Kalkee plains region. Grey self-mulching cracking clays (Ug 5.24) (Northcote, 1975) predominate with some red clay-loams on wind deposited rises. PH_{CaCl} varies from 6.5 to 8 depending upon soil type and management. The profile is particularly deep by Australian standards (greater than 1.5m), allowing good moisture retention, minimal waterlogging and relatively high levels of organic matter. Plant available water capacity is generally in the range of 180 to $200mm/m^3$. The sandy soils of the Mallee in comparison have plant available water contents of about 80mm. Hence the potential effectiveness of fallowing is much greater and crops generally have a good chance of "finishing" in a dry spring period. This has proved to be a key factor in the successful production of pulses in the area.

These soils characteristically occur in semi-arid environments of the inland, either on flood plains or on landscapes that have developed from shales and mudstones. The original predominating landscape was grassland. In the northern Australian cropping belt the cracking clays are often described by their original landscape of belah *(Casuarina cristata)*, coolabah *(Eucalyptus coolabah)* or brigalow *(Acacia harpophylla)*. The soils are generally regarded as being fertile but their recognition as cropping soils has had to await the development of modern technology in many cases, particularly regarding the expansion of irrigation on these soils over the last 30 years. Generally they are heavy textured, uniform soils with a characteristic structural profile development. The range of characteristics is extremely varied. Their defining feature however is that they all crack seasonally upon drying and are generally strongly structured with smooth faced peds throughout the profile. Cracking invariably leads to the surface horizon being self-mulching. This surface layer is sometimes capped with a crust of light, sandy clay.

The surface is generally a light to medium clay overlying heavier clay (45 to 80% clay) in the B-horizon which commences at a depth of 50 to 100mm. This subsoil generally has a well developed sub-angular to angular blocky structure. These blocks swell and shrink with the season. This cracking pattern greatly influences recharge of the soil.

The surface layers vary from acid to alkaline in nature, becoming strongly alkaline at depth. Many of these soils will vary across paddocks due to the formation of wind deposited gilgai formations. Hence grey heavier clays occur at the lowest points in the paddock, with brown and red loamy-clays in higher parts of the paddock, as is the case on the study farm.

As Figure 82 shows the cracking nature of the soil upon drying. This photo of a chickpea crop at Natimuk, on similar soils to that of the case study farm, shows cracking where knife points have sown the crop at ten inch spacings as well.

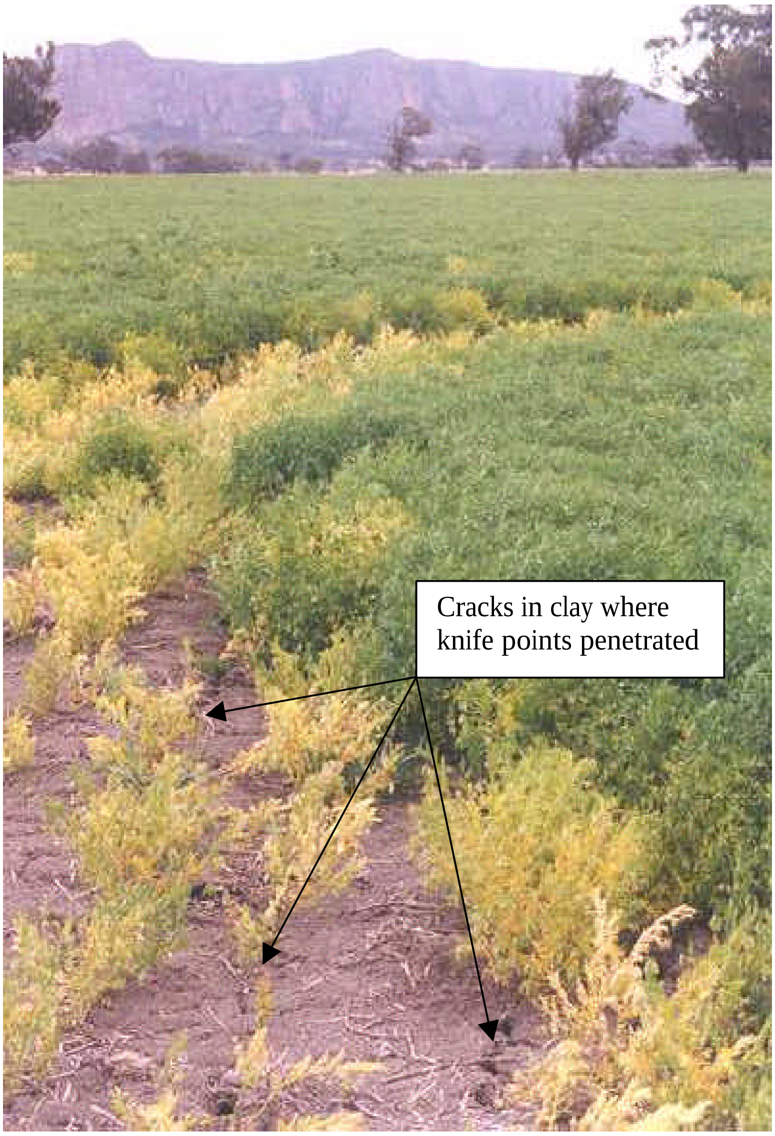


Figure 82 - cracking grey clays at Natimuk in the Wimmera.

These soils are moderately fertile in the natural state, but less so than black earths. Hence fertility declines more quickly with cropping than happens with the black earths. Total nitrogen levels in soils such as these have decreased from 0.2 to 0.07 percent after continuous farming in the Wimmera (Storrier, 1994). Phosphorus deficiency is widespread, particularly on alluvial soils, while responses to molybdenum, zinc, sulphur, and manganese have been recorded in most areas. Zinc deficiency, in particular occurs where gilgai soils have been levelled, exposing the calcereous subsoil. Toxic levels of boron in the subsoil have also been reported and have recently been implicated in reduced production in the Wimmera and Mallee. Cation exchange capacity varies according to clay minerals present. The exchange complex is usually calcium saturated in the upper horizons, with sodium exceeding 15% of the exchange capacity in the subsoil. Available water storage is not as great as the black earths due to the presence of non-expanding clays, lower clay content or poor subsoil structure. However if these factors are managed by appropriate use of fallow systems, deep tillage and amelioration with gypsum, improved recharge can greatly influence yields under dryland farming.

High sodium levels and the related dispersive effects can influence the development of massive and compacted structures and reduced seedling emergence. Gypsum can reduce these effects and increase yields on most soils, including the Wimmera. Addition of the calcium carbonate increases permeability by replacing sodium in the low permeability layers, increasing water available to the crop. Soluble salts are also prevalent at depth. This has lead to the development of salinity when these soils are irrigated.

The soils have been extensively cropped in the Wimmera where traditionally fallowing was used to release soil nitrogen and to store water for satisfactory wheat production. Rice production occurs on Southern NSW clays where phosphorus application is not needed due to the release of native phosphorus for the crop. In summer rainfall areas both summer and winter crops are produced under bare fallow and stubble mulch conditions. Much of northern NSW is renowned for high protein wheat production on these soils. In Queensland the black earths have been the preferred soils for agricultural production rather than the clays but with adequate moisture storage successful production of wheat, sorghum and oilseeds has occurred. Cotton production is extensively carried out on these soils in both northern NSW and Queensland.

4.15.3. RAINFALL

The Horsham region is said to be in an 18 inch rainfall belt (450 millimetres). As with almost all other areas of crop production in Australia, this rainfall can be extremely. This can be seen in the graph of Longerenong's rainfall over the last 15 years. Longerenong is approximately 10km's from the farm.

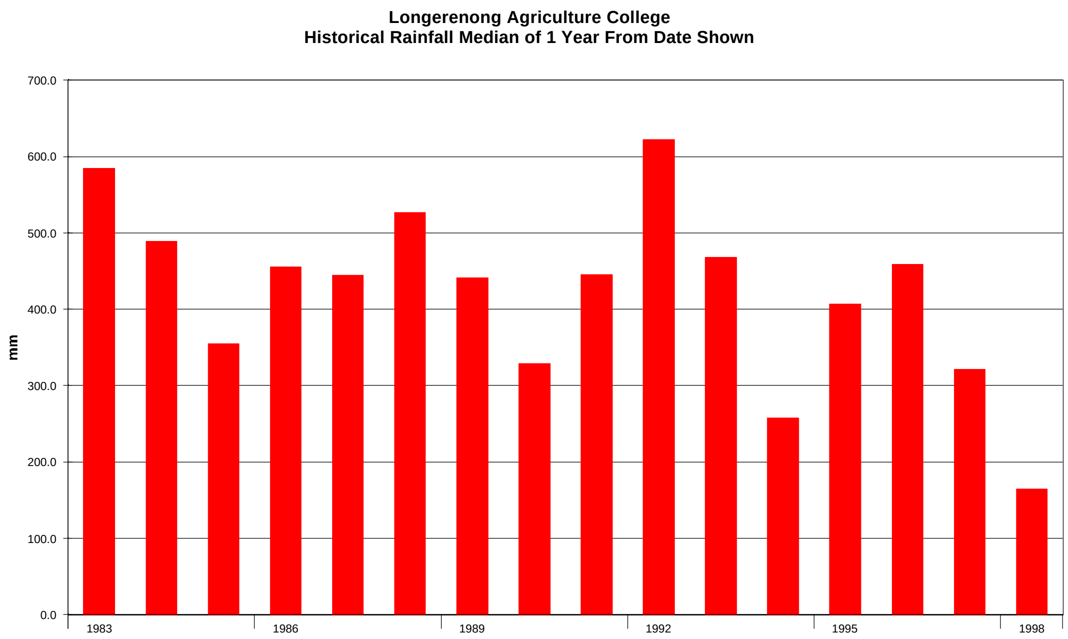


Figure 83 – Rainfall in the last 15 years at Longerenong (nb. 1998 only up to June 30)

The graph above shows the variability of the rainfall but patterns are generally winter dominant as expected in this semi-Mediterranean environment.

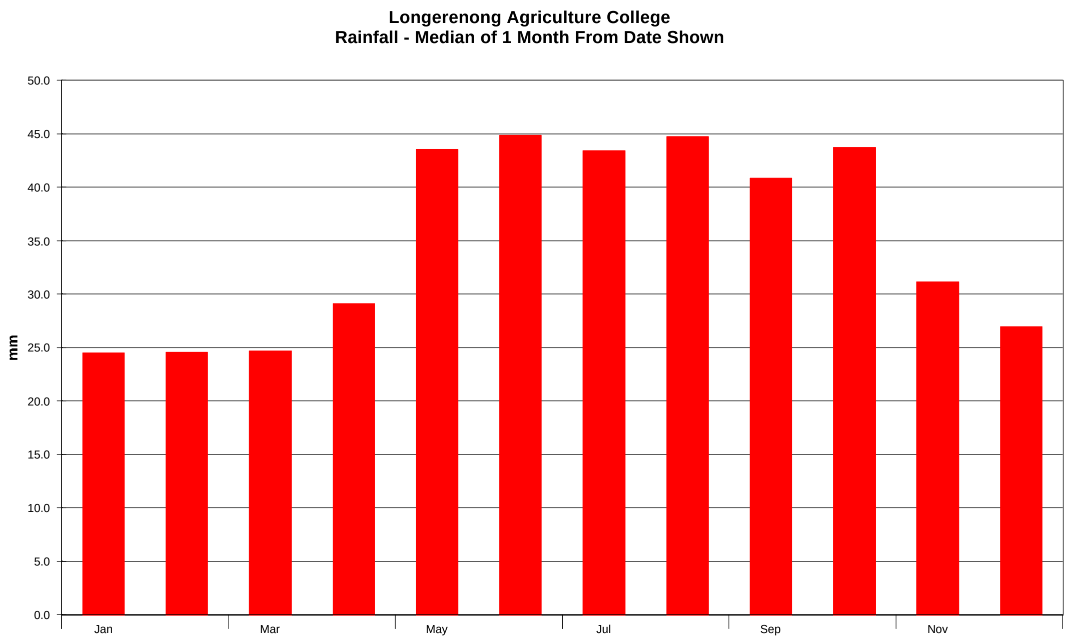
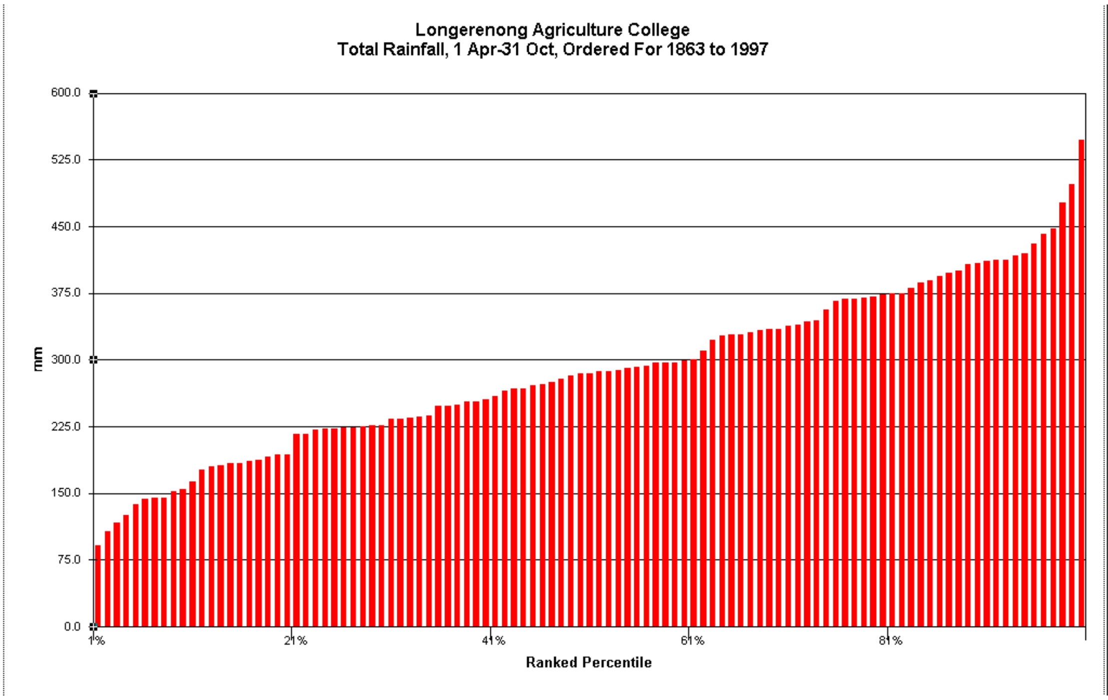


Figure 84– Average monthly rainfall at Longerenong



An important crop production factor is the timing of the break. This will confer the time that crops can be sown and in turn help determine their potential yields.

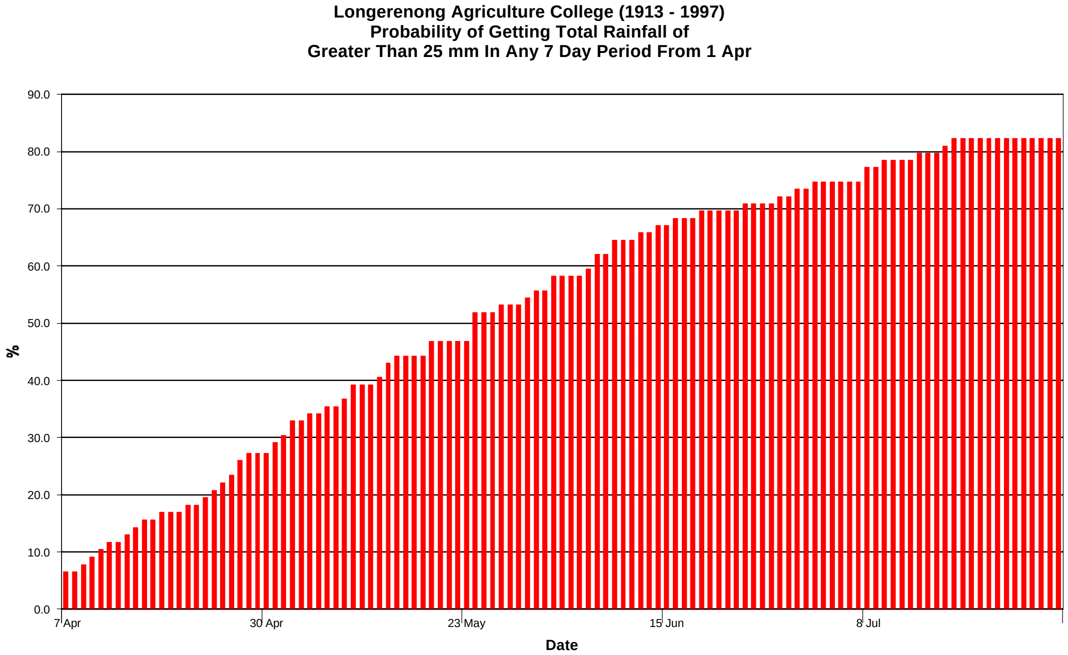


Figure 85– The probability of receiving rains of greater than 25mm in a period of a week in autumn

As shown in Figure 85, the average date for a reasonable break is late May. This means that shorter season crops than those seen in southern NSW will be employed but the finishing ability of the deep soils in the area will offset this to some degree. The result is that harvest in the area will usually start at a date later than most areas of the state.

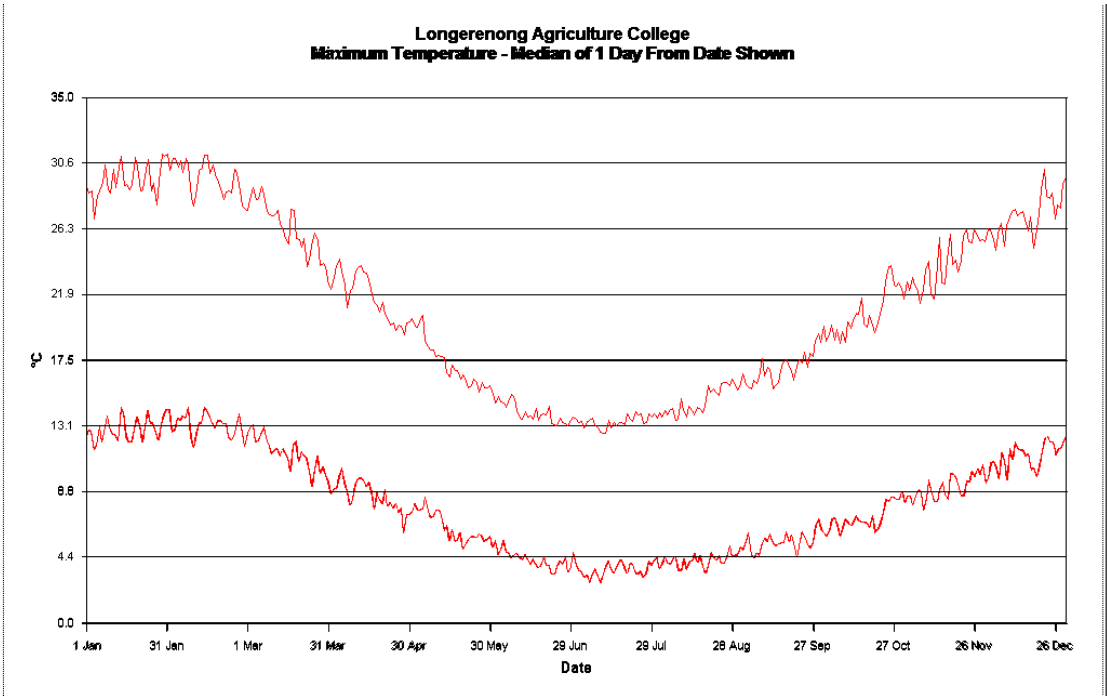


Figure 86– Average long term maximum and minimum temperatures at Longerenong.

4.15.4. CROPPING EXPANSION, MACHINERY AND MANAGEMENT PRACTICES

The farmers changed to continual cropping in 1984. Since this time every paddock, with the exception of some paddocks that have been used for green manuring, has been cropped. Prior to 1984, a traditional rotation of wheat, barley and mechanical fallow was used. The family sold the last of the cross-bred sheep operation in 1989, although there has been some chemical fallowing in 1998. The main related factor in the change to continuous cropping was the introduction of legumes. Legumes and conservation cropping were integrated into the farm at the same time so it is difficult to attribute benefits to either of the changes. Without the introduction of legumes the move to continuous cropping could not have happened as effectively.

Conservation cropping has allowed great improvements in erosion control on the farm. In the past it was common to plough the paddock into ridges just to stop the soil from blowing. Although the heavy soil is not particularly prone to wind erosion, the lighter rises are susceptible to wind erosion. Conservation cropping has alleviated this problem in many areas.

The farm's machinery is some of the best in the region. Machinery purchases are usually new and all equipment is kept in good working order. Any machinery not used extensively was sold in recent times to cater for the move to minimum tillage cropping.

The crops are sown with a 14.2m (44') Flexicoil 820 seeding bar, purchased in 1996. A Flexicoil 1720 airseeder is towed behind. The high breakout tines allow penetration into the hard setting soils. Row spacing is 22cm (9") for all crops. Keech spear-type points are used. The non-abrasive soils have allowed the points to last the 6 years since years since purchase. The seeder is pulled by a Verstatile 936 (230hp) 4WD tractor, purchased in 1988. The seed opening is closed with coil packers, which were purchased in 1998.

Prior to the present 820 Flexicoil sowing equipment an 800 Flexicoil was used. Prior to this a 16.45m (51') Shearer 4150 bar was used.

Spraying is carried out with a thirty one metre (95'), 3000 litre Goldacres boomspray, purchased in 1993. This spray tank size allows about sixty hectares to be sprayed. This is usually towed by a John Deere 7700 (140hp) front wheel assist tractor.

Any cultivation is carried out with an 80 plate offset disc (1993). Secondary cultivation is done with 19m (60ft) folding harrows and the seeding bar.

Harvesting is done with a 1996 Case IH 2188 harvester. The standard 9.6m or 11.6m front operates in cereals while canola is harvested with a 1995 Smale pick up front. Legumes are harvested with both the pick-up front and the open flexi-front. A windrower was purchased in 1995 to windrow canola.

Cereals are harvested and in summer residues are mulched with a 24ft slasher. The high amounts of stubble are mulched into lengths that are able to pass through the airseeder tines.

The operation has a large capacity to store grain. 2 bogey drive tip trucks are used to transport grain from the paddock to farm silos at harvest time. Any additional transport of grain required is done using a Scania 142 with 36' Lusty tipper tray. This usually carries around 30t of grain. This is also used to transport grain from the farm to private traders in Ballarat. A 30' Sherwill auger and a Westfield tubulator supply timely elevation to the 2700t (2x350t + 4x500t) of storage space. These silos were constructed by the growers on farm, costing about $100,000 in total. Four one hundred tonne silos also exist, costing a total of $23,000. In addition the farm has a 60 tonne weighbridge to accommodate the year round sales program. This cost $15,000. A grain cleaner was also purchased in 1997 for $36,000.

Total machinery investment is large. Once the farm had moved to conservation cropping a lot of excess machinery was offloaded, which offset the cost of some machinery, but the farm is still heavily capitalised in machinery.

Table 97 – Machinery schedule from the study farm. Supplementary items are not included.

Machinery item	New purchase cost	Year Bought
Versatile 936 Tractor	$167,739	1989
JD 7700 Tractor	$102,425	1994
Flexicoil airseeder	$48,998	1994
Flexicoil seeding bar	$68,790	1994
Flexicoil packers	$36,426	1998
Ennor 26' offset disc	$45,000	1993
Goldacres boom	$33,000	1993
Case IH 2188 header	$241,365	1996
Smale Pickup front	$6,800	1995
Versatile Windrower	$10,500	1995
Superior slasher	$26,000	1996
Grain cleaner	$36,000	1997
Scania 142	$85,000	1996
36' Tray	$30,000	1990
42' Tray	$19,000	1998
2 Acco's	$22,690	1991
4 x 500t silo's	$72,000	1986-93
2 x 350t silo's	$30,000	1988
4 x 60t silo's	$18,600	1988
Westfield tubulator	$18,000	1990
Weighbridge	$20,000	1998
Dual cab ute	$30,050	1992

The total value of the plant and equipment is in the vicinity of $700,000. Precise estimation is difficult due to the vagaries of the second hand market but given an annual depreciation rate of 10 percent for motorised machinery and lower rates for fixed assets such as silos, the annual depreciation cost would be around $70,000. This cost highlights one consequence of owning high capital cost machinery. The counter argument is that not losing crop from adverse weather and poor machinery workrates justifies significant machinery investment.

4.15.5. ROTATION

The rotation is very flexible, allowing opportunity cropping to occur. Price signals play a major role in the cropping program in any year. Soft wheat, malting barley, kabuli and desi chickpeas, lentils, peas and canola are the main crops grown on the farm. A complete rotational history for nearly 20 years in each paddock is shown in Table 98 below.

Table 98– Rotational history of paddocks on case study farm.

Paddock	1982	1983	1984	1985	1986	1987
Farm	John's					
Avalon East	W	Mf	W	Fp	Mf	W
Avalon West	W/Mf	W/Mf	W/Mf	W/Fp	Fp/Mf	W/B
Baker's East	n/a	n/a	n/a	n/a	n/a	n/a
Baker's North	n/a	n/a	n/a	n/a	n/a	n/a
Baker's South East	n/a	n/a	n/a	n/a	n/a	n/a
Baker's South West	n/a	n/a	n/a	n/a	n/a	n/a
Burns'	n/a	n/a	n/a	n/a	n/a	Mf
Church Hill	n/a	n/a	n/a	n/a	n/a	B
Dogwood East	Mf	W	B	Mf	W	Fp
Dogwood West	W	B	Mf	W	Fp	B
Finlaysons	Mf	W	B	Fp	Mf	W
Harris/house	Mf	W	Mf	W	Fp	B
Harris/Jung	W	Mf	W	Mf	W	Fp
Harris/Max	Mf	W	Mf	W	B	Fp
Highway	n/a	n/a	n/a	n/a	n/a	B
Nat's 110	Mf	W	B	Fp	Mf	W
Nat's 160	W	Mf	W	Mf	W	Fp
Nat's North	Mf	W	Mf	W	Fp	B
Nat's south	W	W	B	Fp	B	Fp
Plantation	n/a	n/a	n/a	n/a	n/a	n/a
Point	Mf	B	Mf	W	B	Fp
Rush's	Mf	W	Mf	W	Fp	B
School	Mf	W	Fp	W	Mf	W
Springbank	W	Mf	W	Mf	W	Mf

Paddock	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Farm	John's											
Avalon East	Fp	B	CpD	CpD	W	CpD	W	W	B	Le	Cf	Ca
Avalon West	Fp	B	CpD	B	CpK	Ca	W	W	CpD	Cf	Ca	W
Baker's East	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	B	CpD	B	Fp
Baker's North	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Le	B	Le	Ca
Baker's South East	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	B	Le	W	Fp
Baker's South West	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	B	Le	W	CpK
Burns'	W	Fp	B	CpD	CpD	W	CpD	W	Le	Ca	W	Le
Church Hill	Fp	B	Fp	CpD	W	CpD	B	B	Ca	W	Le	B
Dogwood East	W	Fp	B	CpD	B	Fp	Ca	B	CpD	B	Le	Ca
Dogwood West	Fp	B	CpD	Fp	W	CpD	Ca	B	CpD	B	Le	Ca
Finlaysons	B	Fb	W	B	Fp	W	CpD	W	CpD	B	Le	W
Harris/house	Fp	B	Fb	W	CpD	W	CpD	B	CpD	B	Cf	Ca
Harris/Jung	B	Fp	W	CpK	B	Fp	W	Ca	W	Le	B	Cf
Harris/Max	Mf	W	Fp	B	CpK	B	CpD	B	Ca	W	CpK	B
Highway	Fp	B	Fp	W	CpK	W	CpD	B	CpK	W	CpK	B
Nat's 110	Fp	B	CpD	CpD	W	CpD	Ca	W	CpD	B	Le	Ca
Nat's 160	B	Fp	W	CpD	B	Fp	Ca	W	Ca	W	B	B
Nat's North	Fp	B	Fp	W	Fp	W	CpD	CpD	W	Le	B	Le
Nat's south	B	Fp	B	CpD	W	CpD	Vm	Ca	W	CpD	B	Cf
Plantation	n/a	n/a	n/a	n/a	n/a	n/a	n/a	CpK	W	CpD	W	B
Point	B	Fp	B	Fp	W	CpD	Ca	B	B	Cf	Ca	W
Rush's	Fp	W	Fb	B	CpD	B	CpK	B	Ca	W	CpK	W
School	Fp	B	Fp	W	CpK	W	CpD	W	B	Cf	Ca	W
Springbank	W	Fb	W	CpD	B	CpD	Ca	W	B	Cf	Ca	W

Table 99 – Percentage of farm under particular crops in last decade.

Crop	1982	1983	1984	1985	1986	1987
Farm	John's					
Wheat	30	37	21	25	15	16
Barley		4	16		14	31
Field Peas			1	21	17	25
Mech Fallow	32	21	25	15	16	11
no data	38	38	38	38	38	17
Total Area %per year	**100**	**100**	**100**	**100**	**100**	**100**

Crop	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Farm	John's											
Wheat	14	8	16	11	30	22	18	35	15	26	15	19
Barley	19	41	17	20	15	8	10	34	24	21	22	25
Field Peas	43	25	24	4	7	11						8
Faba Beans		8	6									
Chick Peas - Kabuli				4	18		2	1	3		12	4
Chick Peas - Desi			20	43	13	34	28	3	24	12		
Lentils									11	21	27	10
Canola						7	17	11	22	7	13	24
Vetch - Green Manure							6					
Chem Fallow										13	11	11
Mech Fallow	6											
no data	17	17	17	17	17	17	17	16				
Total Area %per year	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Cereals

Soft wheat (cv. Vectis) and malting barley (cvs. Arapiles and Galleon) are the main cereals grown on the farm. The area is set to increase in 1999 due to the problems with chickpea production. The treatment of wheat has changed markedly in recent times. Prior to the adoption of conservation cropping trifluralin was integral to the weed control plan. Working the soil into a fine tilth was thought to be a pre-requisite for the use of the chemical. This has been replaced by the use of suflonylureas chemicals. These residual chemicals are very effective against a range of weeds, are cheap, but do not break down quickly in soils with high pH levels. This has created problems in lentil crops in recent years. Cereals were previously sown into worked legume stubbles. These stubbles are now left to breakdown without disturbance. Pre-drilling of urea also occurs in these stubbles at times prior to the cereal being sown.

Legumes

Legumes were previously sown into burnt or mulched cereal stubble. Burning has now been eliminated with mulching occurring over the summer period. Volunteer cereals present a large problem in some legume crops with this method.

1997 was the first year since the introduction of continuous cropping that fallow was been used. Green manure crops, predominantly vetch, have also been used to increase nitrogen levels. Fallowing was also carried out to help eradicate tare (vetch) as a weed in legume crops. Control options are limited in legumes and combined with the inability to grade out the weed seed in crops such as lentils, prices can be reduced or crops refused for sale. The growers are aiming to have around 1/6th of the farm green manured and fallowed every year to tackle the problems of vetch in subsequent crops, herbicide resistance and depleted soil nitrogen levels.

The change in the type of crops grown can be seen in Table 100 below.

Table 100 - Area (ha) of crops over time.

Year	Wheat	Barley	Canola	Field Peas	Faba Beans	Chick Peas- Kabuli	Chick Peas - Desi	Lentils	Green manure	Chem. Fallow	Mech. Fallow
1999	354	469	447	152		68		181		201	
1998	289	403	248			219		511		202	
1997	480	395	128				226	395		248	
1996	279	418	417			63	487	208			
1995	662	631	201			25	53				
1994	346	196	322			36	530		117		
1993	410	156	140	209			632				
1992	556	285		123		339	244				
1991	212	366		76		84	809				
1990	295	321		448			367				
1989	156	775		470	116						
1988	264	352		811	146						
1987	297	584		462							204
1986	285	253		325							297
1985	477			398							285
1984	391	292		16							461
1983	693	76									391
1982											592

*Nb. 1999 are budgeted figures only

The changing acreages of different crops on the farm over time indicate the change that has confronted crop farmers in the Wimmera over the last 5 years. A summary of the acreages planted to various crops reveal that this farm was one among many adopting legumes and canola.

Table 101 - Area ('000 ha) of crops over time in Wimmera/Bordertown agroecological zone.

Year	Wheat	Barley	Oats	Triticale	Lupins	Canola	Field Peas	Faba Beans	Chick Peas-	Vetch	Lentils	Safflower	Crop ha ('000ha)
1996	389	257	82	21	41	77	74	41	102	9	11.5	17	1122
1995	381	282	103	18	53	71	87	30	98	8		23	
1994	268	182	39	7	45	57	95	40	118	6		13	

1993	268	245	56	4	43	22	87	43	84	6	0.6	21	889
1992	278	211	66	3	36	12	75	56	66	18	0.3	12	
1991	211	211	51	3	31	15	79	45	77	4	0.2	15	
1990	298	175	48	4	22	7	67	34	51	1	0	5	712
1989	403	204	58	5	29	9	88	23	19	1	0	8	
1988	375	184	47		30	10	123	17	10	11	0	13	
1987	397	187	53	4	33	14	143	13	8	0	0	10	
1986	527	139	49	6	24	9	127	9	4	0	0	4	898

Source: (GRDC, 1999)

The increased intensity of cropping in the Wimmera is clear in Table 101. The growth of the canola, chickpea and lentil industries has driven this increase. The top 25 percent (ranked by rate of return) of producers in this zone had annual returns to capital of nine percent over the years 1992/3 to 1996/7. Their average farm size was 980 hectares and cropping intensity was 55 per cent. The bottom 25 per cent averaged –6 per cent return to capital from an average farm size of 664 hectares, cropped at 32 per cent intensity. The equity of the bottom 25 per cent was on average higher than that of the top 25 per cent at 86 per cent (c.f. 84 per cent). Adoption of direct drilling/minimum tillage (73 per cent c.f. 46 per cent) and stubble retention (96 per cent c.f. 77 per cent) was much higher in the top 25 per cent of producers. Expenditure on spraying and nitrogen fertiliser was also greater in the top producers. Phosphate fertiliser spending was actually greater in the bottom 25 per cent of producers. Cropping specialists in the Wimmera produced much greater returns than mixed farmers in the area over the period from 1995 to 1998 (GRDC, 1999). Average farm cash income in these three years for grain producers was $125,089 compared to mixed growers, who averaged $50,943. The latter produced negative operating profit in two of these years. Admittedly these years were good for most croppers in terms of price and yield (1997 yields were down), but the message over a sustained period of time has been clear. Higher cropping intensity, greater land area, adoption of alternative crops, minimum tillage and stubble retention have increased operating profits. This has been the situation in this case study farm.

There are a range of reasons for cash flow and operating profits being good for the case study farm in recent times. Starting in 1982, the family embarked on a program of expansion. Forty hectares was purchased in 1982, 400 in 1985 and another 280 in 1997. Financial pressure following the first two purchases has forced the family to attempt to maximise gross income over the past ten or so years. In latter times a run of good seasons and favourable prices has seen this pressure decrease however. The result is that the operation can now afford fallowing and green manuring, whereas once a crop was needed in every available season. The result has been the expansion of the farm to the present 2178 hectares. It is estimated that the average area of farms in region is around 600 to 720ha. In this case the 2111 hectares has to provide for three families and the expansion has enabled benefits of size to be reaped.

In essence, the rotation is flexible so as to allow the opportunistic choice of the potentially most profitable crops in each year. The legume options maintains soil fertility in most paddocks. The cropping mix is likely to change dramatically in 1999 however. In 1998 legume crops were devastated by frost and an explosion of the acsochyta virus in chickpea crops. Many crops in the Wimmera were destroyed by a combination of these factors last year. Some damage in a chickpea crop can be seen in Figure 87 with the yellow patches signalling infection.

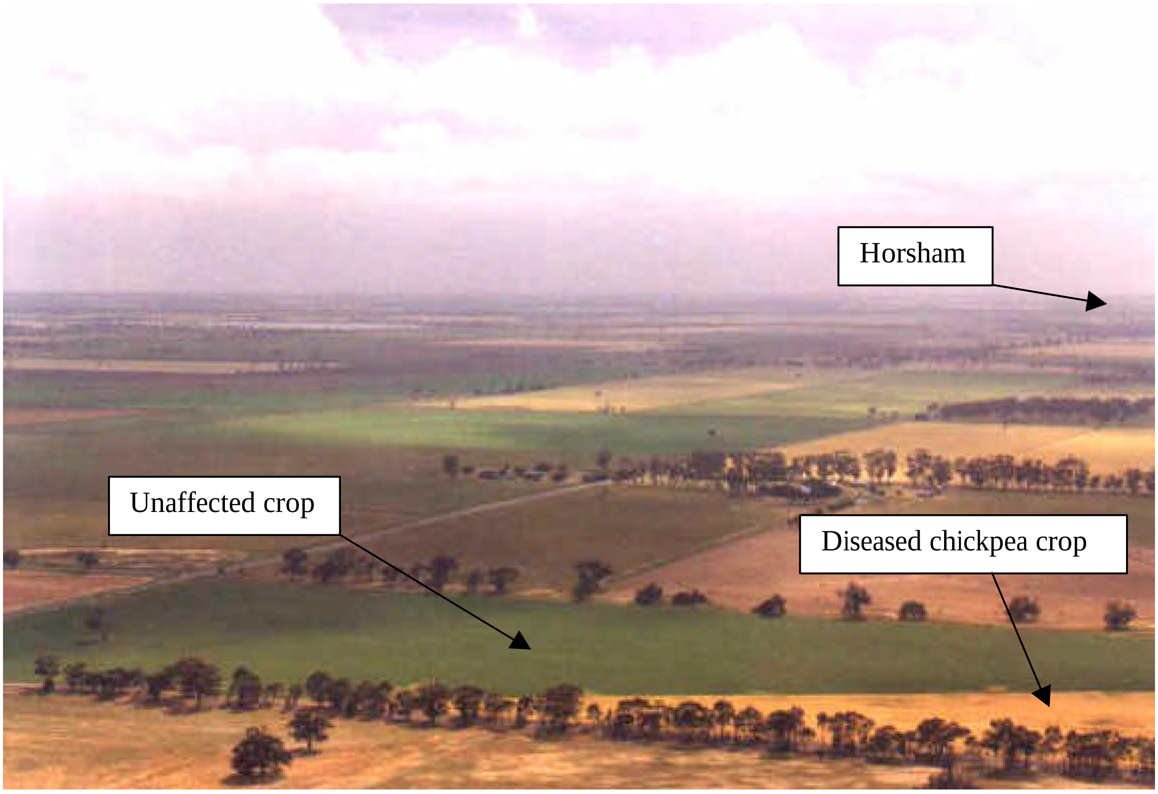


Figure 87 – the effect of disease on Wimmera crops as seen from the top of Mount Natimuk, October 1998. Note the paddock in the foreground. Green is unaffected chickpea crop with diseased crop in bottom corner.

The only course of action for many growers was to plough the crops into the ground to at least get a green manuring effect for the next years crop.

Figure 88– offset disc working in a chickpea crop in the Wimmera, October 1998.

The ascochyta virus attacks the stem of the plant, cutting translocation of nutrient and moisture while causing the plant to collapse. Lesions can be seen in a lightly infected crop in Figure 89 below.

Figure 89– Ascochyta lesion on chickpea crop in October 1998.

The result for growers of the area were large financial losses in 1998 and a much reduced chance of large profits in 1999. Crop options will be severely limited for many growers due to the lack of resistant cultivars and fear of a repeat of last years infections. Even if the crops are grown the profits will be reduced because of the need to regularly apply relatively expensive fungicides.

4.15.6. HERBICIDES AND WEED CONTROL

The diverse rotations on the farm should help ensure that herbicide resistance risks are limited. The main factor that limits the development of herbicide resistance at present is the reliance on Group B chemicals such as Glean. These residual chemicals can persist into the next year on the high pH soils, reducing the growth of non-tolerant crops. Volunteer cereals and tares in legumes are also a problem.

Despite the existence of a large range of crop options, high soil pH limits the use of many compounds as the residual risks are high. The result is the extensive use of group D and M chemicals (see Table 102). Although Table 102 only constitutes one paddock on the farm, the consistent rotations over the farm make this paddock representative of the farm. The increased selection pressure to these chemicals is of concern.

Table 102 – Herbicide applications on one paddock of the case study farm.

Herbicide Resistance History

Avalon East		A fop	A dim	B G/L	B	C	D	E	F	G	H	I	J	K	L	M	N
1982	Wheat						X										
1984	Wheat						X										
1985	Field Peas						X										
1987	Wheat				X												
1988	Field Peas						X										
1989	Barley				X							X					
1990	Chick Peas - Desi	X				X											
1991	Chick Peas - Desi					X	X									X	
1992	Wheat						X									X	
1993	Chick Peas - Desi					X	X									X	
1994	Wheat						X									X	
1995	Wheat						X									X	
1996	Barley	X			X		X		X							X	
1997	Lentils					X	X									X	
1998	Chem Fallow															X	
1999	Canola						X									X	

Herbicide Resistance Classes

4.15.7. STUBBLE MANAGEMENT AND NUTRIENT SUPPLY

Stubbles have generally been maintained on the property over time. In recent times stubbles have been mulched with a slasher to allow seeding machinery to pass through.

Fertiliser application on the property is around the average for the district. The fertile soils of the Kalkee plains supply reasonably high levels of nutrient to the soil. In general, wheat crops receive 70 kilograms of DAP with urea topdressed later at a rate that depends on seasonal conditions. Canola receives similar treatment. The use of legumes over the years has reduced the need for nitrogen fertilisation.

4.15.8. HARVEST

Harvest of the crops is done efficiently by the high capacity axial flow Case IH 2188 header. The canola crop is windrowed with the Flexicoil windrower. A Smale pick-up front reduces losses significantly. The legume crops are harvested with an open flex-front. This allows ground following ability in the low legume crops.

4.15.9. MARKETING

The marketing of the crop is advanced by Australian standards. A range of niche markets are filled with the growing of soft wheats, which are sold privately to millers, biscuit wheats, malting barley, lentils, kabuli and desi chickpeas and canola. No grain is sold to the traditional marketing authorities. The expansion of the storage capacity on the farm has in part been aimed to obviate the need to enter the traditional marketing routes. The growers believe that they can take care of the storage risks and for the most part capture profits that come from being able to store and hold onto grain to sell at higher prices during the year.

4.15.10. ECONOMIC AND FINANCIAL SITUATION OF THE FARM

The long-term health of the business is demonstrated in the listed below in Table 103.

Table 103 - Operating profit over time.

Financial Year	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Annual Rainfall (mm)		623	580	458	841	792	361	716	628	386	498
Growing season rainfall		451	495	332	548	399	141	496	373	260	381
Operating Profit											
Income - Wheat	$ 81,466	$ 120,453	$ 144,698	$ 49,756	$ 169,955	$ 201,807	$ 84,474	$ 244,649	$ 365,733	$ 327,381	$ 174,268
Barley	$ -	$ 92,494	$ 64,350	$ 171,560	$ 140,646	$ 160,314	$ 34,840	$ 19,830	$ 437,194	$ 85,767	$ 75,185
Canola	$ 75,201	$ -	$ -	$ -	$ -	$ 110	$ 75,815	$ 19,686	$ 132,882	$ 103,328	$ -
Chickpeas	$ -	$ -	$ -	$ -	$ -	$ -	$ 426,934	$ 7,658	$ 356,141	$ 220,937	$ 89,889
Lentils	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 47,708	$ 182,397
Peas and lupins	$ 323,887	$ 274,982	$ 191,586	$ 127,220	$ 72,100	$ 596,284	$ 66,528	$ -	$ -	$ -	$ -
Beans	$ -	$ -	$ 30,490	$ 11,842	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Livestock	$ 18,039	$ 42,577	$ 999	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Wool	$ 21,284	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Gross Income	**$ 519,877**	**$ 530,506**	**$ 432,123**	**$ 360,378**	**$ 382,701**	**$ 958,515**	**$ 688,591**	**$ 291,823**	**$ 1,291,950**	**$ 785,121**	**$ 521,739**
Chemicals	$ 14,082	$ 25,178	$ 17,481	$ 44,606	$ 44,258	$ 32,335	$ 42,432	$ 43,828	$ 59,549	$ 44,192	$ 86,234
Fertilisers	$ 14,520	$ 27,051	$ 28,181	$ 30,806	$ 51,031	$ 54,973	$ 64,489	$ 52,679	$ 98,734	$ 29,653	$ 82,387
Fuel	$ 43,058	$ 33,227	$ 34,732	$ 26,168	$ 37,707	$ 50,270	$ 31,356	$ 32,373	$ 38,942	$ 44,849	$ 33,366
Seed and Freight	$ -	$ 9,379	$ 10,131	$ 33,553	$ 17,600	$ 9,441	$ 15,193	$ 18,250	$ 26,925	$ 5,954	$ 10,019
Livestock costs	$ -	$ 239	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Other	$ -	$ 163	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total variable costs	**$ 71,660**	**$ 95,237**	**$ 90,525**	**$ 135,133**	**$ 150,596**	**$ 147,019**	**$ 153,470**	**$ 147,130**	**$ 224,150**	**$ 124,648**	**$ 212,006**
Farm Gross Margin	**$ 448,217**	**$ 435,269**	**$ 341,598**	**$ 225,245**	**$ 232,105**	**$ 811,496**	**$ 535,121**	**$ 144,693**	**$ 1,067,800**	**$ 660,473**	**$ 309,733**

1997-98		1998-99	
	498		
	381		
$	174,268	$	30,407
$	75,185	$	42,954
$	-	$	167,280
$	89,889	$	4,554
$	182,397	$	20,466
$	-	$	-
$	-	$	-
$	-	$	-
$	-	$	-
$	**521,739**	**$**	**265,661**
$	86,234	$	84,031
$	82,387	$	87,363
$	33,366	$	35,394
$	10,019	$	18,367
$	-	$	-
$	-	$	-
$	**212,006**	**$**	**225,155**
$	**309,733**	**$**	**40,506**

Cash overhead costs

Accountancy/agronomist	$ 869	$ -	$ 2,452	$ 3,690	$ 3,937	$ 5,953	$ 7,000	$ 11,617	$ 12,917	$ 6,324	$ 4,620	$ 4,620
Advertising	$ -	$ 20	$ 243	$ 26	$ 165	$ 100	$ 75	$ 30	$ 36	$ 249	$ -	$ -
Casual labour	$ -	$ 807	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Computer supplies	$ -	$ 1,000	$ 1,097	$ 498	$ 3,716	$ 1,383	$ 1,002	$ 3,167	$ -	$ -	$ -	$ -
Contractors	$ -	$ 9,750	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Dogs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Electricity (70%)	$ -	$ -	$ 175	$ 208	$ 238	$ 434	$ 229	$ -	$ -	$ -	$ -	$ -
Private electricity	$ -	$ 301	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 313	$ 313
Farm advisory fees	$ 680	$ 1,295	$ -	$ -	$ -	$ 3,269	$ 1,214	$ -	$ -	$ -	$ 1,440	$ 1,440
Insurance	$ 240	$ 133	$ 2,895	$ 3,805	$ 5,382	$ 6,764	$ 3,155	$ 4,915	$ 4,479	$ 3,399	$ 4,726	$ 4,726
Legal	$ 190	$ -	$ 649	$ 2,140	$ 645	$ 75	$ 2,065	$ -	$ -	$ -	$ -	$ -
Licences & registrations	$ 680	$ 1,012	$ 2,747	$ 1,435	$ 1,565	$ 1,379	$ 1,129	$ 1,510	$ 5,119	$ 1,415	$ 1,895	$ 1,895
Machinery R&M	$ -	$ 19,778	$ 13,935	$ 10,533	$ 22,628	$ 15,955	$ 21,495	$ 8,524	$ 22,677	$ 8,824	$ 13,712	$ 13,712
Motor vehicle expenses	$ 4,401	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,362	$ 2,362
Other R+M	$ 18	$ 61	$ 2,011	$ 101,053	$ 9,047	$ 35,148	$ 1,332	$ 1,494	$ 1,069	$ -	$ 293	$ 293
Pest Control	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Plant hire	$ -	$ 668	$ -	$ -	$ -	$ 138	$ 1,768	$ -	$ 140	$ -	$ 2,460	$ 2,460
Postage & stationary	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 340	$ 701	$ 701
Private non deductable	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Protective clothing	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Rates	$ 9,859	$ 12,224	$ 13,580	$ 18,692	$ 15,802	$ 16,769	$ 18,282	$ 18,651	$ 19,169	$ 13,640	$ 17,755	$ 17,755
Repairs and general mair	$ -	$ 1,131	$ 8,473	$ 9,210	$ 9,374	$ 4,640	$ 3,070	$ 1,359	$ 29,538	$ 2,164	$ 664	$ 664
Subscriptions	$ -	$ -	$ 290	$ 90	$ 457	$ 589	$ 649	$ -	$ 6,095	$ 3,067	$ 368	$ 368
Superannuation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 900	$ 506	$ -	$ -
Telephone (90%)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,555	$ 1,555
Telephone private	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Travelling expenses	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Wages	$ 1,813	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8,483	$ -	$ -
Workers comp.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 525	$ 525
Total Cash overhead cos	**$ 18,750**	**$ 48,180**	**$ 48,547**	**$ 151,380**	**$ 72,956**	**$ 92,596**	**$ 62,465**	**$ 51,267**	**$ 102,139**	**$ 48,411**	**$ 53,389**	**$ 53,389**

Depreciation#	$ 11,208	$ 22,165	$ 22,643	$ 21,058	$ 20,727	$ 22,569	$ 33,328	$ 34,309	$ 60,200	$ 64,059	$ 62,728	$ 62,728
Drawings	$ 77,782	$ 255,150	$ 64,508	$ 61,115	$ 94,894	$ 77,081	$ 232,195	$ 72,444	$ 137,011	$ 120,055	$ 73,249	$ 73,249
Operators allowance	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000	$ 90,000
Operators allowance in exc	$ -	$ 165,150	$ -	$ -	$ 4,894	$ -	$ 142,195	$ -	$ 47,011	$ 30,055	$ -	$ -
Operating profit	**$328,259**	**$274,924**	**$180,408**	**$37,193**	**$48,422**	**$606,331**	**$349,328**	**$30,883**	**$815,461**	**$458,003**	**$103,616**	**$103,616**
Interest to creditors	**$ 76,549**	**$ 46,205**	**$ 141,063**	**$ 17,853**	**$ 19,393**	**$ 166**	**$ 182**	**$ 133**	**$ 143**	**$ 30**	**$ 18,857**	**$ 18,857**
Net Farm Income	**$251,710**	**$228,719**	**$39,345**	**-$55,046**	**$29,029**	**$606,165**	**$349,146**	**-$31,016**	**$815,318**	**$457,973**	**$84,759**	**$84,759**

Net Cash Flow

Sources - Cash in

Sales	$ 519,877	$ 530,506	$ 432,123	$ 360,378	$ 382,701	$ 958,515	$ 688,591	$ 291,823	$ 1,291,950	$ 785,121	$ 521,739	$ 521,739
Other sources of income	$ 44,750	$ 48,770	$ 122,066	$ 67,212	$ 82,010	$ 103,275	$ 59,034	$ 142,608	$ 219,538	$ 133,429	$ 164,065	$ 164,065
New borrowings											$ 600,000	$ 600,000
Total	**$ 564,627**	**$ 579,276**	**$ 554,189**	**$ 427,590**	**$ 464,711**	**$ 1,061,790**	**$ 747,625**	**$ 434,431**	**$ 1,511,488**	**$ 918,550**	**$ 1,285,804**	**$ 1,285,804**

Uses - Cash out

Variable costs	$ 71,660	$ 95,237	$ 90,525	$ 135,133	$ 150,596	$ 147,019	$ 153,470	$ 147,130	$ 224,150	$ 124,648	$ 212,006	$ 212,006
Cash overheads	$ 18,750	$ 48,180	$ 48,547	$ 151,380	$ 72,956	$ 92,596	$ 62,465	$ 51,267	$ 102,139	$ 48,411	$ 53,389	$ 53,389
Income tax	$ -	$ -	$ 93,656	$ 30,678	$ 45,398	$ 58,552	$ 243,728	$ 68,869	$ 177,334	$ 264,385	$ 113,596	$ 113,596
Consumption	$ 77,782	$ 255,150	$ 64,508	$ 61,115	$ 94,894	$ 77,081	$ 232,195	$ 72,444	$ 137,011	$ 120,055	$ 73,249	$ 73,249
Interest	$ 76,549	$ 46,205	$ 141,063	$ 17,853	$ 19,393	$ 166	$ 182	$ 133	$ 143	$ 30	$ 18,857	$ 18,857
Principal	$ -	$ -	$ -	$ 72,761	$ 137,416	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Land purchase and improv	$ -	$ -	$ 3,420	$ 301	$ -	$ -	$ 360	$ -	$ 61,747	$ 373,152	$ 240,000	$ 240,000
Machinery replacement	$ 58,600	$ 167,733	$ 29,000	$ -	$ 17,185	$ 46,997	$ 176,223	$ 47,300	$ 404,155	$ 115,295	$ 45,000	$ 45,000
Land leasing	$ 17,531	$ 17,351	$ 8,765	$ -	$ -	$ -	$ -	$ 2,135	$ -	$ -	$ -	$ -
Investment	$ -	$ -	$ -	$ 100,000	$ -	$ -	$ 220,000	$ -	$ 140,800	$ 50,000	$ -	$ -
Total	**$ 320,872**	**$ 629,856**	**$ 479,484**	**$ 569,221**	**$ 537,838**	**$ 422,411**	**$ 1,088,623**	**$ 389,278**	**$ 1,247,479**	**$ 1,095,976**	**$ 756,097**	**$ 756,097**
Net Cash Flow	**$243,756**	**$50,580**	**$74,705**	**$141,631**	**$73,127**	**$639,379**	**$340,998**	**$45,153**	**$264,009**	**$177,426**	**$529,707**	**$529,707**

Assets –Land	$ 2,778,503	$ 3,969,290	$ 3,969,290	$ 3,969,290	$ 3,969,290	$ 3,969,290	$ 4,031,040	$ 4,789,330	$ 4,789,330	$ 4,789,330	$ 4,789,330	$ 4,789,330
Assets - Machinery	$ 148,910	$ 294,478	$ 300,835	$ 279,777	$ 276,234	$ 300,662	$ 443,557	$ 456,549	$ 800,503	$ 851,739	$ 834,011	$ 834,011
Assets - Stock	$ 17,440	$ 80,140	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Assets - Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 146,183	$ 146,183
Total Assets	**$ 2,944,853**	**$ 4,343,908**	**$ 4,270,125**	**$ 4,249,067**	**$ 4,245,524**	**$ 4,269,952**	**$ 4,474,597**	**$ 5,245,879**	**$ 5,589,833**	**$ 5,641,069**	**$ 5,769,524**	**$ 5,769,524**
Liabilities – overdraft	$ 50,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Long term loans and other	$ 294,344	$ 291,634	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total liabilities	**$ 344,344**	**$ 291,634**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**
Equity ($)	**$ 2,600,509**	**$ 4,052,274**	**$ 4,270,125**	**$ 4,249,067**	**$ 4,245,524**	**$ 4,269,952**	**$ 4,474,597**	**$ 5,245,879**	**$ 5,589,833**	**$ 5,641,069**	**$ 5,769,524**	**$ 5,769,524**
Equity (%)	88.3	93.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Return to equity	12.6	6.8	4.2	0.9	1.1	14.2	7.8	0.6	14.6	8.1	1.8	1.8

-$ 2,356,754 -$ 50,580 $ 74,705 -$ 141,631 -$ 73,127 $ 639,379 -$ 340,998 $ 45,153 $ 264,009 -$ 177,426 $ 529,707
10.4%

Table 104 – Annual operating profit, operating profits, IRR and annual return on equity over time.

	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-9
Annual Operating Profit	$328,259	$274,924	$180,408	-$37,193	$48,422	$606,331	$349,328	-$30,883	$815,461	$458,003	$103,616	-$170,849
Asset value	$2,944,853											$6,196,618
Investment cash flow	-$2,616,594	$274,924	$180,408	-$37,193	$48,422	$606,331	$349,328	-$30,883	$815,461	$458,003	$103,616	$12,393,237
Internal Rate of Return	20.29%											
Annual Return on Capital	11.15%	6.33%	4.22%	-0.88%	1.14%	14.20%	7.81%	-0.59%	14.59%	8.12%	1.84%	-2.76%

The farm has consistently generated large total farm gross margins over time, as shown in Figure 90, particularly since the introduction of pulses to the operation. The addition of extra land has also seen the earning capacity of the business increase. The nominal average annual farm gross income over the period 1987-88 to 1998-99 was $585,749. Average annual variable costs over the same period were $148,061. Thus the nominal average annual farm gross margin was $437,688.

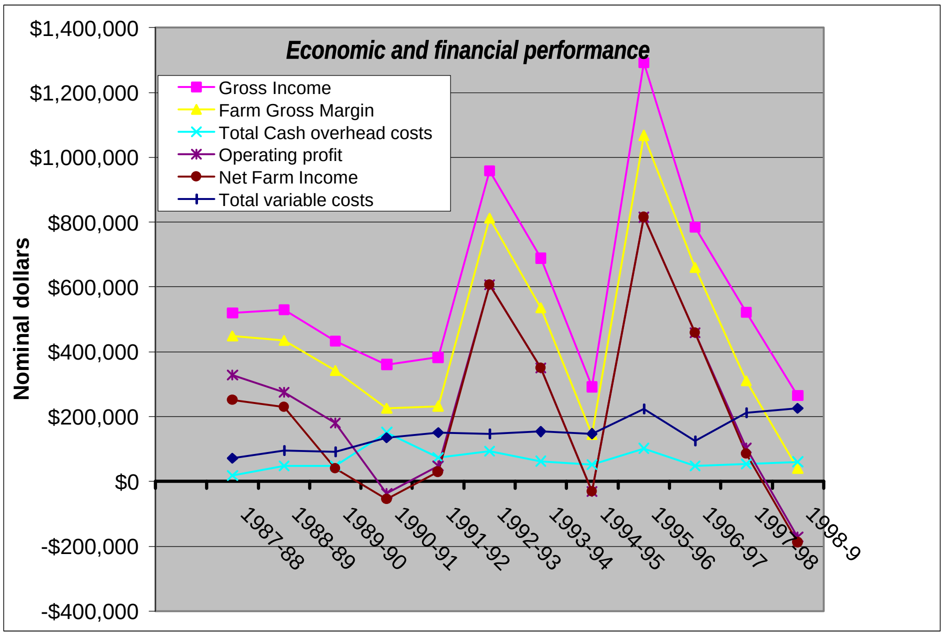


Figure 90 – Farm economic performance over time.

At the same time, overhead cash costs of the business have not been particularly high for a business of such scale; averaging annually $67,545. The combination of high gross margins, and low overhead costs, have contributed to the impressive record of operating profits over time. In only three of the twelve analysed years has the farm failed to generate a positive operating profit. The nominal average annual operating profit for the farm was $243,819. This is a significant achievement given the high level of machinery depreciation on the farm. This high, non-cash cost testifies to the high level of machinery capital held by the business. The fact that three families have to be supported by the business also reduces the nominal operating profits. A flat operators allowance of $30,000 per family has been allocated. In years where drawings were in excess of combined nominal operator's allowances of $90,000, the residual amount was ignored to calculate the operating profit. Given these structural costs were often not cash costs, the high operating profits are all the more impressive.

The low level of farm debt contributed to positive net farm income in nine of the twelve analysed years. Average annual interest to creditors was $28,162, although much of this figure was present only in the late 1980s and early 1990s. Expansion has taken place with retained earnings rather than borrowing. This, in turn, has created high net farm incomes over time. Average nominal annual net farm income was thus an impressive $215,657.

Inflation over the period 1987-8 to 1998-99 averaged 4.0 per cent. Given the high inflation of the late eighties many of the early sums of money are worth considerably more in today's dollars.

As with other case studies, comparison of earnings of the farm with other forms of investment was calculated using an internal rate of return based on nominal operating profits. If we treat the business as an investment, with the asset value of the business in year one as the initial cost, operating profits over time as the returns, and the estimated total value of the assets of the business at the end of the recorded period as the salvage value, an internal rate of return (IRR) can be calculated. If we assume that land was worth $1750 per hectare in 1987-8, and increased to be worth $2,500 per hectare in 1998-99, then the IRR acheived is 20.29 per cent. This is a very strong return over time given that inflation over the same period averaged 4.0 per cent. Thus the real rate of return was 16.29 per cent. This return compares very favourably to returns that could have been achieved in alternative, non-agricultural forms of investment. As with other case studies, some of this return is generated from increased land value but resource use has been very efficient in this operation using conservation cropping.

The average annual return to capital in this operation was found to be 5.43 per cent. Again, this is comparable to other non-agricultural forms of investment. This also indicates that a large proportion of the investment growth of the business has been generated by increased asset value.

Net cash flow on the farm is somewhat different to that of the operating profit. Other sources of income unrelated to the farming operation significantly increase the sources of cash flow to the whole farm business. The reasonably complete picture was obtained, and positive cash flows were found in seven of the twelve years. In the years of negative cash flow, much of the cash use was on items that were increasing equity. The use of income equalisation deposits also blurs the true cash position. The lack of borrowing over the last ten years of the analysis displays the strong financial position of the farm however.

The result of the strong cash flows over time has been an increase in farm equity. Nominal equity has increased from an estimated $2.8m in 1987-8 to almost $6.0m in 1998-99. Much of this calculation is based on the nominal land price increasing from $700 per acre to $1000 per acre. This is reasonable as land prices have increased dramatically in the Wimmera in recent years. Business equity presently stands at around 91 per cent following a recent land purchase. 100 per cent equity was maintained in much of the 1990s.

The cumulative cash flow over time reveals the strong build-up of cash over time.

4.15.11. SUMMARY

The use of conservation cropping has not adversely affected the business significantly over time, as it would seem the business has performed at least as well as it could have performed under any alternative cropping regime. The integration of legume crops and additional land holdings over time has also increased the earning potential of the property. The dramatic disease impact on chickpea crops in 1998 may change the future cropping patterns. An expansion of the areas sown to lentils and canola, along with increased use of green manuring and chemical fallowing has offset the reduction in chickpeas grown. The strong financial position of the farm sees it particularly well placed for any event. Debt is minimal and the land area is large enough to generate good net returns for the three families.

4.16. CASE STUDY 4 – WYCHEPROOF – SOUTHERN MALLEE

4.16.1. INTRODUCTION

The farm is situated in the southern Mallee, between Wycheproof and Birchip (Latitude 36°0'S Longitude 143°2'E). This region is primarily a cropping zone, with extensive livestock enterprises as well. This property has been intensively cropping since 1972. A single person operation, the family has been farming in the area for around fifty years, the present property being taken over in 1949. Since this time expansion has occurred in various stages as outlined in Table 105. The farm presently encompasses around 1050 hectares of land.

Table 105 – Expansion of the families operations since farming in the region.

Year of change	Aquired area (ha) and new area farmed (ha)	Owned Area (ha)	Farmed Area (ha)
1894	Area opened up for agriculture.		
1949	Bought first holding of 280 hectares (700 acres) for $120/ha.	280	
1953	Bought another 176 hectares (440 acres).	456	
1964	Bought 200 hectares (500 acres)	656	
1976	Bought 162 hectares (400 acres).	818	

1979	Bought 100 hectares (250 acres).	918	
1982	Bought 121 hectares (300 acres)	1037	

The spouse undertakes full time employment in Birchip. The off-farm income is important to the business.

4.16.2. GENERAL CROPPING ENVIRONMENT - SOILS

The soils of the area are mixed in nature, typically changing from being hard pedal red duplex soils (Gc2.33) to calcareous earths (Gc 1.12). Typically the topsoil is red or brown loams over heavier clays. Boron and pH levels are usually high in the subsoil restricting root growth. Topsoils are nuetral to alkaline. Subsoils are strongly alkaline and have high to moderate soluble salt contents. Many of these soils are hard setting or sodic in nature.

The calcareous earths have indistinct horizons with gradually changing soil properties with depth (Northcote, 1975). Surface soils range from being brownish sandy to loamy soils. Likewise, soils can be non-sodic to strongly sodic. Subsoil ESP's are usually less than 14 in Gc1.2 and Gc 2.2 but are greater than 14 in Gc.1.1. These soils tend to be structureless.

The hard pedal red duplex soils (Gc2.33) have strong texture contrast between the hard setting A horizon and the moderately pedal clayey B horizon. Topsoils are weakly structured and the red-brown clay subsoils become mottled with depth. Subsoil structure is usually blocky or prismatic. Carbonate nodules may occur these soils with gypsum appearing in some of the 2.33 soils. With prolonged cultivation organic matter levels decrease, lightening the colour of the dark red to dark brown soils. Infiltration is restricted in these soils. Nitrogen and phosphorous are usually highly deficient and the soil will respond to fertiliser application. Zinc deficiency may also occur. Gypsum will ameliorate hard-setting in many of these soils and make cultivation easier and increase infiltration rates.

Land in the area is generally worth around $300/acre.

4.16.3. RAINFALL AND TEMPERATURE

The farm is in a 350 millimetre (14 inch) annual rainfall belt. Rainfall is extremely variable however as seen in Figure 91. Standard deviation from the mean of 349mm is 111mm.

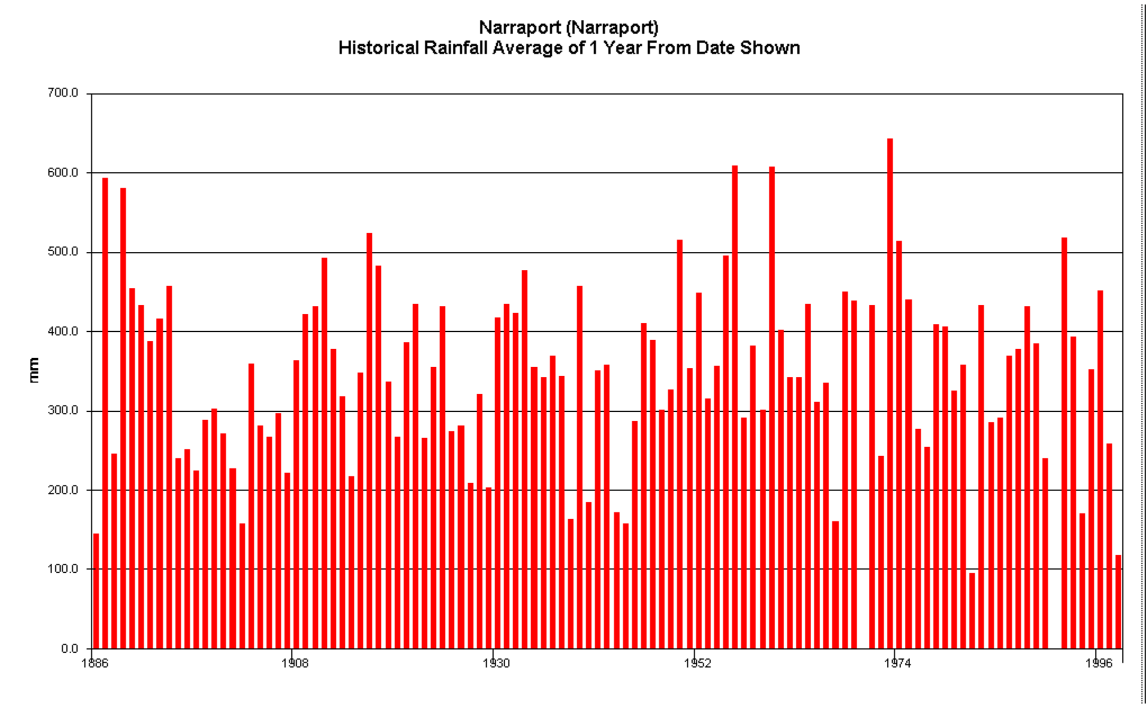


Figure 91 – Historical annual rainfall at Narraport (closest met station).

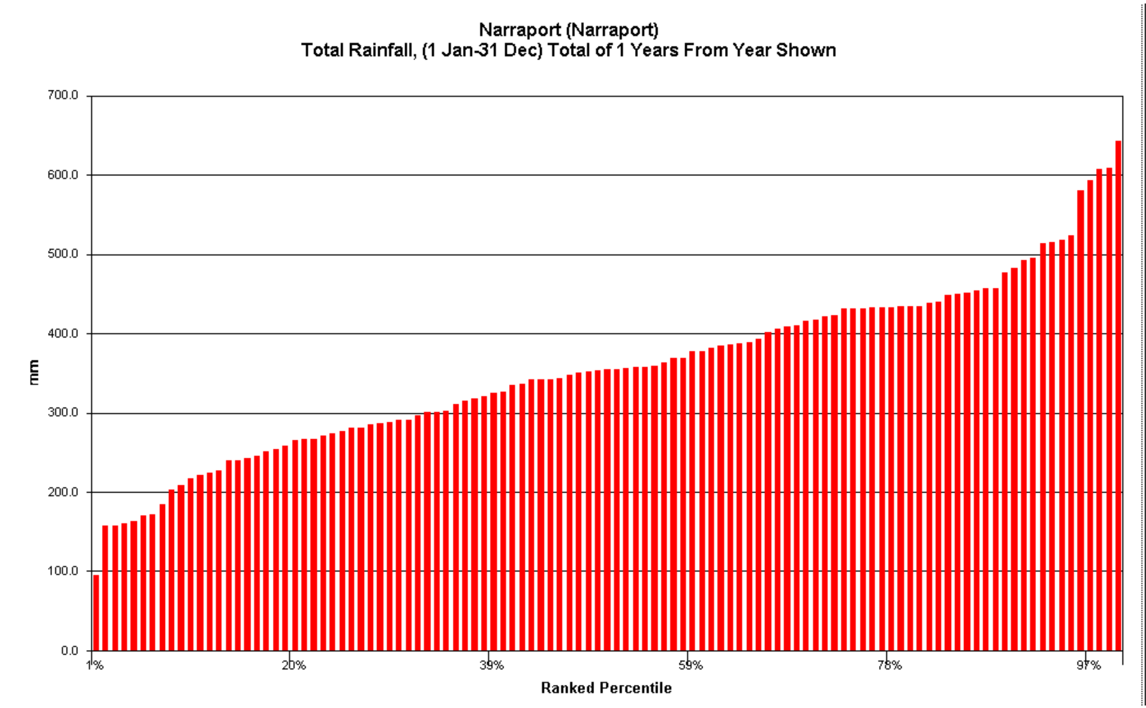


Figure 92– Sorted historical annual rainfall at Narraport (closest met station).

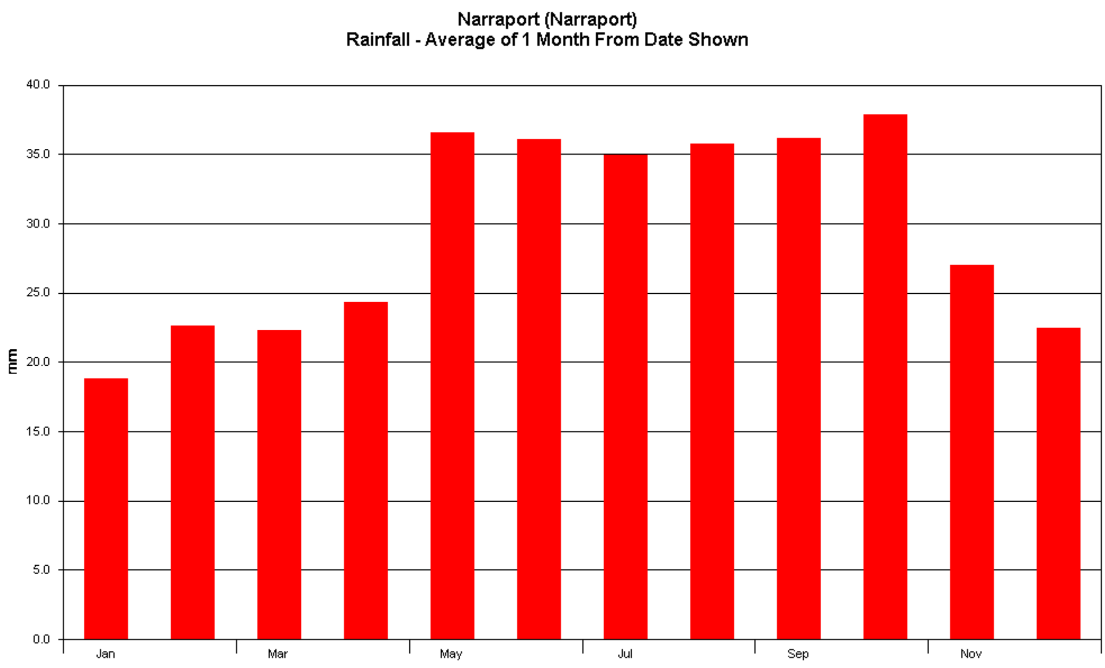


Figure 93 – Historical average monthly rainfall at Narraport (closest met station).

The winter dominant rainfall can be observed from Figure 93.

Average growing season rainfall 237 mm with a standard deviation of 76mm.

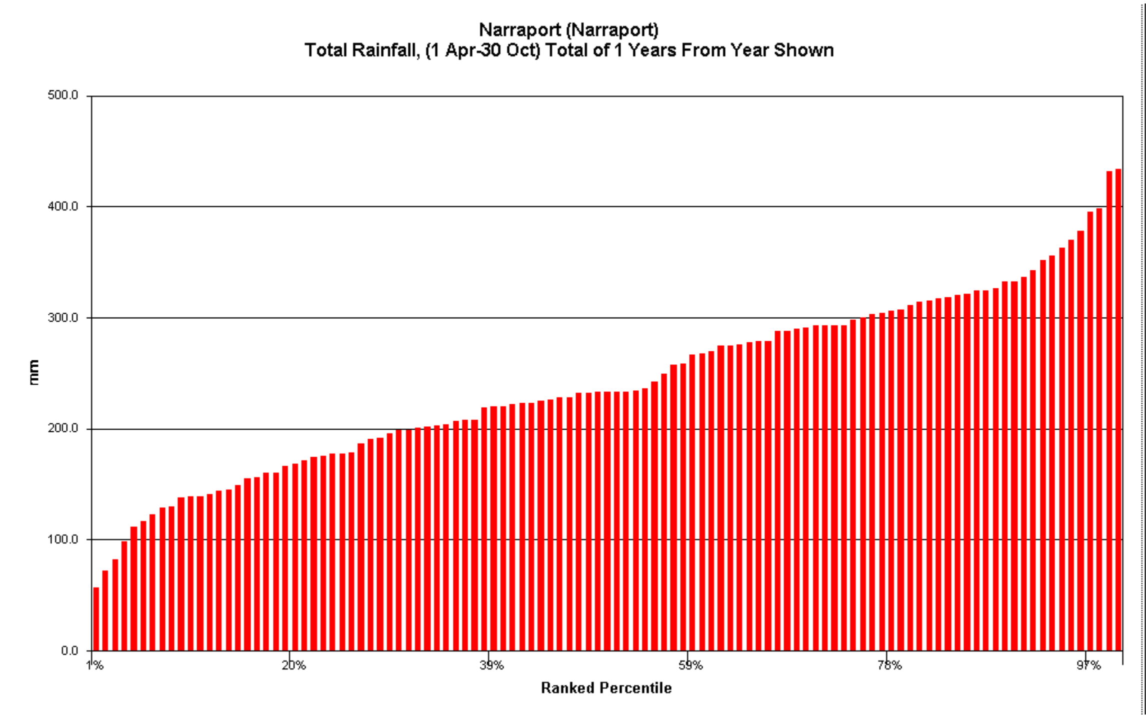


Figure 94 – Ranked growing season rainfall (April 1 to October 1).

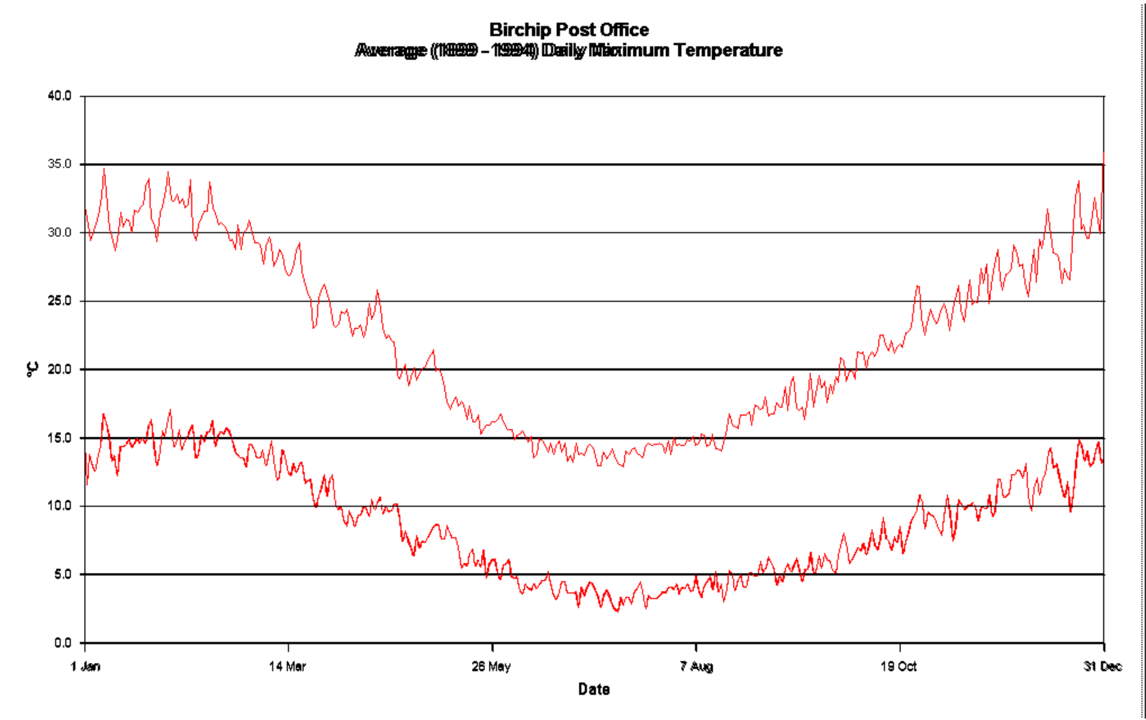


Figure 95 – Average daily temperature at Birchip based on years 1899 to 1994.

The daily temperature regime shows is typical of southern Australia. The growing season of the area is relatively short and variable, which in combination with the harsh soils, makes for a difficult cropping environment.

4.16.4. CROPPING EXPANSION, MACHINERY AND MANAGEMENT PRACTICES

The farmer in this case study has progressively moved to a more intensive cropping program. The reduced profitability of livestock farming in the area has seen that trend mirrored in most of the area's operations. The purchase of a 10.6 metre John Shearer trashworker and airseeder in 1980 saw the move into conservation cropping methods established on the farm. Previous to this the farm had been continuously cropping since 1972 with the use of extensive cultivation. Stubble was retained in most cases. Only three stubbles have been burnt since 1972 and in these cases mice infestation was the reason. Fallowing was extensively used prior to 1983. This involved cultivation first in August, then in the summer and two cultivations usually in March, before and after trifluralin application. Sowing then occurred. Post 1983 the trashworker, trailed by rotary harrows, became the preferred method of sowing. The purchase of the unit enabled the one way disc, combine and scarifier to be sold. Prior to the purchase of the Trashworker, direct drilling was done using the old combine.

Direct drilling has been used since 1983. The legumes were the first crops to be completely sown by this method. At this time, wheat was always sown into mechanically fallowed land, so direct drilling of wheat was not possible. Chemical fallowing was introduced on the farm in the late 1970's. The knockdown chemicals Sprayseed and Roundup allowed this, but mechanical fallowing was still frequently used. Chemical fallowing consisted of spraying in the previous spring and cultivation in the summer if weed control was poor, as it was on many occasions. Stubble mulching (cutting with a Melways mulcher) is generally carried out on any significant quantities of crop stubble so that the residue will break down, and weed control will be more effective. Fallowing was phased out in the early 1990's and the use of the trashworker on 12-inch points and rotary Hesslop harrows has continued until the present day.

Change continued in 1986 with a move to narrow points. These points had a two inch knife welded to the bottom of a fifty millimetre (two inch) point to provide soil disturbance at depth. These were attached at an angle so that a narrow ridge was opened up. Seed and fertiliser were dropped at a level equal to that of the bottom of the boot.

Increasing numbers of mice have been a problem in a few years. Extra cultivation was found to remedy this to an extent. The 1993 crop lost an estimated 45 percent of the yield due to mice. Neighbouring farms that did not direct drill received only minor losses. This was a particular spur to move back to a system that included more cultivation. In the three years since the drought of 1994-5 the use of direct drilling has been limited. A move back to wide sweep points (300mm) has occurred in the meantime.

4.16.5. ROTATION

The present rotation involves continuous cropping. The sequence is long fallow, canola, wheat, barley and peas. This is by no means fixed, and opportunities are taken to increase areas of certain crops given seasonal and economic outlooks. A conventional four-year rotation of fallow-wheat-barley-pasture was followed pre-1983. Wheat was sown into mechanically cultivated fallow and barley was sown into disced and scarified wheat stubbles. Medic pasture regenerated from the cropping sequence. The introduction of legumes changed the farming system. In 1984 the direct drilling of barley on wheat stubble took place. This practice was not continued in the long term however.

Fallows of any sort were phased out in the early 1990's. The mixed nature of seasons in the 1990's however, has seen the return of some long fallowing. The value of attempts at moisture conservation on land with hostile subsoils which limits root exploration such as these has to be questioned.

Table 106– Rotation in the last seven years on the property. (Pg – pasture, Ca – canola, W – wheat, B – barley, Fp – Field peas, Cf – chemical fallow, Fb – faba beans, CpD – desi chickpeas)

1997 Crop Selection

Paddock	Crop
Angle	Cf
Angle	Ca
Bens	W
Devitts	B
Hill	Cf
House	W
Jacks	Ca
Kerrs	Cf
Kerrs	Ca
School	Cf

Crop Type per year | Crop Area per year | Crop % Area per year

Paddock	1992	1993	1994	1995	1996	1997	1998
Angle	Pg	Cf	W	B/Pg	W/Cf	Ca/Cf	W
Bens	W	B	Fp	W	Ca	W	Fp
Devitts	W	B	B	Ca/S	W	B	CpD
Hill	B	Pg	Pg	Pg	Pg	Cf	B
House	Fb/Vg	W	Fp	W	Ca	W	B
Jacks	W	Pg	Pg	Cf	W	Ca	W
Kerrs	B	Fp	B/Ca	W	W/B	Ca/Cf	W
School	Pg	Cf	W	Cf	W	Cf	B
Smalls	Fp	W	Pg	W	Cf	W	Ca
Warburtons	O	Fb	W	B	W	Cf	W

4.16.6. HERBICIDES AND WEED CONTROL

The onset of herbicide resistance was concomitant with the introduction of knockdown herbicides for pre-crop sowing, and the repeated use of fop and dim type grass herbicides in crops.

The reintroduction of Treflan and cultivation has overcome some of these problems. Trifluralin was abandoned in the late 1980's until recent reintroduction. It was replaced by the use of knockdowns pre-seeding and use of selective herbicides in crops. Roundup is generally applied at 0.4-0.6 litres per hectare on direct drilled crops. Diuron is also applied at 250 mls per hectare in conjunction with one litre of Trifluralin. The grower sees that rotation is the key to weed control rather than the direct drilling.

An MCPA/Lontrel mix is used for broadleaf weeds. Wheat is sown at 65 kilograms per hectare, barley at 55 kilograms per hectare, canola at five kilograms per hectare and legumes at 80-90 kilograms per hectare. Weed control over the summer period has proved to be problem for the farm. Bathurst burr is the predominant weed.

4.16.7. STUBBLE MANAGEMENT AND NUTRIENT SUPPLY

Crops have predominantly been retained over the last two decades. Slashing, incorporation and use of prickle chains have maintained surface cover in most years.

1997 was the first year that pre drilled urea was applied to the crop. The use of urea in barley crops following wheat. Pre-drilling of urea at 80kgs per hectare now occurs on wheat crops as well. 50 kilograms per hectare of urea is pre-drilled under canola crops. Grain legume super with zinc coating is sown with legumes.

4.16.8. ECONOMIC AND FINANCIAL ASPECTS

Farm performance has been extremely variable over 1988-9 to 1996-7. Annual farm gross income has averaged $155,100, but varied from $26,100 in the drought year of 1994 to $261,000 in 1996-7. Annual variable costs averaged $60,533 annually, producing an average, annual farm total gross margin of $94,568. Cash overhead costs have averaged $45,791. Once depreciation costs and an operators allowance of $30,000 has been deducted operating profit has proven to be minimal on average at around $6,102.

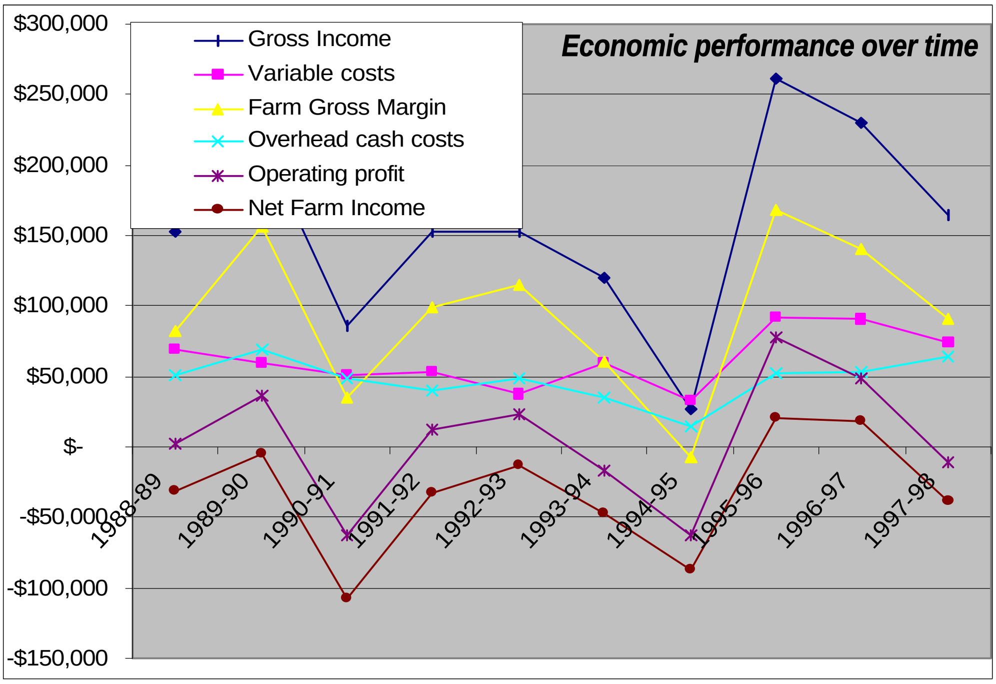


Figure 96 – Farm performance over the last decade.

Positive operating profits have been recorded in six of the eleven years analysed. The calculation of the net farm income found that the high level of farm debt produced negative net farm incomes in all two of the eleven analysed years. Average annual interest payments over the eleven years were $37,579. Average annual net farm income over the same period was $-31,476.

Again the operation was treated as an investment to determine the efficiency of resource use on the farm using conservation cropping technologies. If we assume that land was worth $625 per hectare in 1988-89, and increased to be worth $900 per hectare in 1997-8, then the IRR acheived is 1.86 per cent. This has not kept pace with inflation over the period and thus represents a poor return in comparison to alternative forms of investment. Additionally, most of this return is generated from increased land value. On this property either the efficiency of resource use, business structure and/or climatic conditions have reduced the profits available from the farm. The question is whether the use of conservation cropping has played a part in this poor performance.

As a result of the mediocre economic performance, net cash flows have been under pressure. New borrowing has had to be undertaken to make up for shortfalls in cash availability. Diversification of the business in the late eighties to undertake a sheepskin tanning business significantly drained cash reserves on the farm. A mix of seasons in the time since this period has not had significant impact on the debt situation. A run of favourable years, contributing to higher yields, are need to reduce the debt. Equity stood at around 65 per cent in 1997-98. This has dropped in the time since this figure was calculated.

Table 107 - Operating profit over time.

Financial Year	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Annual Rainfall (mm)										
Growing season rainfall										
Operating Profit										
Income - Wheat	$ 82,224	$ 97,788	$ 49,885	$ 75,395	$ 76,038	$ 53,446	$ 14,169	$ 191,845	$ 125,023	$ 116,307
Barley	$ 47,890	$ 63,684	$ 17,331	$ 9,322	$ 26,212	$ 13,613	$ 6,024	$ 27,202	$ 25,499	$ 14,050
Oats	$ -	$ -	$ -	$ 26,754	$ 9,053	$ -	$ -	$ -	$ -	$ -
Legumes	$ -	$ -	$ -	$ 15,087	$ 39,581	$ 44,412	$ 5,940	$ -	$ -	$ -
Canola	$ -	$ -	$ 830	$ -	$ -	$ -	$ -	$ 40,537	$ 73,241	$ 17,414
Fodder	$ 20,375	$ 50,667	$ 18,058	$ 14,608	$ 1,575	$ 8,360	$ -	$ 681	$ -	$ 3,906
Livestock	$ 1,713	$ 4,088	-$ 310	$ -	$ -	$ -	$ -	$ 468	$ 4,406	$ 8,591
Wool	$ -	$ -	$ 135	$ 11,022	$ -	$ -	$ -	$ -	$ 2,030	$ 4,560
Gross Income	**$ 152,202**	**$ 216,227**	**$ 85,929**	**$ 152,188**	**$ 152,459**	**$ 119,831**	**$ 26,133**	**$ 260,733**	**$ 230,199**	**$ 164,828**
Costs - Chemicals	$ 24,540	$ 24,146	$ 33,231	$ 23,159	$ 12,942	$ 26,523	$ 16,986	$ 23,949	$ 16,708	$ 27,589
Fertilisers	$ 11,261	$ 11,743	$ 8,674	$ 15,817	$ 12,386	$ 15,147	$ 1,345	$ 35,638	$ 46,799	$ 23,257
Fuel	$ 17,194	$ 15,782	$ 7,594	$ 12,941	$ 7,540	$ 12,904	$ 7,376	$ 22,492	$ 16,751	$ 12,866
Seed and Freight	$ 5,049	$ 7,648	$ 1,090	$ 1,404	$ 4,240	$ 4,433	$ 7,224	$ 7,363	$ 10,030	$ 10,569
Livestock costs	$ 11,478	$ 347	$ -	$ -	$ -	$ -	$ 290	$ 2,629	$ -	$ -
Total variable costs	**$ 69,522**	**$ 59,666**	**$ 50,589**	**$ 53,321**	**$ 37,108**	**$ 59,007**	**$ 33,221**	**$ 92,071**	**$ 90,288**	**$ 74,281**
Farm Gross Margin	**$ 82,680**	**$ 156,561**	**$ 35,340**	**$ 98,867**	**$ 115,351**	**$ 60,824**	**-$ 7,088**	**$ 168,662**	**$ 139,911**	**$ 90,547**

Cash overhead costs

Accountancy/agronomis	$	395	$	570	$	730	$	850	$	630	$	630	$	530	$	1,045	$	900	$	1,350
Casual labour	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	769
Computer supplies	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Contractors	$	7,560	$	8,770	$	11,390	$	13,498	$	16,837	$	10,127	$	505	$	15,696	$	19,629	$	11,786
Dogs	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Drawings	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Electricity (70%)	$	391	$	261	$	-	$	883	$	409	$	737	$	765	$	705	$	720	$	637
Private electricity	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Farm advisory fees	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Insurance	$	6,069	$	5,537	$	2,116	$	2,170	$	5,744	$	4,094	$	1,316	$	7,016	$	5,335	$	6,297
Legal	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Licences & registrations	$	905	$	1,511	$	3,382	$	1,691	$	990	$	773	$	686	$	1,024	$	2,046	$	1,414
Machinery R&M	$	12,574	$	30,106	$	5,926	$	7,560	$	8,152	$	4,194	$	1,569	$	-	$	8,098	$	-
Motor vehicle expenses	$	2,595	$	2,533	$	2,037	$	-	$	2,013	$	2,196	$	2,428	$	3,720	$	3,816	$	13,714
Other	$	190	$	-	$	-	$	308	$	-	$	-	$	-	$	-	$	-	$	-
Pest Control	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Plant hire	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Postage & stationary	$	286	$	745	$	766	$	265	$	374	$	183	$	-	$	95	$	959	$	-
Private non deductable	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-
Protective clothing	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-	$	-

Rates	$ 8,326	$ 9,108	$ 9,673	$ 9,989	$ 10,122	$ 10,310	$ 5,501	$ 14,969	$ 7,137	$ 8,288
Rent	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Repairs and general ma	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 10,454
Subscriptions	$ 649	$ 484	$ 320	$ 1,221	$ 1,235	$ 845	$ 654	$ 814	$ 1,160	$ 1,881
Superannuation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,588	$ 35
Telephone (90%)	$ 1,427	$ 1,279	$ 833	$ 951	$ 1,157	$ 1,152	$ 606	$ -	$ 1,672	$ 2,331
Telephone private	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Travelling expenses	$ 270	$ -	$ -	$ 140	$ -	$ 391	$ -	$ -	$ -	$ 170
Wages	$ 8,814	$ 7,981	$ 11,730	$ 800	$ 339	$ 36	$ -	$ 6,680	$ 500	$ 4,400
Workers comp.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Cash overhead cc	**$ 50,451**	**$ 68,885**	**$ 48,903**	**$ 40,326**	**$ 48,002**	**$ 35,668**	**$ 14,560**	**$ 51,764**	**$ 53,560**	**$ 63,526**
Depreciation#	$ -	$ 21,938	$ 19,079	$ 16,616	$ 14,491	$ 12,657	$ 11,072	$ 9,701	$ 8,513	$ 7,484
Operators allowance in e	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000
Operating profit	**$2,229**	**$35,738**	**-$62,642**	**$11,925**	**$22,858**	**-$17,501**	**-$62,720**	**$77,197**	**$47,838**	**-$10,463**
Land leasing										
Interest to creditors	**$ 33,102**	$ 40,245	$ 44,838	$ 44,855	$ 35,619	$ 29,342	$ 23,868	$ 56,672	$ 29,666	$ 28,118
Net Farm Income	**-$30,873**	**-$4,507**	**-$107,480**	**-$32,930**	**-$12,761**	**-$46,843**	**-$86,588**	**$20,525**	**$18,172**	**-$38,581**

Table 108 - Net cash flow over time.

Net Cash Flow										
Sources										
Cash in										
Sales	$ 152,202	$ 216,227	$ 85,929	$ 152,188	$ 152,459	$ 119,831	$ 26,133	$ 260,733	$ 230,199	$ 164,828
Other	$ 15,136	$ 7,241	$ 14,301	$ 5,210	$ 18,290	$ 28,745	$ 32,730	$ 9,663	$ 29,767	$ 7,389
New borrowings										
Total	**$ 152,202**	**$ 216,227**	**$ 85,929**	**$ 152,188**	**$ 152,459**	**$ 119,831**	**$ 26,133**	**$ 260,733**	**$ 230,199**	**$ 164,828**
Cash out										
Variable costs	$ 69,522	$ 59,666	$ 50,589	$ 53,321	$ 37,108	$ 59,007	$ 33,221	$ 92,071	$ 90,288	$ 74,281
Cash overheads	$ 50,451	$ 68,885	$ 48,903	$ 40,326	$ 48,002	$ 35,668	$ 14,560	$ 51,764	$ 53,560	$ 63,526
Income tax	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Consumption	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000
Interest	$ 33,102	$ 40,245	$ 44,838	$ 44,855	$ 35,619	$ 29,342	$ 23,868	$ 56,672	$ 29,666	$ 28,118
Principal	**$ -**	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Land improvement	$ 4,072	$ 365	$ 7,790	$ 1,637	$ 1,784	$ 2,170	$ 972	$ 2,763	$ 1,348	$ -
Machinery replacement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 10,891	$ 1,275	$ -
Investment	**$ -**	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 187,147**	**$ 199,161**	**$ 182,120**	**$ 170,139**	**$ 152,513**	**$ 156,187**	**$ 102,621**	**$ 244,161**	**$ 206,137**	**$ 195,925**
Net Cash Flow	**-$34,945**	**$17,066**	**-$96,191**	**-$17,951**	**-$54**	**-$36,356**	**-$76,488**	**$16,572**	**$24,062**	**-$31,097**

Table 109 - Return on equity and growth over time.

Assets –Land	$ 662,578	$ 954,112	$ 954,112	$ 954,112	$ 954,112	$ 954,112	$ 954,112	$ 954,112	$ 954,112	$ 954,112
Assets - Machinery	$ 185,170	$ 163,231	$ 144,152	$ 127,536	$ 113,045	$ 100,388	$ 89,316	$ 79,615	$ 71,102	$ 63,618
Assets - Stock	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Assets - Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Assets	$ 847,747	$ 1,117,343	$ 1,098,263	$ 1,081,648	$ 1,067,157	$ 1,054,500	$ 1,043,428	$ 1,033,727	$ 1,025,214	$ 1,017,730
Liabilities – overdraft	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Long term loans and othe	$ 280,313	$ 212,803	$ 290,982	$ 304,806	$ 283,802	$ 275,708	$ 310,644	$ 268,989	$ 252,912	$ 305,231
Total liabilities	$ 280,313	$ 212,803	$ 290,982	$ 304,806	$ 283,802	$ 275,708	$ 310,644	$ 268,989	$ 252,912	$ 305,231
Equity ($)	$ 567,434	$ 904,540	$ 807,281	$ 776,842	$ 783,355	$ 778,792	$ 732,784	$ 764,738	$ 772,302	$ 712,499
Equity (%)	66.9	81.0	73.5	71.8	73.4	73.9	70.2	74.0	75.3	70.0
Return on equity	0.4	4.0	7.8	1.5	2.9	2.2	8.6	10.1	6.2	1.5

				-$ 96,191	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
Annual Operating Profit	$2,229	$35,738	-$62,642	$11,925	$22,858	-$17,501	-$62,720	$77,197	$47,838	-$10,463
Asset value	$847,747									
Investment cash flow	-$845,518	$35,738	-$62,642	$11,925	$22,858	-$17,501	-$62,720	$77,197	$47,838	-$10,463
Internal Rate of Return	1.86%									

4.16.9. SUMMARY

The use of conservation cropping apparently reduced yields in some years in the early 1990s because of mice damage in crops. It is hard to quantify these losses however. Conservation cropping has also let the farm continue to operate with a minimum of machinery capital tied up machinery. This is reflected in the poor return to investment calculated. Poor seasons on top of a high debt situation increased interest payments, reducing profits and net cash flow. The next couple of years will determine the future of the farm. The high debt situation needs to brought under control in the near future or increasing interest rates will place the business at high risk.

4.17. CASE STUDY 5 – KOOLOONONG – THE MALLEE

4.17.1. INTRODUCTION

The farms in this case study are situated near Kooloonong and Annuello in the Victorian Mallee. Koolonong is seventy-two kilometres north west of Swan Hill, near Piangil (35°30'South and 143°18' East). Farming practices are based on many used in the Mallee, consisting of a three-year cereal-pasture-fallow rotation. This farm however uses two years medic *(Medicago spp.)* pasture, which is chemically fallowed, followed by a wheat or barley crop in preference to the district practice of mechanical fallow-cereal or pasture-mechanical fallow-cereal. Cultivation is minimal prior to cropping in an area strongly accustomed to mechanical fallowing for crop preparation.

This case study is valuable in terms of demonstrating soil conservation and the benefits of conservation cropping to a wider community. The Mallee has just endured what was widely regarded as one of its worst episodes of soil drift. Extensive use of cultivation for fallowing in 1998 resulted in numerous dust storms over the summer of 1998-99. Poor sheep profitability, combined with poor cropping years in 1997 and 1998 has returned many growers to a wheat-mechanical fallow rotation. The use of mechanical fallow delays the cost of herbicide purchase in preference to machinery costs, while the wheat fallow rotation has the potential to return more than a pasture based operation. The results are likely to be rapid reductions in organic matter levels in these cropping soils. This case study profiles one producer who has gone his own way in order to avoid some the soil degradation problems of other growers in the area.

In 1997, 53 per cent of 55 farmers surveyed in the Victorian Mallee operated on a three year improved pasture-fallow-cereal rotation, with 24 percent operating a two-year pasture-cereal rotation. A swing to cereal-fallow rotations in South Australia and New South Wales has been found recently however (Latta, 1998).

The business is operated by one, married grower in middle-age with four daughters. The area was originally settled by the present owner's grandfather in 1918, as part of the soldier settlement scheme. Mallee scrub dominated the landscape prior to clearing. Farms were originally split into 332 hectare (820 acre) blocks but aggregation due to commodity cycles, drought and the agricultural cost price squeeze has greatly increased average farm size in the area. The original holding was expanded and farmed by the present owner and his brother until four years ago when the partnership dissolved. The farms were split up at this time leaving the present operation covering 3175 hectares (7990 acres) spread over two blocks at Kooloonong (1575 hectares) and Annuello (1660 hectares). The Kooloonong home block has been with the family since 1978. Expansions in the business size occurred in 1954, 1962 and 1968 with the purchase of the Annuello block. Recently the owner has decided to sell both blocks and move to Swan Hill, where his wife is currently employed and daughter works. With no one to hand the farm over to and some attractive offers for the land, the farm was sold.

Table 110 – Business development over time.

Year of expansion	Aquired area (ha) and new area farmed (ha)
1918	334
1954	387, 721
1962	25, 746
1968	1659, 2405
1978	1556, 3961
1994	Partnership split, owner left with 3175ha
1999	Properties sold

4.17.2. GENERAL CROPPING ENVIRONMENT - SOILS

The soils of the area generally described as being calcareous loams or sandy earths. Undulating sand dunes over flat Mallee plains predominate the area. These soils occur extensively in Northern Victoria and the Murray Valley into South Australia where Mallee scrub vegetation (Eucalyptus oleosa-dumosa) predominated. Both blocks consist of loams and sands with the Kooloonong farm having greater amounts of heavier country than the Annuello block. Varying soil types facilitate the use of different crops on the hills and lower areas. Barley, being a more efficient user of water and hence more drought tolerant, is planted on sandy rises. Wheat is grown in lower areas. This has been the case since the introduction of wheat quotas in 1969 and 1970. Prior to this, wheat was the primary crop. Some legumes were also tried over this period to avoid reductions in income resulting from the imposition of the quotas. Lupins were used in the period from 1977 to 1984 but were phased out due to the need for early sowing. Early rains are not common in the Mallee, and as a result poor yields made the crop unprofitable. The wheat acreage varies from 50 percent to 66 percent of the total crop acres in most years, depending on which paddocks are cropped.

The sandy soils are susceptibility to wind erosion. Aerial photographs from the mid-1940s show large areas of land in the area suffering from soil erosion. The calcareous earths have indistinct horizons with gradually changing soil properties with depth (Northcote, 1975). Surface soils range from being brownish sandy to loamy soils. Likewise, soils can be non-sodic to strongly sodic. Subsoil ESP's are usually less than 14 in Gc1.2 and Gc 2.2 but are greater than 14 in Gc.1.1. The soils tend to be structureless.

Land in the area is generally worth around $100 an acre ($250/ha). The owner obtained $130/acre and $150/acre for the Annuello and Kooloonong blocks when sold in 1999. He considered that these prices were too good to knock back considering his family's circumstances and the seasonal outlook.

4.17.3. RAINFALL

The area is in a twelve-inch average rainfall belt (300 millimetres). Average annual rainfalls and standard deviation are shown in Table 111.

Table 111– Mean annual rainfall and standard deviation from this mean at selected locations.

Site	Mean annual rainfall (mm)	Standard deviation from average
Piangil 1897-1953	275	99.7
Annuello 1925-1998	293	120
Kooloonong 1938-1965	296	124.6
Burrumbuttock 1889-1998	568	175.4

Source: (Horizon Technology, 1998).

The low average rainfall, and high variability, indicates the difficult environment in which this producer operates.

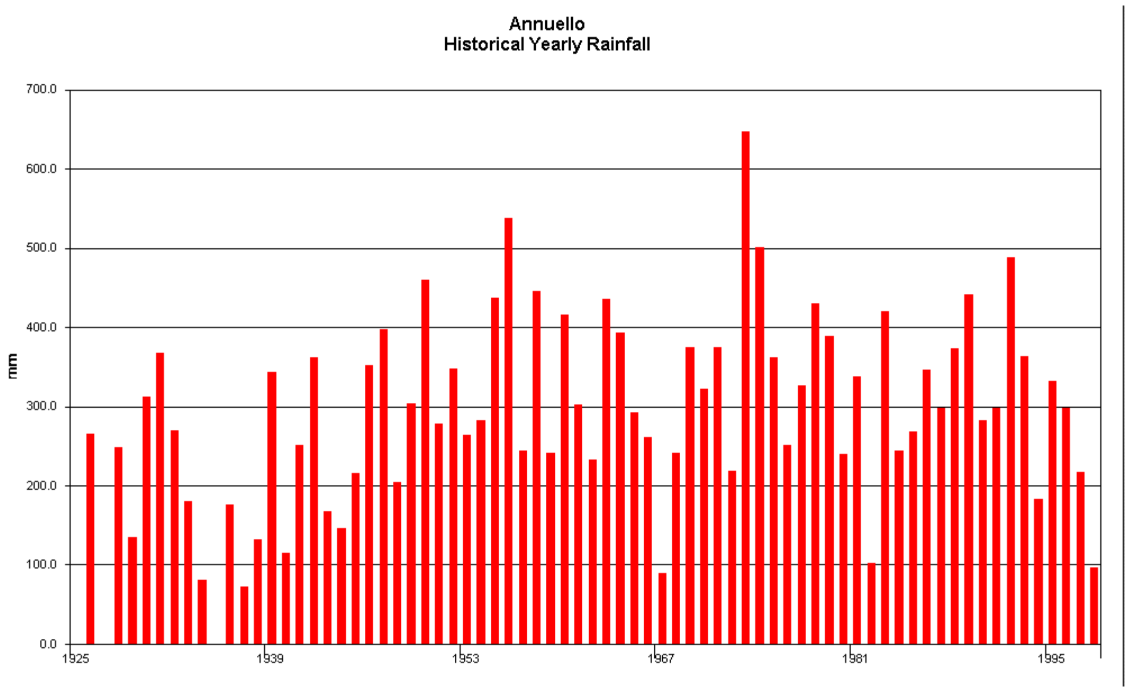


Figure 97 – Historical (1925-1998) rainfall at Annuello.

The highly variable total rainfall is further complicated by the highly variable timing of the autumn 'break'. The average timing of the break, defined as receiving more than 25 millimetres in a week, is around the end of June as shown in Figure 98.

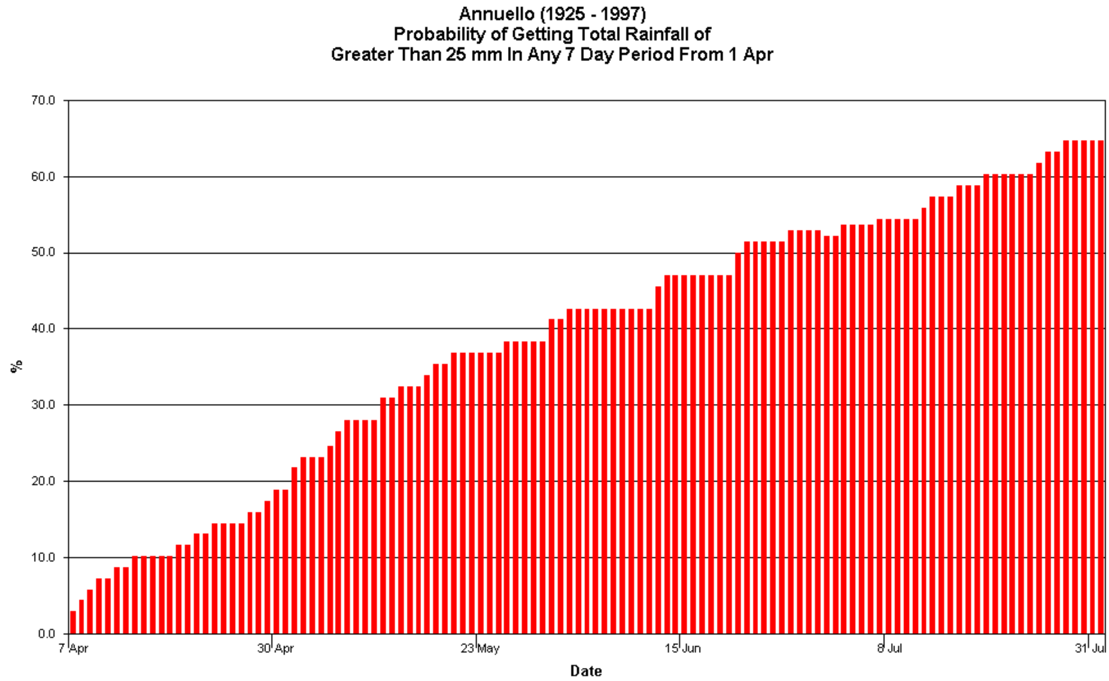


Figure 98 – Cumulative probability of more than 25mm being received in a week over autumn-winter.

The climatic variation results in variable returns from cropping. Various management strategies can be undertaken to alleviate some restrictions but the short growing season and highly variable rainfall patterns make consistent cropping success difficult.

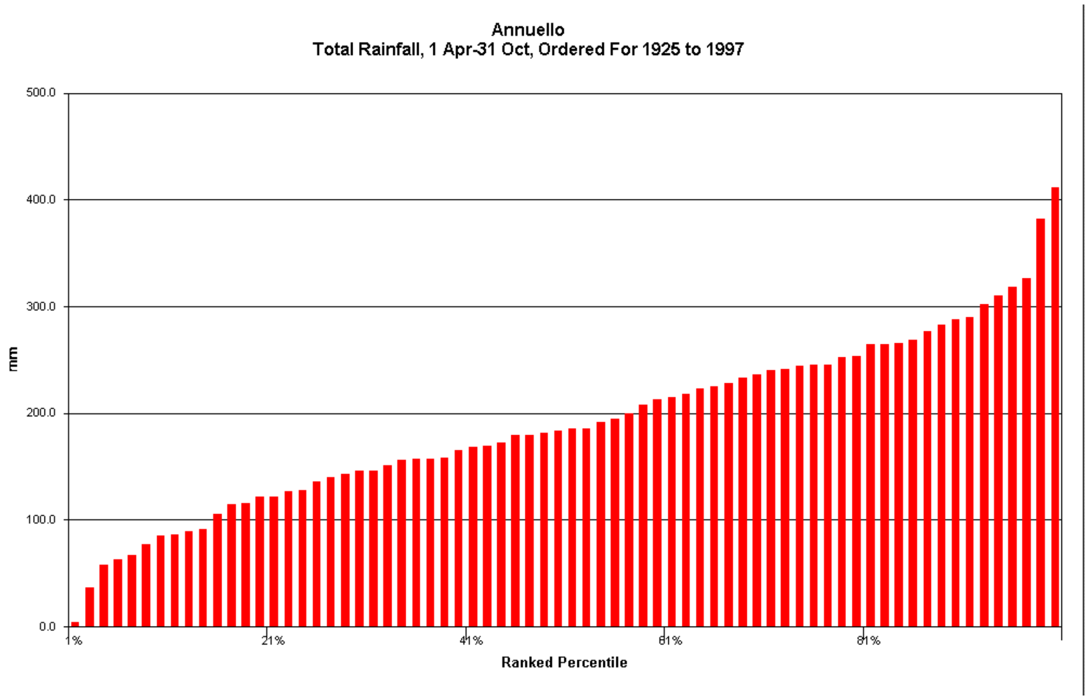


Figure 99 – Distribution of growing season rainfall at Annuello over time.

As Figure 99 shows, growing season rainfall is highly variable and generally low at Annuello. As already stated, this makes consistent cropping success difficult in the area.

4.17.4. CROPPING EXPANSION, MACHINERY AND MANAGEMENT PRACTICES

The move to reduced cultivation has not been simple or easy. Changes to district practice on the case study farm began in the late 1950's with the introduction of a scarifier in deference to one-way disc ploughs. Ground preparation for many years consisted of continual cultivation to facilitate weed control. Farmers in the area using a cereal-fallow rotation found organic matter levels quickly depleted and wind erosion became widespraead. The grower on this farm used the scarifier to avoid complete soil disturbance and inversion. Other growers adopting scarifiers often used harrows behind the implement, leaving ground level and prone to erosion. Roads covered with sand drift were commonplace.

The case study farm used the scarifier as the main form of land preparation until 1978 when blade ploughs and rod weeders were introduced to reduce wind erosion. A few other growers adopted the practice but generally full soil disturbance was the district norm. In this period pasture was worked up for long fallowing to supposedly increase moisture retention. However research at the Mallee Research Station, Walpeup concluded that the use of long fallowing had little effect on moisture accumulation as long as chemical weed control was effective. This provided the first spur to reduce the use of long, mechanical fallowing.

At the same time the prevalence of skeleton weed was increasing. The blade plough in particular blocked with the weed, inadvertantly contributing to a move away from cultivation. Skeleton weed regenerates from cuttings. Every time an infested area is cultivated the potential population increases. On one particular paddock in the 1980's the initial fallowing cultivation with a blade plough was impaired. Hence the pasture was not fallowed. Cultivation prior to seeding was carried out then sown in April and sprayed with Ally. The area blade ploughed produced a normal crop but similarly uncultivated areas plus chemical usage gave an unexpectedly good crop. This gave the growers the confidence to move to full chemical fallowing. Pasture usage was increased as fallowing was delayed until the spring of the second year's pasture rather than autumn six months before. Chemical fallowing left dead plant matter available to livestock, a situation not available to conventional, cultivated fallow. Cultivation is never undertaken until any late summer/autumn rain occurs. This reduces wind erosion risks that play havoc with many farms in the area.

Wide shares on cultivation equipment were used until recently for land preparation. The move to chemical fallowing and minimal cultivation decreased soil tilth and increased soil strength. Subsequently penetration using wide shares was inadequate. Increased tyne breakout pressure and narrow points were thus adopted to accurately place seed in these soils. The changed soil environment saw increased incidence of onion weed, a weed the grower is still presently battling.

The move to higher breakout strength sowing equipment saw the acquisition of a forty-four foot (14.2 m) Flexicoil 820 seeding bar using nine inch (22 cm) row spacings and narrow superseeder (inverted T) points. Over the 1997 and 1998 seasons there were no cultivations except for seeding. In response to the move there is no other cultivation machinery on the farm. Blade ploughs, scarifiers and rod weeders were sold at auction some time ago. The only machinery owned is the Flexicoil, a 100ft Goldacres boomspray, a 250hp Steiger tractor, a couple of trucks and a TR98 New Holland header.

Local research in the Mallee saw that high breakout pressure, narrow points and penetration to ninety millimetres increased grain yield in 1998 (Desboilles, 1999). In particular the Flexicoil seeding equipment, as used by the owner, performed well amoungst other no-till seeding systems.

No-till seeding technologies yielded 74 and 106 percent more than adjacent farmer sampled paddocks in three Mallee locations.

The sowing unit uses deep banding of fertiliser when sowing, increasing timeliness of overall cropping operations even though slower sowing speeds are required to cater for the deeper tillage.

Overall, the advent of selective herbicides in the late 1970's increased weed control options. This lead to the adoption of winter cleaning in the first year of pasture to reduce brome grass, ryegrass and barley grass competition with the barrel medic, and also to reduce seed set for ensuing crops. Barley grass was particularly a problem on the sandier rises. Reductions in competition from grass weeds makes possible increased medic seed production, and thus more plant regeneration in the next pasture phase. Winter cleaning has been effective and the decision as to whether to winter clean in both years of pasture is under consideration. Winter cleaning is done in July-August with the use of Roundup and Gramoxone.

The grower is apparently unusual in the area for his views on crop preparation. The use of winter cleaning, lengthened pasture phase, shortened fallow period and low levels of cultivation are distinctly different from the long fallow, high cultivation practices still common in the Mallee.

4.17.5. ROTATION

The farming systems of the Mallee are very different to other areas of the state. Changes to cropping practices have generally remained unaltered for many years, with some subtle changes.

In the 1960s the pasture phase was based primarily on lucerne. The effectiveness of this species was cut short by the invasion of the lucerne aphid. The aphid devastated non-resistant cultivars used on many of the area's and South Eastern Australia's farms. This reinforced the use of Barrel medic (cv. Harbinger); as it was the next best alternative. Barrel medic still dominates the pasture phase over the farm today as a naturally regenerating legume pasture. Resowing at seeding of the cereal crop is not needed due to the hard seededness of the legume.

Until 1987 the farm was under a pasture/long fallow/wheat rotation consisting of a legume dominated pasture cultivated in the autumn of the second year. This fallowed area was continually cultivated until sowing the next year to reduce weed pressure and increase soil water storage. A cereal was then planted in the third year.

Research in the area showed that long fallows beginning in autumn did not store significantly more water than shorter fallows beginning in spring. As a result the farmer has adopted a two year barrel medic-cereal rotation. The pasture is chemically fallowed in late winter of the second year rather than mechanically fallowed in order to reduce evaporative losses. Minimal cultivation occurs before sowing. The effectiveness of chemical weed control is vital to the cropping enterprise. This was evidenced in 1998 when the grower was incapacitated during summer, resulting in poor control of onion weed. Its moisture use significantly reduced ensuing yields.

Lupins were tried in the late 1970's to mid 1980's but the need to sow early, which is often not possible in the Mallee, gave yields that were generally too variable for this crop to be grown on a consistent basis. More drought-tolerant cereals have been the cropping option since this time.

4.17.6. WEED MANAGEMENT

As previously mentioned, onion weed, silver grass and brome grass are the weeds causing greatest problems in this cropping system. Winter cleaning in June and July of the first year of the pasture phase with combinations of simazine, glyphosate and Gramoxone reduces seed set of grass species in the pasture and increases the medic population. These chemicals reduce the medic seed set. Fallowing then begins in spring of the second year's pasture.

In the cropping phase low rates of metsulfuron-methyl (Ally® @ 5g/ha), Clopyralid (Lontrel® @ 30ml/ha) and MCPA (370-400ml/ha) are used for broadleaf weed control. This mix has the potential to significantly affect medic regeneration (Chambers, 1997) but the low rates being used by the grower limit impact on medic. The need for measures to control grass weeds in the crop phase is reduced because of control in the pasture phase.

The introduction of chemical fallowing in recent years has increased the dependence on effective weed control over summer. Application of 1.5l/ha of Roundup and 1.6l/ha of Surpass (2,4-D Amine) over summer is done to help control onion weed and other broadleaf weeds.

The risks of herbicide resistance risks in a low cropping intensity area such as the central and northern Mallee are much less than in an intensive cropping regime. The dependence on fallowing to produce crops will continually keep selection pressure at minimal levels.

4.17.7. STUBBLE MANAGEMENT AND NUTRIENT SUPPLY

Stubbles are retained on the property. There is no need to reduce stubble levels, as only on rare occasions are crops sown in consecutive years.

Fertiliser management depends particularly on nitrogen fixation in the pasture phase in environments like the Mallee. High rates of nitrogen fertiliser have the potential to increase biomass levels to unsustainable levels if the seasonal finish is 'tight', as it often is in the Mallee.

Hence adoption of nitrogen application has been relatively low. The use of winter cleaning increases the potential fixation by medic pasture while at the same time maintaining potential stocking rates. In effect crops will have access to higher levels of nitrogen nutrition for the cost of the winter cleaning chemicals.

Phosphorus nutrition is important in most Australian soils and this case is no exception. The grower aims to apply twelve to fifteen kilograms of phosphorous per hectare in the cropping phase.

4.17.8. HARVEST

Harvest does not include the use of any specialist equipment or techniques. All of the crop is harvested using the New Holland TR98 header owned by the grower.

4.17.9. MARKETING

A VicGrain silo exists in close proximity to the home block at Kooloonong. Grain is regularly stored for marketing as bulk parcels with other growers in the area. This method of marketing has produced significant premiums on a number of occasions. Market information occurs through the use of newsletters faxed to the grower. Subscription to a regular commercial commodity news report has increased market intelligence.

4.17.10. PRACTICAL ISSUES OF CONSERVATION CROPPING AND MALLEE FARMING SYSTEMS

The main advantage of conservation cropping methods, as perceived by the farmer, has been improved operational timeliness. In 1997 earlier planting allowed the crop to get established sufficiently well to survive the dry period following sowing. Rain in August and the earlier planting allowed the crop saw the crop yield more than many of the neighbours crops. Limited rainfall over September and October placed moisture stress on the crops but the advantages of the system was still evident.

The system makes possible some changes in the pasture phase. Winter cleaning with knockdown and selective herbicides increases feed availability and quality by increasing the medic component. Grass weed and seed production is reduced and potential nitrogen fixation is increased. The result of these management decisions on this farm have been increased stocking rates and, in the farmes judgement, improved crop nutrition and competitive ability of crop plants. The grower hoped to further increase stock carrying capacity from the present 1500 breeding merino ewes to 2000 or 2500. Ewes are brought in and crossed with Poll Dorset rams and the lambs sold at Swan Hill.

A range of issues have been identified in the new conservation cropping system. Of interest is the increasing incidence of mushrooms growing in the paddocks. The combination of stubble retention and reduced cultivation have combined to allow fungal growth to occur. Similarly, Rhizoctonia incidence has increased, reducing yields in some crops. As with the mushrooms, reduced cultivation increases rhizoctonial growth. The use of superseeder points to disturb the soil below the seed zone is hoped to decrease the impact of the disease. Rhizoctonia problems are not confined to direct drilled paddocks however. Many cultivated paddocks also have Rhizoctonia problems resulting in yield reductions. Other common problems of the Mallee such as Take all *(Gaeumannomyces graminis)*, Cereal cyst nematode *(Heterodera avanae)* have not noticeably increased in incidence since adoption.

On the weed front, reduced tillage has increased the incidence of onion grass and silver grass. The small leaf area of these species inhibits herbicidal uptake, reducing control. To control Silver grass, Brome, Ryegrass and Barley grass a mix of 500ml of Gramoxone and 1l of Simazine is used to winter clean. This has an impact on the medic pasture and could cause some problems with the carryover of the seed into the next pasture phase. This has to balanced against in-crop weed control however. Recent work at Walpeup (Scammell, 1997) (Latta, 1998) saw stocking rates maintained in the first of year of winter cleaned pasture-pasture-cereal rotation and then increased in the second year of the rotation compared to the conventional mechanical fallow in the year prior to crop. Wheat yields after chemical treatment (1993 and 1996) were, respectively, forty percent greater and similar to control treatments at Walpeup (Latta, 1998). The use of selective chemicals to winter clean significantly increased yield and protein compared to knockdown cleaning in 1993. No disease was present and medic seed carryover was greatly increased with both grass selective and winter cleaned treatments compared control strategies. Winter cleaning saw increased pasture quality and similar total biomass production to controls. Grass weed populations were almost eliminated in the two years prior to cropping along with in-crop weed populations of the chemically treated crops. Regenerating winter-cleaned pastures had significantly increased densities of medic following the cropping phase except where pasture was spray-topped when medic was flowering. This significantly reduced the medic component of the pasture (Latta, 1998).

Yield increases seen in this experimental work was high enough to justify the expense of selecitive herbicide use to winter clean pastures (Latta, 1998). Despite this encouraging work, there has limited adoption of winter cleaning in semi-arid regions of south-eastern Australia (Latta, 1998) (Grey, 1999). Reasons for non-adoption include cost, conservative stocking rates, potential for herbicide resistance development and lack of silver grass control with present chemicals. The recommended strategy in the Mallee is to remove grass with selective herbicides in year one of the pasture phase; avoid pasture topping and restrict grazing in the spring of year one and then double normal stocking rates in second year pasture paddocks (Latta, 1998).

The grower has noted with interest the progress of the Mallee Sustainable farming project which is showing that conservation cropping methods are not adversely affecting yields in the Mallee.

In summary, the grower sees the implementation of conservation cropping as being one of continual interpretation and refinement. He is aware that it may take the soil and general environment fifteen years to reach an equilibrium that allows the effects of changes to crop and pasture management to be known with certainty.

4.17.11. ECONOMIC AND FINANCIAL ASPECTS

Farm performance has been extremely variable over the period 1994-95 to 1997-98. Separation of the former business in 1994 means that only figures from this time on were of use, and available. Annual farm gross income has averaged $183,830, but varied from $7,316 in the drought year of 1994 to $307,000 in 1996-7. Similarly, annual variable costs varied significantly from year to year, averaging $86,381 annually. Average annual farm total gross margin was thus $97,449. Cash overhead costs have averaged $45,268. Once depreciation costs (average of $25,523) and an operators allowance of $30,000 were deducted, average operating profit was -$3,342. The non-cash nature of these costs, supplemented by full-time, off-farm income from the spouse has overcome any cash difficulties for the family however. Net farm income was marginally less than operating profit due to the interest costs incurred in recent times. Average annual net farm income was $-18,090. Economic performance in the four years is displayed graphically in Figure 100.

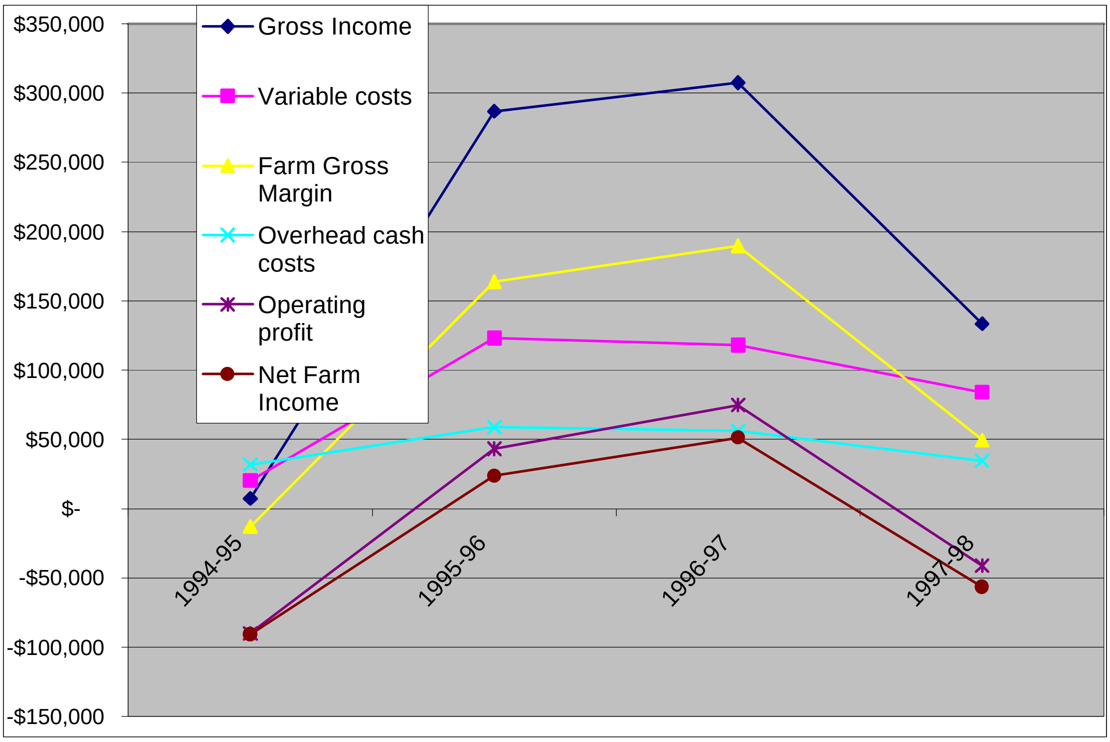


Figure 100 – Economic performance of the business over time.

In summation, two good rainfall years and two poor rainfall years were experienced. The existance of significant on-farm grain storage capacity has also lead to income from particular years being pushed into other years, complicating the picture somewhat. The absence of significant debt prior to this period indicates that the farm had been operating well from an economic point of view prior to this period, where large machinery purchases increased debt.

Investment analysis revealed that the annual internal rate of return from the operation was 9.25 per cent. Initial asset values were based on a land price of $250 per hectare Annuello and $300 per hectare for the block at Kooloonong. These values were increased to the actual achieved sale price of $300 and $375 per hectare for the respective blocks of land to calculate the salvage value. Thus the investment has returned greater than the rate of inflation over the four-year period. The efficiency of resource use is comparable for some more conservative, non-agricultural investments but given the high risk of cropping in the Mallee returns are somewhat less than desirable. Over time the picture may have become clearer.

We should conclude that this rate of return is similar to that of other farms in the area using conventional cultivation. A run of poor seasons finds many farmers in the area presently struggling with high debt and reduced cash availability. Hence the use of conservation cropping has not reduced profits more dramatically than conventional methods. As such, the system has proved its efficiency to a large extent.

Annual net cash flows over the period analysed were affected by the purchase of a new seeder and header. These purchases increased debt, interest costs and principal repayments over the period. Interest and hire purchase costs averaged around $15,000 annually over the four year period. They were a direct result of the split-up of the prior busines run with a brother until 1994. Purchase was necessary to continue operation.

4.17.12. SUMMARY

In summary, the business was performing marginally from an investment point of view however so are many other farming operations in the Mallee. A relatively low debt situation, good working capital and some reasonable seasons would have seen the grower produce some good returns, as the business showed it was capable of in two of the four years analysed. The family situation of the grower and an attractive price offered for the properties has seen the farmer sell the operation however. The farm has shown that conservation cropping can work reasonably well in the Mallee situation. Adherence to, and success with, the methods over a length of time, in combination with the low levels of debt following the use of conservation cropping has shown that the system can work in the area. Many growers still exclusively use conventional tillage however. The need for economies of scale in areas like the Mallee will increasingly see a move to methods that allow more timely sowing and employment of conservation values. Significant research investment in the Mallee region over the next few years will hopefully elucidate some of the biological, chemical or physical reasons why conservation cropping has not been a success in the area.

Financial Year	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	199
Annual Rainfall (mm)		623	580	458	841	792	361	
Growing season rainfall		451	495	332	548	399	141	
Operating Profit								
Income - Wheat	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Barley	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Livestock	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,532	$
Wool	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,784	$
Gross Income	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 7,316**	**$**
Costs - Chemicals	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,360	$
Fertilisers	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,838	$
Fuel	$ -	$ -	$ -	$ -	$ -	$ -	$ 9,117	$
Seed and Freight	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,125	$
Livestock costs	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,824	$
Total variable costs	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 20,264**	**$**
Farm Gross Margin	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**-$ 12,948**	**$**

Cash overhead costs

Accountancy/agronomist f	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,623	$
Casual labour	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Computer supplies	$ -	$ -	$ -	$ -	$ -	$ -	$ 100	$ 1,003	$
Contractors	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 605	$
Dogs	$ -	$ -	$ -	$ -	$ -	$ -	$ 142	$ 629	$
Drawings	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Electricity (70%)	$ -	$ -	$ -	$ -	$ -	$ -	$ 101	$ 537	$
Private electricity	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Farm advisory fees	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 470	$
Insurance	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,142	$ 3,798	$
Legal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Levy	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,228	$
Licences & registrations	$ -	$ -	$ -	$ -	$ -	$ -	$ 121	$ 1,027	$
Machinery R&M	$ -	$ -	$ -	$ -	$ -	$ -	$ 11,912	$ 9,636	$
Motor vehicle expenses	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Pest Control	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,101	$
Plant hire	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 295	$
Postage & stationary	$ -	$ -	$ -	$ -	$ -	$ -	$ 208	$ 45	$
Private non deductable	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$

Protective clothing	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 76	$
Rates	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,023	$ 5,016	$
Rent	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Repairs and general maint	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,512	$ 1,413	$
Subscriptions	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,354	$ 959	$
Superannuation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Telephone (90%)	$ -	$ -	$ -	$ -	$ -	$ -	$ 667	$ 1,422	$
Telephone private	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Travelling expenses	$ -	$ -	$ -	$ -	$ -	$ -	$ 49	$ 98	$
Wages	$ -	$ -	$ -	$ -	$ -	$ -	$ 8,425	$ 24,576	$
Workers comp.	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 218	$
Total Cash overhead cost	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 31,756**	**$ 58,775**	**$**
Depreciation#	$ 14,037	$ 16,158	$ 14,685	$ 13,004	$ 12,464	$ 11,110	$ 15,350	$ 31,786	$
Operators allowance in exc	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$
Operating profit	**-$ 44,037**	**-$ 46,158**	**-$ 44,685**	**-$ 43,004**	**-$ 42,464**	**-$ 41,110**	**-$ 90,054**	**$ 43,095**	**$**
Interest to creditors	**$ -**	$ -	$ -	$ -	$ -	$ -	$ 630	$ 19,433	$
Net Farm Income	**-$ 44,037**	**-$ 46,158**	**-$ 44,685**	**-$ 43,004**	**-$ 42,464**	**-$ 41,110**	**-$ 90,684**	**$ 23,662**	**$**
Net Cash Flow									
Sources									
Cash in									
Sales	$ -	$ -	$ -	$ -	$ -	$ -	$ 7,316	$ 286,846	$
Other	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,190	$ 8,179	$
New borrowings								$ 128,000	
Total	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 7,316**	**$ 414,846**	**$**
Cash out									
Variable costs	$ -	$ -	$ -	$ -	$ -	$ -	$ 20,264	$ 123,190	$
Cash overheads	$ -	$ -	$ -	$ -	$ -	$ -	$ 31,756	$ 58,775	$
Income tax	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Consumption	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$
Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ 630	$ 19,433	$
Principal	**$ -**	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Land improvement	$ -	$ -	$ -	$ -	$ -	$ -	$ 90	$ -	$
Machinery replacement	$ -	$ 38,620	$ 6,008	$ -	$ 13,294	$ -	$ 101,028	$ 179,903	$
Investment	**$ -**	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Total	**$ 30,000**	**$ 68,620**	**$ 36,008**	**$ 30,000**	**$ 43,294**	**$ 30,000**	**$ 183,768**	**$ 411,301**	**$**
Net Cash Flow	**-$ 30,000**	**-$ 68,620**	**-$ 36,008**	**-$ 30,000**	**-$ 43,294**	**-$ 30,000**	**-$ 176,452**	**$ 3,545**	**$**
				-$ 30,000	-$ 73,294	-$ 103,294	-$ 279,746	-$ 276,201	-$
Assets –Land	$ 1,116,500	$ 1,116,500	########	########	########	########	$ 876,800	$ 1,116,500	$ 1
Assets - Machinery	$ 115,203	$ 137,666	$ 128,988	$ 115,984	$ 116,815	$ 105,705	$ 191,383	$ 339,500	$
Assets - Stock	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,404	$ 20,707	$
Assets - Other	$ -	$ -	$ -	$ -	$ -	$ -	$ 98,286	$ 20,820	$
Total Assets	$ 1,231,703	$ 1,254,166	########	########	########	########	$ 1,179,873	$ 1,497,527	$ 1
Liabilities – overdraft	$ -	$ -	$ -	$ -	$ -	$ -	$ 37,828	$ 22,071	$
Long term loans and other	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,537	$
Total liabilities	$ -	$ -	$ -	$ -	$ -	$ -	$ 37,828	$ 195,608	$
Equity ($)	$ 1,231,703	$ 1,254,166	########	########	########	########	$ 1,142,045	$ 1,301,919	$ 1
Equity (%)	100.0	100.0	100.0	100.0	100.0	100.0	96.8	86.9	
Return on equity	3.6	3.7	3.6	3.5	3.4	3.4	7.9	3.3	

	1994-95	1995-96	1996-97	1997-98
Annual Operating Profit	-$90,054	$43,095	$74,734	-$41,144
Asset value	$1,081,587			$1,435,728
Investment cash flow	-$1,171,641	$43,095	$74,734	$1,394,584
Internal Rate of Return	9.25%			

4.18. ANALYSIS OF WEED CONTROL OPTIONS IN INTENSIVE CROPPING PROGRAMS

4.18.1. INTRODUCTION

The potential for weeds to develop resistance to herbicides is one of the major factors to consider in any analysis of cropping systems. Herbicide use has reduced the dependence on tillage and grazing as a means of weed control, allowing farmers to adopt more profitable, higher intensity or continuous cropping options. Increased cropping intensity generally implies an increased use and dependence on chemical weed control. Rapid adoption of chemical farming in the last two decades has contributed to increased Australian crop yield. Despite advances in weed and general cropping technology, financial losses attributable to weeds are estimated to total A$3.3 billion annually (Comellback, 1989); a figure based on costs associated with cultivation, yield loss, herbicides and product contamination (Comellback, 1989). Thus development of resistance by weeds to chemical treatments has the potential to significantly reduce the profitability of cropping operations.

Resistance to herbicides is a naturally inherent trait in any weed population. Repeated application of herbicides creates intense selection pressure. A rapid evolution of resistant populations results. The development of resistance has the potential to reduce farm income and cause crop farmers to change tillage and weed control systems (Powles, 1992).

The problem of weed resistance to herbicides in cropping the cropping zone of southern Australia has been exacerbated by the presence of annual ryegrass (*Lolium rigidum* Gaudin), a ubiquitous weed in this cropping zone. High fecundity (seed production), adaptability and hardiness provide for rapid development of resistance in annual ryegrass. This has happened in many locations. Since the first reported case of herbicide resistance in 1970 (Powles, 1990), exponential growth in resistance development to a range of chemicals has occurred. More than two thousand cases of herbicide resistance in annual ryegrass have been documented in Australia (Matthews, 1994). Resistant weed populations have developed on an estimated three thousand farms in Southern Australia (Henskens, 1996). Further to this, development of cross and multiple resistance to a range of chemicals has occurred extensively (Powles, 1990), posing significant management problems. The adaptability of ryegrass and ability to develop resistance is indicated in Table 112.

*Table 112 –Chemicals to which annual ryegrass (*Lolium rigidum *Gaudin) has developed resistance and cross resistance.*

Chemical to which annual ryegrass has developed resistance and cross resistance*	Common name
Diclofop-methyl*	Hoegrass
Fluazafop*	Fusilade
Haloxyfop*	Verdict
Quizalofop*	Targa
Alloxydim*	Fervin
Sethoxydim*	Sertin Plus
Tralkoxydim*	Achieve
Carbamate	
Triazinone	
Triazine	Gesatop
Simazine	
Chloroacetamide	
Diuron	Diuron
Linuron	Lorax
Fluometuron	Cotoran
Chlortoluron	
Methabenzthiazuron	
Methazole	
Metoxuron	
Chlorsulfuron*	Glean
Metsulfuron*	Ally
Triasulfuron*	Logran
Trifluralin*	Treflan
Metribuzin*	Sencor
Amitrole	Amitrole
Glyphosate	Roundup
Paraquat	Gramoxone
Paraquat and Diquat	Sprayseed
Imidazolinone	Spinnaker

Annual ryegrass is the predominant weed in cropping situations in southern Australia. The extent of crop yield losses caused by annual ryegrass, and the ability of ryegrass to develop resistance dictate that it is the primary focus of this chapter, although some attention is paid to other weeds of the southern cropping regions.

Annual ryegrass has developed resistance to most commercial chemicals to varying degrees around the world, and in Australia (Powles, 1999), as shown in a range of Australian studies. Of the more than one hundred weed biotypes identified as being resistant globally, annual ryegrass is one of only two to exhibit cross resistance to herbicides from different chemical groups (Stewart, 1993). Random surveys in southern NSW found 14 per cent of one hundred and sixty one farms contained ryegrass resistant to diclofop-methyl (Pratley, 1993). Research in Western Australian work found 'fop' resistance in 51 per cent of three hundred samples, with 42 per cent exhibiting cross resistance to sulfonylureas and/or dims. The number of sulfonylureas applications accounted for 67 per cent of resistance levels (Gill, 1993). High levels of resistance were seen after four applications of either chemical. Another Western Australian study found 28 per cent of farms had resistant annual ryegrass (Powles, 1999), with an additional 16 per cent of farms having resistant wild radish problems. Fifty-three confirmed Western Australian populations of resistant wild radish were seen in 1998 (Hashem, 1999). A further survey WA saw 40 per cent of crops containing ryegrass with enough resistance to cause management difficulties (Gill, 1996). A survey of crop farms in the Victorian Wimmera and Mallee found low levels of existing resistance (three percent) but high levels developing (35 per cent) to one or more chemicals (Henskens, 1996). This figure is likely to have since increased with the intensification of cropping in the southern zone.

4.18.2. MODELLING WEED BEHAVIOUR

Until recently there have been few economic studies that present realistic response models of control measures or that assess the determinants of optimal levels of control (Pannell, 1990). A range of studies have redressed this issue (Gressell, 1990) (Pandey, 1990) (Goddard, 1995) (Schmidt, 1996) which have provided a framework for the study of the economics of weed control. A number of these studies have shown the importance of utilising IWM strategies, as they have tended to provide the optimal biological and economic solutions to weed control problems (Goddard, 1995) (Pandey, 1990).

The number of studies to have analysed cropping systems where herbicide resistance has developed to a significant extent is limited. In one scenario a move to pasture-based production systems was part of the optimal solution (Goddard, 1995). Significantly, this study found the use of non-chemical options increased the length of time that cropping can be undertaken profitably. The value of non-chemical measures increased with greater weed-killing effectiveness. However for growers in the Eastern states dealing with herbicide resistance of weeds, a paucity of information exists on weed control strategies. A Microsoft Excel® model, originally developed by Stewart (1993), was expanded to incorporate as many options as possible to allow analysis of various weed control strategies in cropping and mixed farming operations.

The adoption of herbicides has proved beneficial for many growers on soil types susceptible to erosion and structural decline. An initial fear was that herbicide resistance by weeds would return many growers to the days of cultivation and potential land degradation.

The Western Australian model of biological and economic impacts of established and alternative ryegrass control measures was achieved by a deterministic integration of biological and economic principles, where no variation is applied to the conditions or effectiveness of operations in different years. Like all models, this model is a partial representation of reality. Still, irrespective of these limitations, a range of valuable results can be obtained. The model was designed to simulate operation of the Western Australian environment. This in turn was altered by the author to cater for the range of crops and pastures grown in south-eastern Australia. Additionally an extensive range of herbicidal options and non-herbicidal options were added for evaluation. The result is a useful analysis of weed control programs available to growers. The range of assumptions and simulations are detailed below.

4.18.3. OVERVIEW AND BASIC ASSUMPTIONS OF THE MODEL

The operation of the model is over a 20-year period.

Activity gross margin per hectare, and weed density per square metre, are the main outputs in each of the 20 years. All equations are based on these units of measurement.

Crops available for simulation include wheat, barley, triticale, canola, lupins, faba beans, field peas, lentils and chickpeas. Pasture types include lucerne, clover, cadiz serradella and volunteer pasture.

It is possible to specify a maximum number of applications for each selective herbicide after which ryegrass is assumed to be fully resistant.

Ryegrass ecology can be altered to suit the environment.

A large number of non-chemical weed control methods can be evaluated.

Ryegrass and seed populations are estimated at eight points during the year.

It is assumed that all years are identical in terms of their potential production, although the weed populations vary over time, affecting yield accordingly.

It is not an optimisation model. The optimal strategies can be estimated determined for different scenarios through a series of runs.

Weeds other than ryegrass are assumed to be well controlled.

Machinery costs are calculated on a per hectare basis, and include purchase and depreciation costs. The costs are included in every year of the twenty year period if a strategy which requires the machinery is selected.

Because weed control is conducted at different times, combined impacts are assumed to be multiplicative rather than additive. For example, two methods each with sixty percent mortality produce eighty four percent mortality.

The economic analysis in the model derives from crop yields estimated using equations that take into account the effects of ryegrass competition. Inherent variations associated with climate, soil, sowing time and nutritive availability also exert influence but are not considered. The equations used are simply the best estimates currently available. Previous modelling of weed populations (Maxwell, 1990) using this equation provided the best approximation of observed yield losses in the field. The equation however is very sensitive to the parameters used. Estimations of maximum proportions of yield lost to weed competition and the percentage of yield lost to each weed present drastically affect the equation's, and hence model's, outcome. The estimated crop yield is:

$$Y1 = \frac{(P0 + a)}{P0} \times P1 \times \frac{M + (1 - M))}{(a + P1 + (k1,2 \times P2))}$$

Where

Table 113 – Explanation of symbols in yield loss equation

Symbol in equation	Parameter
Y1	Yield after taking account of competing plants
P0	Density of standard crop (pl/m2) (100 for wheat)
a	The background competition factor.
P1	Crop density (pl/m2) determined by crop sowing rate
M	Maximum yield loss at high weed density.
K 1,2	Percentage of yield lost per ryegrass plant present.
P2	Ryegrass density (pl/m2) as determined by the model

Significant gaps in knowledge exist about various crop-weed interactions. This limits the extent to which results from the model can be extrapolated. Yield loss relationships to weed populations are well defined in wheat and lupins, but limited data exist for other crops. The equations and parameters presented result from consultation with weed scientists in Wagga (Sutherland, 1998) (Lemerle, 1998) and Western Australia (Bowran, 1998). The complex interactions are best represented graphically.

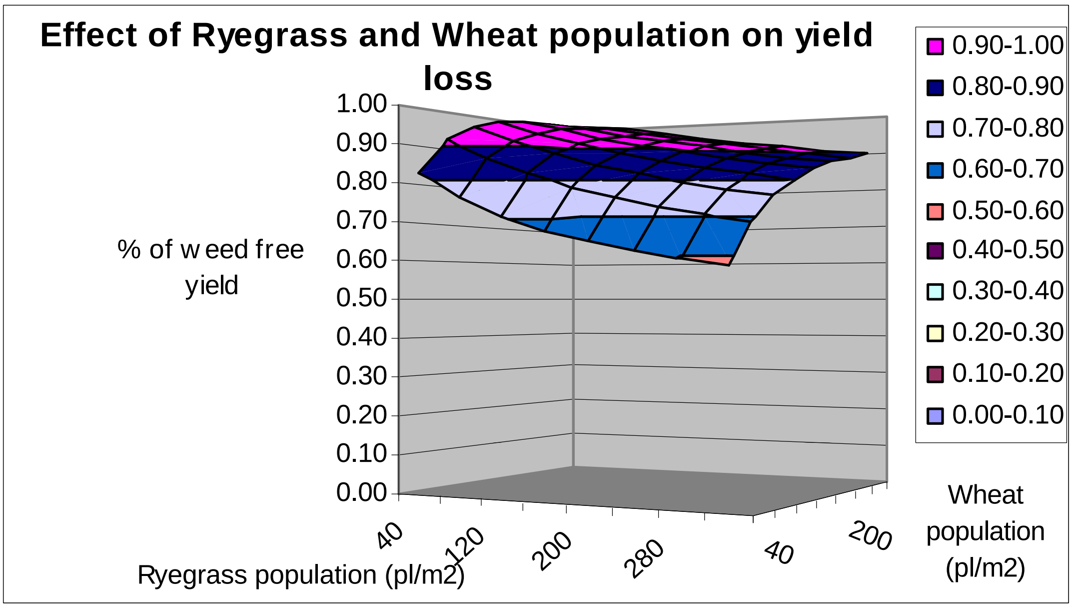


Figure 101 – The effect of ryegrass and wheat density on the proportion of yield lost due to competition.

Higher ryegrass populations increase yield losses in the wheat crops. Conversely, higher established numbers of wheat plants reduce the competitive impact of ryegrass. This relationship, represented in Figure 101, changes dramatically if equation parameters are changed, as sensitivity analysis confirms.

Table 114 – Effect of changing parameters M (maximum yield loss from weed competition) and k1,2 (yield loss per weed present) on the proportion of the weed-free yield produced given wheat and ryegrass densities of one hundred plants per square metre.

k1,2 – percentage of crop yield lost due to each ryegrass plant

M – maximum yield loss due to weed competition, eg. 0.2 = only 20% of crop yield can be lost to weeds.

	0.2	**0.4**	**0.6**	**0.8**
0.1	0.98	0.95	0.93	0.90
0.2	0.96	0.91	0.87	0.83
0.3	0.94	0.88	0.83	0.77
0.4	0.93	0.86	0.79	0.72
0.5	0.92	0.84	0.76	0.68
0.6	0.91	0.82	0.73	0.64
0.7	0.90	0.81	0.71	0.61

Altering parameters has a major impact on yield loss, as shown in Table 114. The estimated values of parameters M and k1,2 in the model equal 0.6 and 0.3 respectively. The model runs for twenty years. As such, errors can have large repercussions on the overall economic analysis. Given the lack of experimental data for parameters relating to other crops included in the modified model, results have to be interpreted cautiously.

Despite the above-mentioned limitations, the model still provides some useful insights. Revelation of the cumulative impacts of control programs over time is a feature of the model, reinforcing knowledge about the benefits of long-term, integrated chemical and non-chemical control measures, rotations, and timings of operations in intensive cropping programs.

4.18.4. THE ECOLOGY OF WEEDS AND THE DEVELOPMENT OF RESISTANCE

The development of herbicide resistance primarily depends on the frequency of resistant genes and fitness, inheritance and gene flows. Simply, weed resistance is accelerated evolution brought about by intensive selection pressure. The aim of modern agriculture is increasingly to share less crop yield with pests, thereby increasing adaptive selection pressure (Maxwell, 1994). By definition, resistant plants are able to withstand substantially higher herbicidal concentrations than the species' wild type via changed morphological and/or physiological traits in response to herbicide uptake, translocation, site of action or metabolism (Maxwell, 1990). Herbicide application occurs at relatively low doses in the Australian environment. This ensures the survival of individuals exhibiting both relatively strong (resistant target site enzymes) and weak (enhanced rates of metabolism) mechanisms of resistance. Progeny derived from the cross-pollinated survivors thus exhibit a range of different resistance mechanisms. Cross-resistance develops rapidly when these conditions exist.

4.18.5. GENE FREQUENCY

Annual ryegrass has a diploid genetic structure and cross-pollinates to reproduce. Hence, populations infesting crops are a conglomeration of cultivars, with ensuing phenotypic variability. Mutational frequency usually occurs at around 10×10^7 or 10×10^6 (Howat, 1987) in most species. However, the rate of mutation in annual ryegrass has been estimated at 10×10^5 (Piper, 1989). The result, with intensive selection, is rapid development of resistance.

The number and complexity of genes at the site of action determine the frequency of resistant genotypes. Seventeen genes confer resistance mechanisms in group A herbicides

(Aryloxyphenoxypropoinates – 'fops', and Cyclohexanediones – 'dims'), dramatically increasing the chance of resistance developing compared to other herbicides (Bowran, 1998). Modes of action and gene structure are the basis of herbicide classification, and this increases the risk of resistance by plants developing.

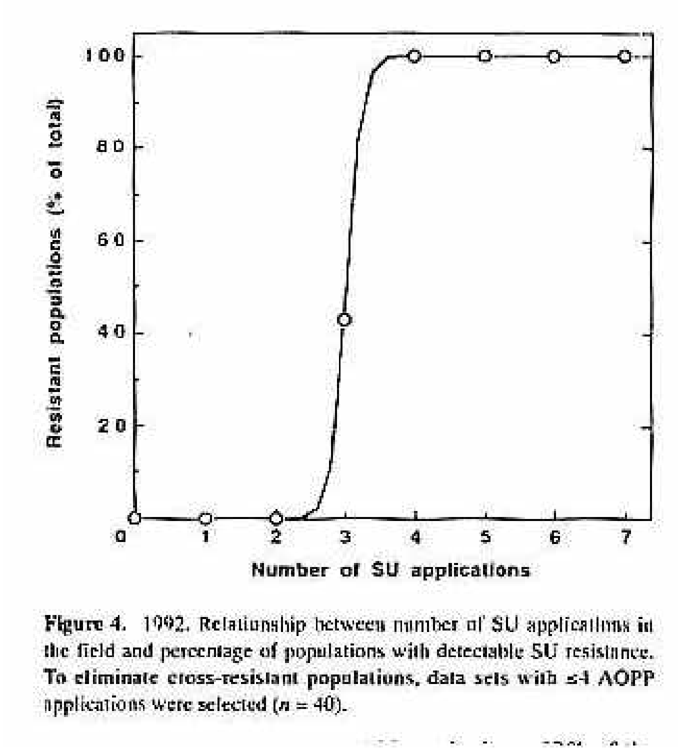


Figure 102 – The development of sulphonylurea herbicide (Group B) resistance over time in annual ryegrass (Gill, 1996).

4.18.6. GENERATIONAL TIME

Longer generation time is one of the reasons why the appearance of resistant weeds has lagged that of insects and bacteria. Faster generation time intensifies selection pressure. Generally only one application of herbicide is made to a particular population. Continual use of antibiotics for example can result in extremely rapid onset of resistance.

4.18.7. SELECTION PRESSURE

The main factor increasing the appearance of resistance is selection pressure (Gressel, 1978). Fitness is less important, while seed banks also modify the rate of resistance development. High seed turnover and elevated selection pressure are symptomatic of Australia's cropping zones. Ninety percent selection/kill increases enrichment of resistant genes ten-fold, inducing rapid population change. Ten years of sustained application increases this enrichment to 10×10^{10} (ten billion fold).

Given average mutational frequencies the chances of resistance problems developing are large if seed numbers are not controlled.

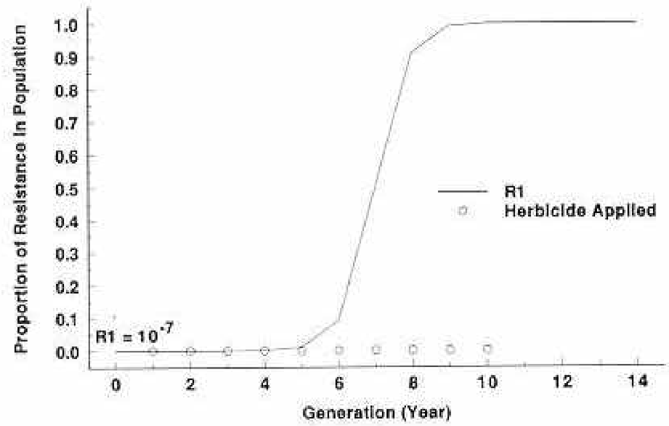


Figure 2. Predicted evolution of a herbicide-resistant phenotype (R1) starting from a mutation proportion (10^{-7}) at generation 0 and exposed to a herbicide with 90% efficacy (removal of susceptible phenotype) for 10 continuous generations. R1 was assumed to be equal in fitness to the susceptible phenotype.

Figure 103 – Estimated development of resistance in annual ryegrass given ninety percent control over ten continuous generations (Maxwell, 1990).

Selection pressure is also influenced by germination patterns and carryover of viable seeds. Seed depth, light, diurnal temperatures and moisture all impact on weed germination. Tight germination periods and low levels of seed carry-over reduce selection pressure.

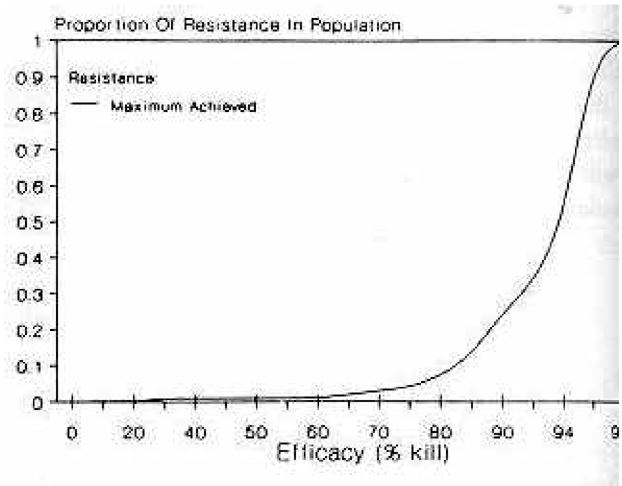


Figure 104 – The influence of herbicide efficacy on resistance development after five continuous years of herbicide application (Maxwell, 1990).

4.18.8. PLANT FITNESS

Selection of resistant biotypes generally induces reduced levels of population fitness compared to wild types, often termed the cost of selection (Maxwell, 1990). For example an exclusively resistant ryegrass population exhibited relative fitness levels equivalent to eighty-one percent of a pure, susceptible population in the same region. When biotypes were mixed the resistant biotype's fitness dropped to sixty four percent (Howat, 1987). Elimination of selection will result in reduced levels of resistance in the field.

Ryegrass plant is an extremely competitive weed, especially early in the season. Eradication at the two-leaf stage potentially increase crop yields by twenty percent or more if established prior to sowing (Reeves, 1975) (Stewart, 1993). Particular crops and increased crop density reduce yield loss, with oats, triticale and barley having the greatest competitive ability followed by canola, wheat, barley, field pea and lupin (Lemerle, 1995).

Improved fertiliser placement enhances the crop's competitive ability against weeds. Where nitrogen was banded below the seed twenty eight to sixty percent less ryegrass tillers were produced compared broadcast nitrogen treatments (Neitschke, 1996).

4.18.9. SEED CARRYOVER

Ryegrass can produce vast quantities of seed. Individual plants capable of producing ten thousand seeds (Henskens, 1998) induce rapid increases in seed banks if control is poor. Ryegrass seeds rarely survive in the soil for longer than three years however. Approximately fifty to eighty percent of the available seedbank will germinate by the end of May (Howat, 1987), a figure increasing with summer rainfall, seeds near the surface and moisture in the soil (Gill, 1996). Tillage also affects germination with relatively undisturbed or lightly soil covered situations increasing germination rates. Thus no-till seeding increases early germination and potential dependence on early, in-crop control. Growers have adopted delayed sowing, allowing the use of knockdown chemicals where seasonal conditions permit. Additional seed with limited potential impact will germinate over the course of the season (Henskens, 1998), but early control is vital to yield and the management of resistance to risk.

4.18.10. THE INFLUENCE OF NO-TILL

Minimal soil disturbance seeding impacts on the ecology of weeds in cropping systems by altering and in some cases broadening the spectrum of weeds (Derksen, 1999) (Minkey, 1999). Increased seed recruitment under favourable conditions offers potentially increased control but conversely higher risks of resistance development if control is ineffective. The tactical use of delayed sowing, ensuring good control with low risk knockdown herbicides, is a key to the continued effectiveness of no-till in southern cropping zones. While these practices can reduce some potential gains from no-till, recent work also suggests that no-till is an effective IWM tool in its own right (Minkey, 1999). The model aims to highlight the importance of integrated weed management (IWM) to manage profitability and resistance risk in a cropping program.

The potential development of resistance has contributed to non-adoption of conservation cropping (Kondinin Group, 1999). Demonstrating the ability of IWM to profitably control ryegrass populations in the longer term helps demonstrate, albiet by default, the potential sustainability of conservation cropping. Whilst profitability has been maintained with a reduced armoury of chemical control methods and reduced tillage in the Western Australian wheatbelt, at least in the short term (Crabtree, 1999), this does not lessen importance of IWM as a long-term key to profitability. As Derksen (1999) put it:

> Farmers who identified the problem were rotating herbicides with the expectation that they could avert the resistance problem on their farm. Herbicide rotation in itself did not provide the intended result. This does not invalidate the practice of avoiding or delaying the onset of single target site resistance. However it does serve as a reminder that herbicide rotation is a stopgap, medium term solution to the problem and reinforces the need for longer term, more integrated approaches to weed management. (Derksen, 1999)

Without the use of integrated weed management practices intensive cropping systems have a limited future. An estimated half a million hectares of Australian cropping land is already infested with herbicide resistant ryegrass (Gill, 1996). The appearance of new chemicals with the potential to alter weed and, in particular ryegrass control is likely to be slow because of the small market, the limited importance of ryegrass internationally, and high development costs of new chemicals (Bowran, 1998). As such, integrated management of existing methods is vital to medium and longer-term effectiveness of broadacre chemicals. The introduction of herbicide resistant crops, and resulting increases in selection pressure, further hasten the need for integrated weed management on a broader scale.

4.18.11. OTHER WEEDS

Thus far some weeds that have displayed the potential to develop resistance have not been considered. The relative importance of each weed varies regionally, but it is worth briefly noting some ecological aspects of the broader weed spectrum and the impact of changed tillage practice.

4.18.12. WILD OATS

Wild oats *(Avena fatua)* are an important grass weed due to their highly competitive ability and potential allelopathic effect in crops. Four different sub-species lead to staggered seasonal germination, but earlier germination predominates. Annual recruitment from seed banks of around sixty percent, and a seed life of three years, confer a limited control of seedbank numbers with the application of one non-residual herbicide. As with ryegrass, seed production per plant depends greatly on competitive factors. Plant densities of greater than fifty plants per square metre produce at least three hundred seeds (Medd, 1996).

The development of resistance in wild oats has not been as spectacular as that of annual ryegrass. Surveys of wild oat resistance have variously found only minor resistance to diclofop-methyl (five percent (Broster, 1998), six percent (Walsh, 1995) and four percent (Neitschke, 1996)). The implementation of minimum tillage farming systems has generally reduced the incidence of wild oat infestation and hence the reduced development of resistance and financial losses due to the weed.

4.18.13. VULPIA (SILVER GRASS)

Vulpia, or silvergrass (*Vulpia* spp.), is a major problem in the southern grain belt because of its allelopathic effect on crops. Reduced cultivation and limited in-crop herbicidal options have increased the incidence of the weed under no-till systems. The off-label use of diuron and treflan confer reasonable control in no-till situations (Bowran, 1996). Simazine is also effective in pulse crops, in combination with diuron. The use of triazine chemicals in triazine-tolerant canola have also helped control vulpia populations.

4.18.14. WILD RADISH

This annual broadleaf *(Raphanus raphanistrum L.)* is a major cropping problem in the cereal belt, especially in pulses where chemical control is limited. Its competitiveness, uneven germination, high levels of seed dormancy, lack of photoperiod requirement and its short season nature, make in-crop and seedbank control difficult. Seed production in cropping situations varies from sixty to one thousand seeds per plant depending on weed density, with ten plants per square metre reducing yield by twenty percent (Reeves, 1981). Economic losses due to the weed are potentially high if uncontrolled, but reduced tillage reduces weed numbers (Reeves, 1981) by shallow burial of seeds, which reduces seed viability. Selection in radish to group B (Imidazolinones, Triazolopyrimidines and Sufonylureas) herbicides is strong, and resistance has been seen to occur after four to seven applications (Hashem, 1999).

4.18.15. WHAT HAPPENS AFTER RESISTANCE IS PRESENT?

The appearance of resistance over large cropping areas can have serious impacts on cropping operations. Loss of a chemical weed control option reduces the number of strategies available to farmers in the short-term, but evidence exists that long-term effectiveness of a chemical may return (Maxwell, 1990). The out-crossing nature of ryegrass means that genes from different plants continually alter the genetic characteristics of populations. This increases resistance levels with initial chemical applications, but after a large proportion of the population has developed resistance, the reverse can occur. The exclusion of selection pressure, in combination with fitness differentials between the susceptible and resistant populations, exerts pressure on the resistant population. The susceptible population's greater fitness increases numbers of susceptible phenotypes, which then out-cross to the resistant population, reducing the level of resistance present. Modelling of the operation of this phenomenon is shown in Figure 105 (Maxwell, 1990). The findings have been supported experimentally in a formerly resistant population at Roseworthy, South Australia (Matthews, 1998).

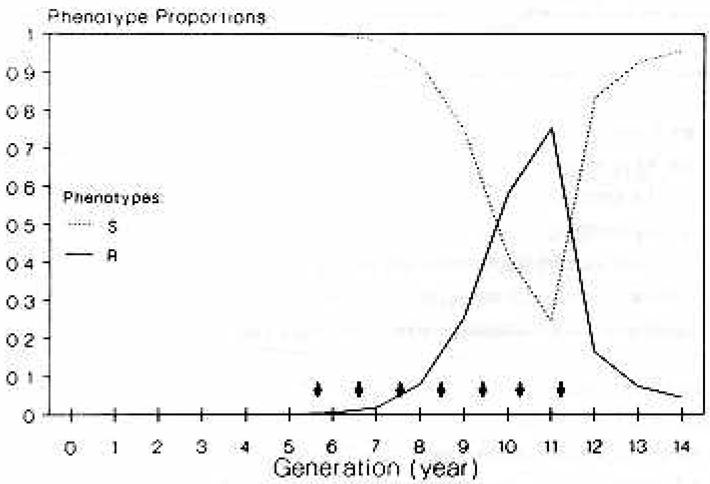


Figure 2. **Model simulations describing the evolution of resistance when the herbicide is used in the system and the subsequent dynamics of resistance in the weed population after the herbicide has been removed. The solid arrows indicate the years of continuous herbicide use.**

Figure 105 – Simulated evolution of resistance development in a ryegrass population over time. S represents the susceptible population; R the resistant population.

By implication then, if the above is true, the long-term impacts of resistance may not be as important as first thought. Reduced cash flow in the short-term may have an impact on business viability but in the medium to long-term, herbicide resistance may not threaten the sustainability of conservation cropping as seriously as was first thought to be the case.

4.18.16. MODEL RESULTS

Running the model

The complex biological functions of ryegrass and crop growth and their interactions, along with the incorporation of economic variables, presents a formidable task to bio-economic systems modellers. The basic framework developed in Western Australia by Stewart (1993) simplified this process, and with the incorporation of additional variables, a large range of scenarios about the effects on ryegrass seedbanks, crop and pasture yield and gross margin per hectare can be examined in detail. The economic analysis is open to some misinterpretation, and thus requires cautious interpretation, as average prices and yields are used over time. There may also be a range of relationships not sufficiently defined by research that may affect biological and economic impacts of selected control strategies. Additionally, 'bugs' are to be expected in all large models, with chances increasing rapidly with size (Pannell, 1996).

With this in mind the above-mentioned considerations, a number of scenarios were modelled to predict possible effects on farm profitability and ryegrass production in south eastern Australia. These are outlined below in Table 115.

Table 115 – Scenarios examined in the model of ryegrass management.

Treatment Number	Description of rotation and treatment
1	Mixed pasture cropping rotation – Wheat-Canola-Wheat-Triticale-Lucerne-Lucerne-Lucerne with limited chemical control.
2	Continuous cropping rotation - Wheat-Canola-Triticale-Lupin with strategic use of chemicals (double knock prior to sowing, crop topping in legumes, use of triazine chemicals in triazine tolerant (TT) canola which is swathed, Treflan® used in every cereal crop, Diuron® in every wheat crop, Glean® on every triticale crop, Hoegrass® on every second wheat crop,

	Select® on every legume crop)
3	As above but without the use of Treflan® in a no-till situation.
4	The impact of seed collection given conditions listed in strategy 3.
5	Conditions as in strategy 4 but without the use of triazine chemicals which is only possible with TT canola.
6	Conditions as in 5 but with every second legume crop (once every 8 years) green manured.
7	As in strategy 6 but with all crop residues burnt after harvest.
8	As in strategy 7 minus the use of seed catching and with no use of the double chemical knock prior to sowing; ie only one knockdown is used.
9	Conditions as in strategy 8 but with every wheat crop sown late with a 10% yield penalty.
10	The use of a Wimmera type of rotation that concentrates on legume production. Alternate 3 year rotation of wheat-canola-chickpeas and wheat-barley-lentils. Applications of Select® and Sertin® in Chickpea and Lentil crops respectively, crop-topping of all legumes, Spinnaker® in Chickpeas, Treflan® in wheat, Hoegrass® in every 2nd wheat crop, Atrazine® in every canola crop and all residues burnt.

The first scenario modeled is one that may be seen on many farms in southern NSW. A rotation of 4 years of cropping (wheat-canola-wheat-triticale) followed by 3 years of lucerne pasture,, cut for hay in each year, is used. Given the high proportion of cereal crops in the cropping rotation the inclusion of lucerne is important for the avoidance of resistance problems, allowing continued use of chemical control in the cropping phase. In a continuous cropping situation the control of ryegrass depends much more on the use of non-chemical options. The results from runs of the various scenarios through the model are given below in Figure 106.

IM Version 98p, Last update 17/3/99	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20
elect Enterprises and Strategies												$ 302 = Annual Profit per ha								
ombined weed kill from whole strategy	100%	100%	100%	100%	99%	95%	95%	100%	100%	100%	99%	95%	100%	95%	92%	100%	99%	96%	100%	98%
ed pool decline relative to no control	99%	98%	99%	89%	99%	95%	95%	99%	98%	99%	89%	95%	100%	95%	82%	98%	89%	85%	98%	96%
eeds setting seed, Sept. (plants/sq m)	6	6	2	9	2	7	19	5	6	1	7	10	1	7	70	41	149	605	153	177
oportion of yield lost (%)	-1%	6%	-2%	-2%	34%	27%	38%	-1%	6%	-2%	-2%	31%	11%	28%	5%	29%	11%	24%	47%	19%
eld (t/ha)	3.68	1.95	2.84	3.05	0.00	0.00	0.00	3.68	1.95	2.70	3.05	0.00	0.00	0.00	3.63	1.47	2.47	2.28	0.96	1.22
ross margin ($/ha)	$381	$472	$188	$177	$462	$80	$55	$381	$502	$286	$289	$432	-$2	-$4	$402	$342	$157	$166	$174	$81
nterprise	50	133	138	140	153	154	155	50	133	138	140	153	154	155	50	133	138	140	141	142
hoose enterprise (Wh, Ba, Tr, Can, Lup, FP, Chi, n, FB, Cl, Z, Luc, V)	Wh	Can	Wh	Tr	Luc	Luc	Luc	Wh	Can	Wh	Tr	Luc	Luc	Luc	Wh	Can	Wh	Tr	Can	Lup
elective Herbicides																				
chieve ($/litre)																				
razine 50% flowable ($/l)		1							1							1			1	
adex pre-emergent ($/litre)																				
adex ($/litre)																				
orrect ($/litre)																				
uron (flowable) ($/litre)																				
ual ($/litre)																				
usilade ($/litre)																				
usion ($/litre)																				
ean ($/kg)				1						1	1						1	1		
yphosate CT ($/litre)																				
ramoxone ($/litre)																				
oegrass ($/litre)	1		1					1		1			1							
exone ($/kg)																				
ogran ($/kg)								1					1							
lect ($/litre)																				
ncor ($/litre)																				
rtin plus ($/litre)																				
mazine 50% flowable pre-em/post-sow ($/l)		1				1			1							1			1	1
pinnaker ($/litre)			1																	
prayseed 250 ($/litre)					1															
omp ($/litre)																				
rga ($/litre)																				
opik ($/litre)																				
ifluralin ($/litre)	1		1	1				1		1	1				1		1			
istar ($/litre)																				
erdict ($/litre)																				1
eld ($/litre)				1																
on- selective herbicides and other methods																				
ramoxone (Litres/ha) - Crop top lupins															1					
yphosate (litres/ha) - Pasture topping					1															
yphosate at sowing (Group M)	1	1	1	1	1			1	1	1	1	1			1	1	1	1	1	1
orayseed at sowing (Group L)	1	1	1	1	1			1	1	1		1			1	1	1	1	1	1
owing of crop or legume pasture																				
razing																				
gh intensity grazing winter/spring																				
gh crop seeding rate (extra cost only is shown)																				
reen manure																				
ow pasture																				
ut for hay					1	1	1					1	1	1						
ut for silage																				
vath prior to harvest		1							1							1			1	
urn crop or pasture residues																				
ed catch - dumps burnt																				
ed catch - remove dumps																				
yclone - cyclone trail burnt																				
yclone - total burn																				
indrow - windrow burnt																				
indrow - seed catch																				
ultivate, delay sowing 1 month***																				
ultivate, delay sowing 10 days***																				
ser defined option A																				
[illegible]																				

Figure 106 from previous page– Spreadsheet example of a mixed cropping/pasture rotation. Use of particular weed control methods are indicated by the number 1.

No. of uses of selective herbicide groups before weeds are mainly resistant.	Group A (FOP)	6
	Group A (DIM)	0
	Group B	8
	Group C	10
	Group D	9
	Group K	0
(These limits are not absolutely enforced.	Group L	17
Warning messages display if exceeded).	Group M	17
Enterprise grown 1 year before Year 1?		Luc
Enterprise grown 2 years before Year 1?		Luc

Figure 107 – Use of chemical groups given rotation and treatment in scenario 1.

The highlight of strategy one is the predicted excellent control of ryegrass over time. Ninety –five per cent control is achieved in most years. This control has cumulative effects on the profitability of following crops. Over the course of the simulated period, the number of chemical applications of each group pose some resistance risk, but are not expected to facilitate extensive resistance. It is important to note frequent use of highly selective Group A and B chemicals even though a pasture phase is included. Annual profits are maintained however due to the effective control of the weed population in the canola and lucerne phases.

In a continuous cropping sequence dominated by cereal production and lack of non-chemical control, the chances of resistance developing are high. The introduction of alternate strategies affects the level of chemical application and profit per hectare. A summary of the relative resistance risks posed by each of the strategies as well as the effect on profitability of various measures are seen in Table 116.

Table 116 – The effect of different strategies on profitability and resistance risk.

		Number of times that each chemical group is applied over twenty year planning period						
No.	**Profit/ha**	**Fop**	**Dim**	**B**	**C**	**D**	**L**	**M**
1	$302	6	0	8	10	9	17	17
2	$282	3	5	3	14	10	20	20
3	$232	3	5	3	14	0	20	20
4	$317	3	5	3	14	0	20	20

5	$304	3	5	3	4	0	20	20
6	$275	3	5	3	4	0	20	20
7	$267	3	5	3	4	0	20	20
8	$227	3	5	3	4	0	5	20
9	$237	3	5	3	4	0	5	20
10	$224	4	6	3	4	7	6	20

4.18.17. DISCUSSION OF STRATEGIES

The primary consideration for producers trying to deal with resistance is the profitability of alternative strategies. Reduced profits to obviate the impact of resistance may be tolerated in the short-term but in the long term the profit motive will dominate. As such, the first strategy of a mixed pasture and cropping rotation was shown to be very profitable. These returns may be over-estimated to some extent because of poor knowledge about the risks associated with lucerne establishment, and possible over-estimations of returns from hay production.

Apart from this strategy, other simulations in the analysis are based on continuous cropping programs. The aim of the model in these simulations is to demonstrate if continuous cropping can be carried out without intolerable levels of resistance risk. Continuous cropping proved to be able to be carried out even in a situation primarily dependent on chemical applications, such as Strategy Two. The key to Strategy Two was the use of a rotation of crop types. In a close rotation of cereals, the resistance risk quickly increases, but the inclusion of triazine-tolerant canola and legumes allowed the use of different chemical groups. The result was a much reduced resistance risk, while maintaining rotational gross margin at around $282 per hectare.

The value of using different chemical groups is shown by the negative impact on profit if the use of Treflan® is removed in Strategy Three. Rotation gross margin per hectare drops from $282 to $232, a direct result of increased ryegrass competition and reduced yield. A decrease in annual rotation gross margin of fifty dollars per hectare is significant over a twenty-year period in a large cropping program. The value of this chemical is even greater in situations where resistance has developed to group A and group B chemicals, as is the case in much of the Western Australian wheatbelt. Grower dependence on Treflan® greatly increases the risk of resistance and reduced long-term profitability.

The use of non-chemical control appears very effective in certain situations. Given the same scenario used in Strategy Three, which generated a rotation gross margin of $232/ha, the use of a seed collection cart at harvest to separate weed seeds from grain (Strategy Four) increased average profit over the twenty year period to $317/ha. This was the highest rotation gross margin generated in any run of the model, reflecting the method's excellent seedbank control. Alternative strategies that depend on control in the early part of the growing season ignore control of late germinating weeds, which set seed and reduce ensuing rotation gross margin per hectare. This loophole is closed to an extent by the use of seed collection, which was estimated to collect sixty percent of the season's ryegrass left by harvest. The method however, carries its own risks of resistance. Prolonged use (five years or more years) in Western Australian has seen selection of phenotypes shorter in stature and/or that shed their seed prior to collection at harvest (Crabtree, 1999). Again high selection pressure of the highly adaptable ryegrass plant has combined to frustrate growers. Removal of the strategy significantly drops rotation gross margin per hectare from $292/ha to $208/ha, a direct result of increased ryegrass populations. The model may overestimate the benefits of the control, but the message is clear. The use of non-chemical controls can be extremely effective and profitable, at least in the short term.

The positive impact of chemically tolerant crops is demonstrated in Strategy Five. With the same conditions as Strategy Four, but assuming the use of normal, non-triazine tolerant canola varieties instead of TT canola, annual rotation gross margins are reduced from $317 per hectare to $304 per hectare. Over the size of the Australian cropping industry the existing and potential benefits of investment in selective breeding and biotechnology are potentially large. The imminent release of imidazolinone-tolerant and Roundup Ready® canola for the 2000 and 2002 cropping seasons offer producers potentially increased profitability in a well managed integrated weed management system. However in poorly integrated systems the risks of resistance development are likely to increase. Careful management and extension of IWM information will be required to achieve wide adoption and long term usage.

The use of green manuring (the ploughing-in of legume crops for nitrogen and weed control benefits) has been advocated in many locations in the south-eastern grain belt in recent times to manage resistant populations. The effect on production of manuring every second legume crop (Strategy Six), or once every 8 years, is obvious. Rotation gross margin per hectare is reduced to $275/ha even though levels of weed seed control are excellent. Where resistance is present however benefits may occur to longer-term profitability. With a broad spectrum of chemical control still available however the reduced cropping area will reduce farm profits considerably.

The impact of burning crop residues on weed control is seen in Strategy Seven. Burning reduces viability of ryegrass seed, especially in the case where cereal stubbles are burnt. This does not have an effect on profitability as ryegrass control is complete when green-manuring is used. Alternative runs of the model where green manuring was not used saw profit increase in comparison to stubble retention systems.

Strategy Eight is the same as Strategy Seven except for the exclusion of seed collection at harvest and one knockdown spray prior to sowing. The use of a 'double knock', comprising sequential applications of both Roundup® and Sprayseed®, aims to reduce ryegrass populations without the use of selective, in-crop sprays. At the same time it aims to reduce the chances of resistance developing to either of the major knockdown chemicals. This potentially adds much to the sustainability of conservation farming in the longer term. When this scenario was modelled, rotation gross margin was reduced to $227 per hectare compared to $267 per hectare when the measures are included. This again shows the implicit value of the seed collection, but the exclusive monetary effect of the 'double knock' was not quantified in this analysis. It stands to reason however that the long-term sustainability of intensive cropping systems is particularly dependent on this strategy.

Late sowing is often advocated to reduce weed problems. A ten percent yield reduction was included to represent later sowing, but the reduction in weed seed numbers, and hence increase in crop yield, was not great due to the already effective early season weed control measures. Rotation gross margin increased by $10/ha to $237/ha, but once again the benefits of control would be much greater if weed numbers were high, as in a resistant situation or use of alternative methods was limited.

So far, all of the options investigated have related to cropping practices that would be seen in areas such as southern NSW and Western Australia. In the Victorian Wimmera, the use of pulses is more widespread. This was particularly true prior to the large losses suffered from *Ascochyta* blight in the 1998 cropping season. Chickpeas were grown every second year on some properties, greatly increasing the build up of disease inoculum, resulting in the devastating impact on chickpea crops in 1998. The need for reduced rotational intensity is built into the model, which uses a six-year rotation of wheat-canola-chickpeas-wheat-barley-lentils. Weed control is primarily based on chemical application. Rotation gross margin was seen to be $224 per hectare and good weed control was achieved over the course of the program because of diverse selection of crops available to crop farmers in the area. This may explain why resistance is not as large an issue in this area as in other cropping areas, despite the intensive cropping rotations employed.

4.18.18. CONCLUSIONS

In summation; the possibilities to plan weed control programs are many using the bio-economic weed model described above. This planning is based on average yields, prices and weed control success over time, and will alter with seasonal variation. However, some sound general directions and approaches can be identified. The number of possible combinations of actions and methods dictates that simulations specific to paddock by paddock circumstances of individual farmers is of greater practical use than summarising large numbers of possible hypothetical simulations. Still, the limitations of the model some conclusions can be drawn from the questions investigated using the model. Many of these have implications for the continued use of conservation cropping systems. These include:

High intensity and continuous cropping programs are highly dependent on the integration of a range of control methods to avoid resistance and maintain profitability in the long term. Given proper management and use of these options, production can be profitable and can be maintained.

The value of non-chemical control methods such as seed collection is high. Control at times not usually seen in 'conventional' weed control programs alters the ecology of the weed population and hence offers large advantages in the long term. Many non-chemical controls come at a price however and the size of the cropping operation, which is not considered in this analysis, needs to be taken into account.

The value of non-chemical control measures grows as the intensity of cropping is increased.

The value of genetically modified and naturally herbicide resistant crops is high over the course of a rotation. The integration of these crops offer significant weed control benefits in addition to the break crop benefits.

The development of new control measures such as crop-topping in legume crops, seed collection at harvest, 'cycloning' of crop residues, swathing crops prior to harvest, high seeding rates, double knocking with knockdown herbicides prior to sowing and pasture topping provide an effective armoury of weapons to combat the resistance threat. The continual development of methods will be important for the continued expansion of cropping, and of conservation cropping, in Australia.

There is a need to consistently maintain vigilance. Losing control of seedset in one year condemns growers to reduced profits over at least the ensuing one to two years. Longer periods of reduced profits will be seen if the mistake is not acted on quickly.

As with profits, if control lapses for a period of time, the risk of resistance is greatly increased. Optimistically, resistant plants occur in the order of one in 10^6 or 10^7 plants. If seed production numbers are kept low over time the length of time taken for resistant plants to occur is increased, therefore decreasing the chance of resistant genotypes becoming a reproductive phenotypes in the paddock. Large weed infestations greatly increase the rate of resistance development.

Reliance on chemical control methods has a limited future in intensive cropping systems. Even in well-managed situations, incorporation of non-chemical methods is necessary to ensure long-term viability of chemical use.

The onset of extensive chemical resistance has offered opponents of conservation cropping reason to doubt the long-term effectiveness of the system. Development and operation of the weed bio-economic model has indicated that continuous or high intensity cropping programs can be sustainable in the long-term. The model has shown that, if managed effectively, ryegrass resistance problems can be managed effectively and profitably. Practical experience in Western Australia has confirmed this finding.

The main weapon against weeds of all sorts is the use of appropriate rotations and the diversity of control that varied cropping programs offer. Monoculture lends itself to increased weed and disease problems that are often alleviated when rotations are altered. The model confirms the weed part of this assertion.

Further development of the model is warranted given the eminence of weed control and resistance issues in the grains industries. Expansion to include a wider range of weeds affecting growers in different regions, more exacting estimates of control effectiveness under different seasonal conditions, and greater knowledge of crop and weed specific relationships would increase the validity, usefulness and practicality of the model. However, gaining this knowledge and systematically incorporating it into the model is a sizeable challenge. Acknowledgment of the risks of resistance, the potentially high cost it brings, and implementation of more systematic control programs, may result from extension of the use of the model and its findings to farmers. Concomitantly, recognition of the ability of conservation cropping systems to manage weed burdens may also occur, increasing adoption of conservation cropping and that of integrated weed management (IWM) systems.

RIM Version 98p, Last update 17/3/99

Select Enterprises and Strategies

$ 296 = Annual Profit per ha

		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 15	Yr 16	Yr 17	Yr 18	Yr 19	Yr 20
	Combined weed kill from whole strategy	100%	100%	99%	100%	98%	100%	94%	98%	100%	100%	99%	98%	98%	100%	94%	98%	100%	100%	99%	98%
	Seed pool decline relative to no control	99%	98%	89%	99%	88%	98%	84%	98%	99%	98%	89%	98%	88%	98%	84%	98%	99%	98%	89%	98%
	Weeds setting seed, Sept. (plants/sq m)	4	4	16	3	17	11	60	26	5	6	21	10	42	26	138	56	17	15	56	26
	Proportion of yield lost (%)	-2%	4%	-1%	1%	0%	11%	2%	15%	-1%	6%	-1%	4%	2%	22%	7%	26%	0%	15%	2%	15%
	Yield (t/ha)	3.69	1.98	3.03	1.48	1.96	1.76	2.94	1.27	1.88	1.87	3.02	1.44	1.65	1.47	2.79	1.12	1.86	1.69	2.95	1.28
	Gross margin ($/ha)	$368	$484	$180	$111	$230	$512	$235	$117	$140	$556	$285	$208	$63	$308	$221	$81	$115	$450	$201	$92
	Enterprise	50	133	140	142	2	37	140	142	2	37	140	143	3	38	140	142	2	37	140	142
	Choose enterprise (Wh, Ba, Tr, Can, Lup, FP, Chi, Len, FB, Cl, Z, Luc, V)	Wh	Can	Tr	Lup	Wh	Can	Tr	Lup	Wh	Can	Tr	FP	Wh	Can	Tr	Lup	Wh	Can	Tr	Lup
	Selective Herbicides																				
1	Achieve ($/litre)																				
2	Atrazine 50% flowable ($/l)		1				1				1				1				1		
3	Bladex pre-emergent ($/litre)																				
4	Bladex ($/litre)																				
5	Correct ($/litre)																				
6	Diuron (flowable) ($/litre)	1				1				1				1							
7	Dual ($/litre)																				
8	Fusilade ($/litre)																				
9	Fusion ($/litre)																				
#	Glean ($/kg)			1								1								1	
#	Glyphosate CT ($/litre)																				
#	Gramoxone ($/litre)																				
#	Hoegrass ($/litre)	1								1								1			
#	Lexone ($/kg)																				
#	Logran ($/kg)																				
#	Select ($/litre)				1				1				1				1				1
#	Sencor ($/litre)																				
#	Sertin plus ($/litre)																				
#	Simazine 50% flowable pre-em/post-sow ($/l)		1		1		1				1				1				1		
#	Spinnaker ($/litre)																				
#	Sprayseed 250 ($/litre)																				
#	Stomp ($/litre)																				
#	Targa ($/litre)																				
#	Topik ($/litre)																				
#	Trifluralin ($/litre)	1		1		1		1		1		1		1		1		1		1	
#	Tristar ($/litre)																				
#	Verdict ($/litre)																				
#	Yield ($/litre)																				
	Non- selective herbicides and other methods																				
#	Gramoxone (Litres/ha) - Crop top lupins				1				1				1				1				1
#	Glyphosate (litres/ha) - Pasture topping																				
#	Glyphosate at sowing (Group M)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
#	Sprayseed at sowing (Group L)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
#	Sowing of crop or legume pasture	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
#	Grazing																				
#	High intensity grazing winter/spring																				
#	High crop seeding rate (extra cost only is shown)																				
#	Green manure																				
#	Mow pasture																				
#	Cut for hay																				
#	Cut for silage																				
#	Swath prior to harvest		1				1				1				1				1		
#	Burn crop or pasture residues																				
#	Seed catch - dumps burnt																				
#	Seed catch - remove dumps																				
#	Cyclone - cyclone trail burnt																				
#	Cyclone - total burn																				
#	Windrow - windrow burnt																				
#	Windrow - seed catch																				
#	Cultivate, delay sowing 1 month***																				
#	Cultivate, delay sowing 10 days***																				
#	User defined option A																				
#	User defined option B																				

Figure 108 – Scenario two; a continuous cropping program with extensive chemical use.

4.19. SOWING TIME, SCALE AND MACHINERY INVESTMENT IN SOUTH EASTERN AUSTRALIA.

4.19.1. INTRODUCTION

One of the major constraints on increasing net cash flow for crop farming businesses is the scale of cropping production. A suite of factors hinder expansion of cropping, such as existing farm machinery, historical enterprise mix, management ability, soil type, working capital constraints, crop rotational requirements and the availability of labour.

In this analysis, the aim is to investigate the effect of machinery scale and establishment methods on the timeliness of cropping operations, which in turn affects the cropping area and intensity on many farms. Cropping intensity is defined as the percentage of the total farming area sown to crop in a cropping year.

The effect of machinery scale as a factor of production has to be seen in terms of the timing of the seasonal 'break' in a particular year. An earlier break will confer greater sowing opportunity for many crops, in effect increasing the available scale of cropping operations, providing that livestock operations and rotational requirements do not restrict the availability of land for cropping. In southern Australia, maximum yields are achieved when flowering occurs sufficiently late to avoid spring frosts but sufficiently early to allow long grain filling periods before the high evaporative demand and consequent soil water deficits of early summer (Conner, 1992). The two main management options available to control crop development are selection of cultivar and time of sowing. Appropriate combinations of these two factors enable effective use of growing season rainfall. Hence, yield, and thus relative profitability, is sensitive to sowing date and increasingly so since the widespread adoption of semi-dwarf varieties in the late 1960's. These varieties comprised eighty five percent of the wheat crop in 1990 (Fischer, 1996) and would now be an even higher proportion of the total wheat crop.

In terms of constraints caused by machinery capacity, the reduction of cultivation passes associated with the adoption of conservation cropping can theoretically lead to improvements in the timing of cropping operations. Multiple cultivation passes increase machinery use and labour requirements compared to a one pass, direct drill system. The substitution of chemical weed control for cultivation has the potential to allow sowing closer to optimal sowing dates, particularly in larger operations.

4.19.2. SOWING TIME AND YIELD

Extensive research on appropriate time of sowing has identified the optimal sowing periods for different crops and cultivars in addition to relative yield loss when sown after these optimal periods. A central and southern NSW review of breeding and sowing trials carried out between 1981 and 1990 (Penrose, 1993) determined that early sowing (mid April to early May), whether they be of winter or spring wheat types of crop, produced yields 15 per cent higher than later (mid May) sown crops. For crops sown between April 20 and 25 the advantage was 34 per cent. The advantage was reduced to 18 per cent for crops sown between April 26 and 31. The advantage decreased when compared to sowings occurring in the supposedly optimal period.

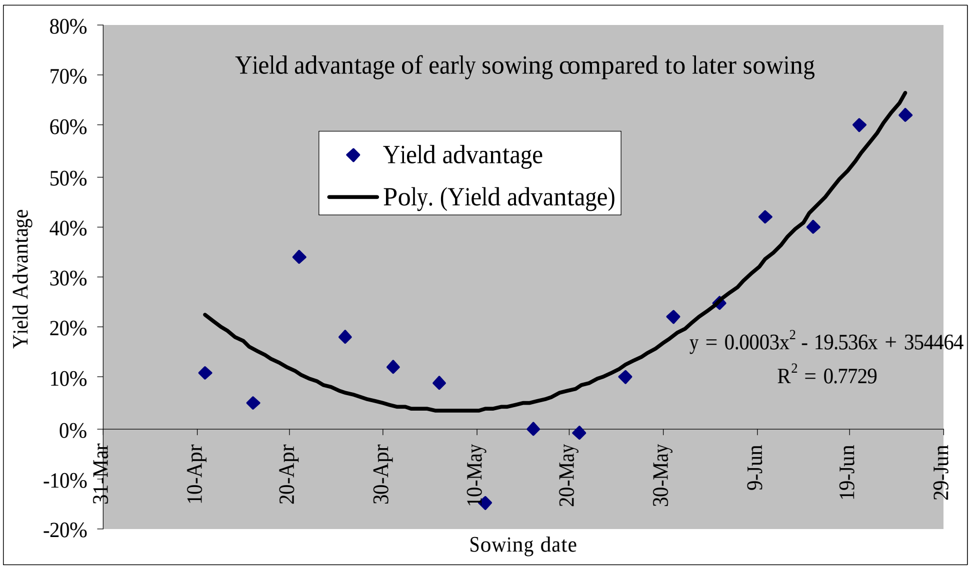


Figure 109 – Relative yield advantage (y axis) associated with mid April to early May sowing in southern NSW compared to sowing at earlier and later dates (indicated by x axis) (Penrose, 1993) *ie. 60% yield advantage of crop sown in mid April to early May compared to that sown in late June.*

When sown after mid-May, spring cultivars mature too late compared to the maturation of the earlier sowing's and hence encounter moisture stress. In essence, timely sowing has significant potential to add to yields, and crops can be sown over a longer time frame. Spring wheats require sowing at the optimal time or yield quickly decreases. CSIRO simulation modelling of southern NSW predicts wheat yields decrease by five per cent for every one week delay in sowing after late April (Stapper, 1998). Unpublished analysis by the same author of seven hundred wheat crops in south-eastern Australia established an average yield loss of four per cent per week after late April, which represented an eight per cent decrease in crop gross margin.

Cultivars with winter habit yielded six per cent greater than spring types when sown early (April 26 to 31) but there were no differences when sown at the later time of mid to late May. Yields of the early sown trials declined before and after the optimum sowing time of late April. Very early sowing (before

April 20) reduced yield substantially. The yield of spring wheats declined linearly with delays in sowing past early May.

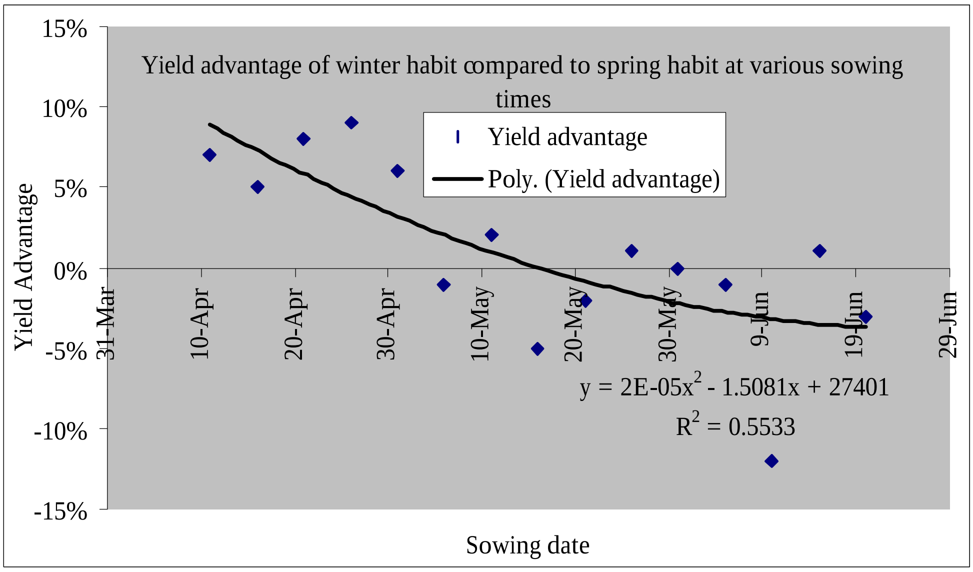


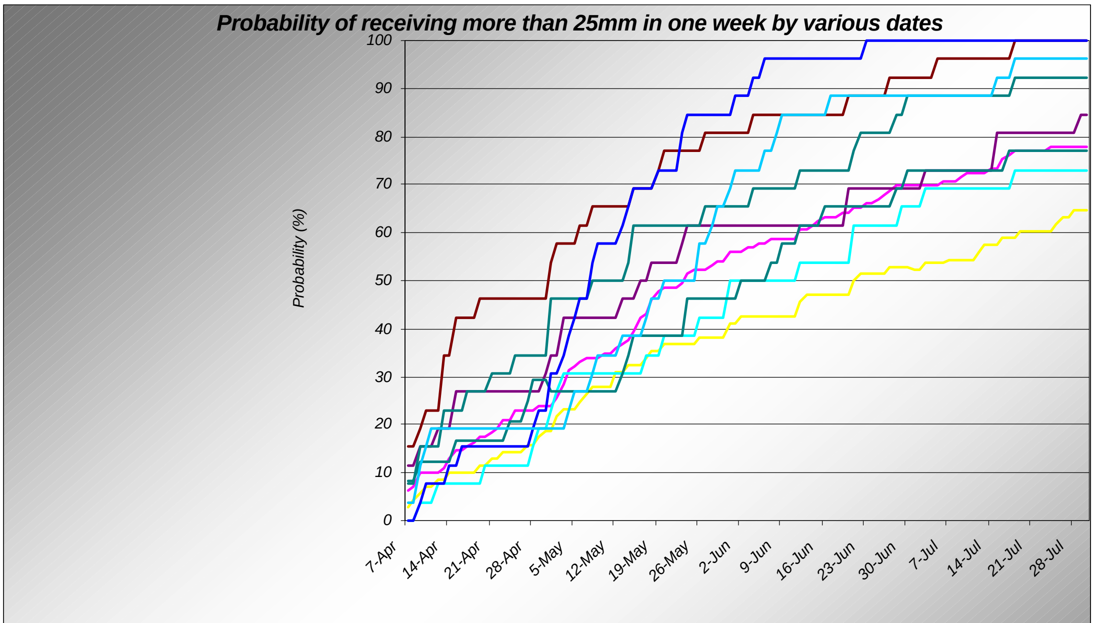
Figure 110 – Yield advantage associated with winter habit cultivars in southern NSW compared to spring habit varieties. (Penrose, 1993).

The analysis of sowing time is not straight-forward. In the simulation model used in the CSIRO research cited above, average yield declines by four to seven per cent for every one week delay in planting beyond the optimal time. This decline can rise to ten per cent per week for canola but more conservative values were used in the economic model used to follow. Benefit from timely sowing need to be balanced against potential frost risk; a factor reinforced by the disastrous frosts of the 1998 season. In general, anthesis is delayed by one day for every three days delay in sowing. The benefits of sowing on time and in a timely manner will be dependent on the varieties that are to be employed in a particular area. The likely advantages will be large in areas like the north east Victoria and southern NSW where present cropping practices include the widespread use of canola and early sown wheat varieties, with smaller areas of lupins and faba beans. In the Wimmera the where late sown crops like chickpeas, lentils and peas are employed extensively the advantages will not be as clear cut.

4.19.3. ENVIRONMENTAL RESTRICTIONS

The ability to sow crops in a timely manner will provide advantages that are regionally dependent. Historical probabilities of breaks occurring by specific dates and season lengths, in combination with specific sowing equipment, cultural practice, optimal sowing dates and associated yield losses determine the relative efficiency of different sowing systems in simulated cropping programs.

The timing of the break will vary greatly according to location as seen in Figure 111 below.

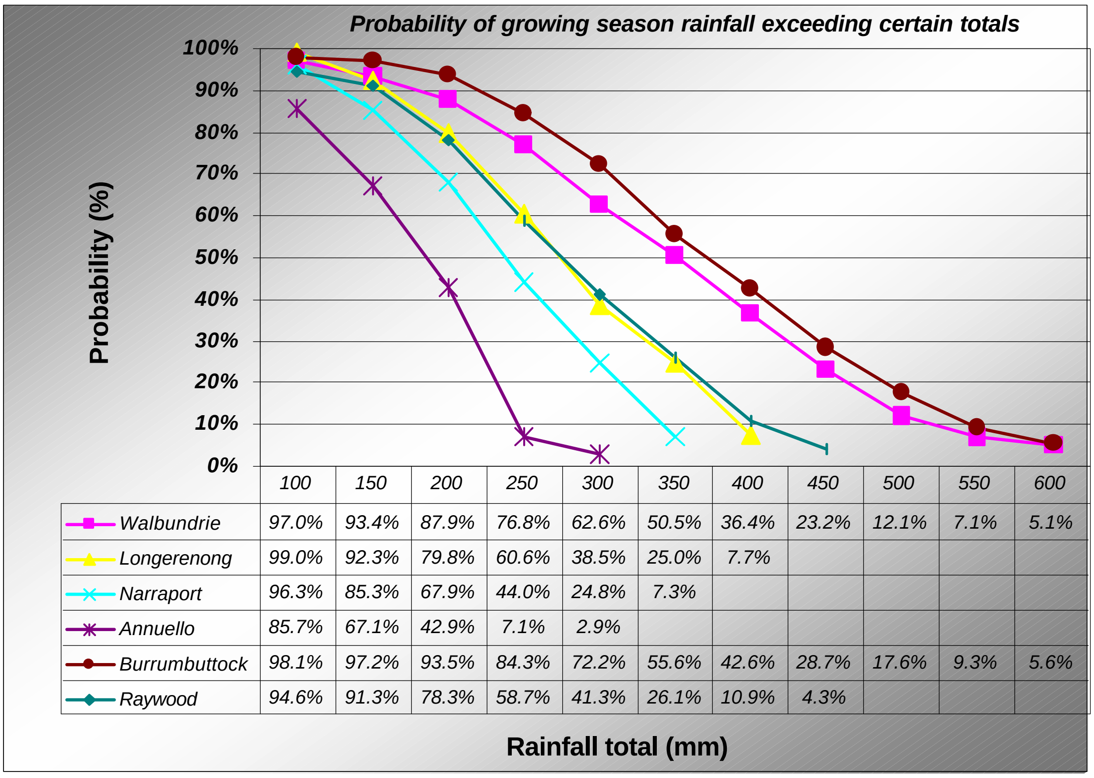


	7-Apr	15-Apr	23-Apr	2-May	10-May	18-May	26-May	4-Jun	12-Jun	20-Jun	28-Jun	6-Jul	15-Jul	23-Jul
Narraport (Narraport) (1887 - 1997)	6.4	14.7	21.1	25.7	34.9	45.9	52.3	56.9	60.6	64.2	69.7	70.6	73.4	77.1
Annuello (1925 - 1997)	2.9	10.1	14.5	21.7	27.9	35.3	38.2	42.6	45.6	47.1	52.9	53.6	57.4	60.3
Robinvale Srwsc (1939 - 1964)	0	7.7	11.5	26.9	30.8	34.6	42.3	50	53.8	53.8	61.5	69.2	69.2	73.1
Raywood Post Office (1939 - 1964)	11.5	26.9	26.9	34.6	42.3	53.8	61.5	61.5	61.5	69.2	69.2	73.1	80.8	80.8
Burrumbuttock (Holyrood) (1939 - 1964)	15.4	42.3	46.2	57.7	65.4	69.2	76.9	84.6	84.6	88.5	92.3	96.2	96.2	100
Walbundrie (Billabong Street) (1939 - 1964)	7.7	23.1	30.8	46.2	50	61.5	61.5	69.2	73.1	73.1	84.6	88.5	88.5	92.3
Longerenong Agriculture College (1939 - 1964)	8.3	16.7	16.7	26.9	26.9	38.5	46.2	50	61.5	65.4	69.2	73.1	73.1	76.9
Geraldton (Narra Tarra) (1939 - 1964)	0	11.5	15.4	30.8	57.7	69.2	84.6	92.3	96.2	96.2	100	100	100	100
Lake Grace P.O. (1939 - 1964)	3.8	19.2	19.2	19.2	34.6	46.2	57.7	73.1	84.6	88.5	88.5	88.5	92.3	96.2

Rainfall total (mm)

Figure 111 – Cumulative probability of seasonal break (defined as being more than twenty five millimetres falling in a week) timing at various locations.

Higher probability of early seasonal breaks is seen in high rainfall areas and Western Australian locations.



	100	150	200	250	300	350	400	450	500	550	600
Walbundrie	97.0%	93.4%	87.9%	76.8%	62.6%	50.5%	36.4%	23.2%	12.1%	7.1%	5.1%
Longerenong	99.0%	92.3%	79.8%	60.6%	38.5%	25.0%	7.7%				
Narraport	96.3%	85.3%	67.9%	44.0%	24.8%	7.3%					
Annuello	85.7%	67.1%	42.9%	7.1%	2.9%						
Burrumbuttock	98.1%	97.2%	93.5%	84.3%	72.2%	55.6%	42.6%	28.7%	17.6%	9.3%	5.6%
Raywood	94.6%	91.3%	78.3%	58.7%	41.3%	26.1%	10.9%	4.3%			

Figure 112 – Probability of receiving various growing season (April to October) rainfall totals at various locations in south eastern Australia.

4.19.4. DISCUSSION

Rainfall probabilities (Figure 112) and seasonal timings (Figure 111) provide indications of yield stability in the various case study locations. Lower rainfall environments of the Mallee have highly variable break timings in addition to a low growing season rainfall. Soil type will also influence the climatic relationships however. Longerenong has high probability of late breaks but soil moisture is generally more assured due to the heavier soil conditions and rainfall stability.

In contrast, some of the Western Australian locations exhibit high rainfall security even though rainfall is relatively low. At Lake Grace in the eastern wheatbelt, one in two years receive sowing rains by the 10th of May. Only one in five years Lake Grace does not receive planting rains by June 11. The relative likelihood of planting rains in the Western Australian wheatbelt may also help explain the large adoption of conservation cropping in the state. The more seasonally defined, Mediterranean conditions contribute to a shorter season and lower spring rainfall. Hence, increasing sowing efficiency potentially has a large impact on profitability in this environment, improving the 'adoptability' of conservation cropping systems that allow more timely sowing.

Given the conditions in south-eastern Australia, a simulation based on machinery, rainfall and optimal sowing period was developed using an Excel® spreadsheet.

Using southern NSW as an example, the recommended sowing times for wheat, barley, triticale and canola; the main crops of the area (Gammie, 1998) are shown below.

Table 117 – Recommended sowing times for various crop varieties.

Key to sowing times:

Earlier than ideal but OK
Optimum sowing time
Later than ideal but OK

Southern NSW Wheat	**March**		**April**				**May**				**June**	
Weeks	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**
Rosella*, **Currawong***, **Triller***, Whistler*, Sunsoft 98, Warbler												
Osprey*, Sunbri, Snipe*												
Sunbrook, Batavia, **Hybrid Apollo**, Cunningham												
Swift, **Janz**, Grebe, Vulcan, Tern, Petrel, Goldmark												
Dollarbird, **Diamondbird**, Tailorbird												
Silverstar, Galaxy H45												

Key - * = Winter Wheat. **High Yielding**

Southern NSW Barley	**March**		**April**				**May**				**June**				**July**		
Weeks	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**

Yerong														
Franklin, Yambla														
Skiff, **Tantangara**														
Brindabella, Arapiles														
Tilga, O'Connor, Schooner, Sloop, Namoi, Wyalong														
Chebec, Galleon, Barque														

Southern NSW Triticale	**March**		**April**				**May**				**June**			
Weeks	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Maiden														
Abacus														
Muir, **Tahara**. Credit														

Southern NSW Canola	**March**		**April**				**May**			
Weeks	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Dunkeld, Range, Pinnacle®, Siren®										
Scoop, Grouse, Oscar, Rainbow Clancy®										
Hyola 42, Monty, Drum®, Karoo®										

®=Triazine resistant cultivars (these generally yield around 70-80% of non resistant varieties)

Other Southern NSW crops	**March**		**April**				**May**				**June**			
Weeks	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Faba Beans														
Lupins														
Peas														

As shown, the period from mid-April to late-May is the optimal time of planting for most of the preferred crops of southern NSW. Decisions have to be made about the order of sowing by the farmer; a product of the technical factors, likely profitability and operational logistics of the farm.

4.19.5. MODELLING AND ANALYSIS

In the following analysis situations that might typically occur in a particular region, given different methods of crop establishment, are investigated. The perspective of the analysis is as follows:

Recent advances in crop establishment include the introduction of deep cultivating knife points and three bin airseeder boxes that allow fertiliser to be banded below or to the side of the seed. Need for post-sowing fertiliser applications are reduced, fertiliser efficiency is improved, while preferential nutrition of the crop has reduced weed populations in a range of cropping situations (Rainbow, 1999). Yield gains have consistently been demonstrated in recent years by a number of researchers (Slattery, 1995) but the question remains – 'How does this system rate in comparison to conventional crop establishment methods in terms of operational timeliness?' Figure 113 below is taken from the spreadsheet developed for the analysis.

3 Bin Airseeder	
Width - airseeder (m) =	8.0
Speed - airseeder (km/hr) =	8.0
Workrate - airseeder (ha/hr)	6.4
Hopper Capacity - Urea (t) =	1.5
Hopper Capacity - Starter (t) =	1.5
Hopper Capacity - Seed (t) =	1.5
Time before Urea runs out (hr)	2.34
Time before Starter runs out (hr)	2.34
Time before Seed runs out (hr)	46.88
Delivery to field (min) =	5.0
Manoeuvering (min) =	4.0
Filling (min/t) = Urea	3.0
Filling (min/t) = Starter	3.0
Filling (min/t) = Seed	3.0
Down time per fill (min) =	23
Time between refill (min) =	141
Total time per fill (min) =	163
Ha/fill =	12.00
Fills per day =	4.4
Theory area sown/day (ha) =	66.2
Field efficiency (%) =	80%
Area sown/day (Ha)	53.0
Days to sow cropping area	37.8
Area sprayed and sown/day (ha)	**33.0**
Sprayer efficiency	
Width - spray unit (m) =	15.0
Speed - spraying (km/hr) =	15.0
Workrate - sprayer (ha/hr)	22.5
Size of tank (l)	2000
Water rate (l/ha)	100
Number of hectares until refill	14.0
Time until water runs out (mins)	37.3
Time to refill water and chemical (mins)	30.0
Total time/tank (mins)	67.3
Field efficiency (%) =	70%
Fills per day =	6.2
Area sprayed/day (ha)	**87.3**
Days to spray cropping area =	22.9

Pre drill/sow	
Predrill airseeder width (m) =	*8.0*
Speed - airseeder (km/hr) =	*8.0*
Workrate - airseeder (ha/hr)	*6.4*
Predrill Capacity - Urea (t) =	*3.0*
Predrilling urea rate (kg/ha)	*100*
Time b/f Urea runs out (min)	*281*
Filling (min/t) = Nitrogen	*3.0*
Manoeuvering (min) =	*4.0*
Down time per fill (min) =	*16*
Total time per fill (min) =	*297*
Fills per day =	*2.4*
Ha/fill =	*30.0*
Theory area sown/day (ha) =	*72.7*
Field efficiency (%) =	*80%*
Area predrilled/day (Ha)	*58.1*
Days to Predrill completion =	*27.5*
Seeding speed (km/hr) =	9.0
Workrate - (ha/hr)	7.2
Hopper Capacity - Starter (t) =	1.5
Hopper Capacity - Seed (t) =	1.5
Time before Starter runs out (hr)	2.08
Time before Seed runs out (hr)	41.67
Delivery to field (min) =	5.0
Manoeuvering (min) =	4.0
Filling (min/t) = Starter	3.0
Filling (min/t) = Seed	3.0
Down time per fill (min) =	18
Time between refill (min) =	125
Total time per fill (min) =	143
Ha/fill =	12.00
Fills per day =	5.0
Theory area sown/day (ha) =	67.1
Field efficiency (%) =	80%
Area sown/day (Ha)	53.7
Days to sow cropping area	37.2
Area sown and sprayed/day (Ha)	**22.8**

Figure 113 - Calculation of sowing efficiency in deep banding, spraying and pre-drilling operations.

A number of assumptions are used in the analysis. These include:

A total cropping area of one thousand hectares, located in southern NSW

Rotation is wheat-canola-wheat-legume-triticale

All seeders analysed are eight metres in width

Growing season rainfall is three hundred and fifty millimetres

Seasonal break occurs on May 15

Sowing takes place for an average of twelve hours each day

Only canola and cereals are predrilled with urea

Crop related factors such as optimal sowing time, water use efficiency, yield at optimal sowing dates, average prices per tonne, decreases in yield for every week after optimal sowing date, percentage of area devoted to each crop and the area that needs to be predrilled for this simulation are given below in Table 118.

Table 118 – Assumptions used in the model of sowing efficiency.

		Canola	Winter wheat	Lupins	Main wheat	Triticale	Late wheat	Peas
	Crop ideal time of sowing	25-Apr	25-Apr	25-Apr	15-May	15-May	30-May	30-May
	Water use efficiency (kg/mm of GSR)	8	14	7	13	13	11	7
	Yield at this time	1.92 t/ha	3.36 t/ha	1.68 t/ha	3.12 t/ha	3.12 t/ha	2.64 t/ha	1.68 t/ha
	Price ($/t)	$350	$130	$180	$130	$110	$130	$230
	% decrease in yield per week after optimum date	5%	4%	4%	4%	4%	4%	4%
	Decrease in yield (kg/day) after optimum	14	19	10	18	18	15	10
100%	**% of total area sown to**	25%	10%	10%	15%	20%	10%	10%
	Area (ha)	250	100	100	150	200	100	100
	Area to be predrilled if needed	250	100	0	150	200	100	0

Fertiliser requirements are similar for all methods of establishment.

In this instance we can see that the eight metre seeder using a one-pass operation for twelve hours can sow around fifty three hectares of crop per day. This assumes that urea is being banded at around one hundred kilograms per hectare with one hundred kilograms per hectare of di-ammonium phosphate (DAP) applied with the seed.

We also need to assume that the cropping area will be sprayed with a knockdown spray prior to sowing. The substitution of cultivation with chemical weed control reduces the extent of the apparent advantages of sowing timeliness from reduced tillage compared to conventional methods. Assumptions for the spraying operation include:

Spraying takes place for an average of seven hours each day, limited by climatic conditions

Fifteen metre boom spray used

Two thousand litre tank, spraying chemical solution at one hundred litres per hectare

Ground speed of fifteen kilometres per hour.

Field efficiency of seventy percent

When the need to spray and sow are combined in a one-person operation we can see that the crop sowing rate is cut back to around thirty-three hectares per day. This may be compromised further by the incidence of inclement weather preventing spraying and sowing.

Comparing the above mentioned system to a system where nitrogen is applied prior to sowing by pre-drilling in a pass prior to sowing, the efficiency gains are obvious. The pre-drilling operation can only sow twenty-two hectares per day given the same width of machine, speeds and seed and fertiliser applications and spraying operations. This low rate of sowing area per day has significant implications for businesses when yield penalties for different crops are taken into account. Offsetting such potential losses however it is likely growers using pre-drilling would work longer hours, pre-drill prior to the seasonal break, or use different cultivars that may offset the low sowing capacity.

Sowing using the above methods is also compared with direct drilling of seed and fertiliser in a single pass, and with conventional sowing methods consisting of multiple, weed killing cultivations prior to sowing. Cultivation speed is based on the relative efficiency compared to sowing.

Direct drilling			*Conventional sowing*		
Width (m) =	8.0		**Width (m) =**	8.0	
Speed (km/hr) =	8.0		**Speed (km/hr) =**	8.0	
Workrate (ha/hr)	6.4		**Workrate (ha/hr)**	6.4	
Hopper/BoxCapacity - Starter (t) =	1.5		**per/BoxCapacity - Starter (t) =**	1.5	
Hopper/Box Capacity - Seed (t) =	1.5		**pper/Box Capacity - Seed (t) =**	1.5	
Time before Starter runs out (min)	140.6		**e before Starter runs out (min)**	140.6	
Time before Seed runs out (min)	2812.5		**ime before Seed runs out (min)**	2812.5	
Delivery to field (min) =	3		**Delivery to field (min) =**	3	
Manoeuvering (min) =	4		**Manoeuvering (min) =**	4	
Filling (min/t) = Starter	3		**Filling (min/t) = Starter**	3	
Filling (min/t) = Seed	3		**Filling (min/t) = Seed**	3	
Down time per fill (min) =	16		**Down time per fill (min) =**	16	
Time between refill (min) =	140.6		**Time between refill (min) =**	140.6	
Total time per fill (min) =	156.625		**Total time per fill (min) =**	156.6	
Ha/fill =	15.0		**Ha/fill =**	15.0	
Fills per day =	4.6		**Fills per day =**	4.6	
Theory area sown/day (ha) =	69.0		**Theory area sown/day (ha) =**	69.0	
Field efficiency (%) =	80%		**Field efficiency (%) =**	80%	
Area sprayed and sown/day (Ha)	55.2		**Area sown/day (Ha)**	55.2	
Days to sow cropping area	18.1		**% workrate of sowing implement**		
Area sprayed and sown/day (ha)	**33.8**	**0**	**Scarify**	125%	0 ha/day
		1	**Cultivator**	120%	66 ha/day
		1	**Offset**	80%	44 ha/day
		1	**Harrows**	200%	110 ha/day
			Average sowing rate/day (ha)		**21 ha/day**

Figure 114 – Estimated sowing rate of direct drill and conventional cultivation treatments.

The direct drilling operation will theoretically sow around thirty-four hectares per day. Conventional cultivation, involving workings with an offset disc, cultivator and harrows before sowing will, on average over the sowing season, allow twenty one hectares per day to be sown. Given the potential yield for most likely seasons, optimum sowing dates, water use efficiencies, prices, areas sown and yield losses after optimal sowing dates we can establish the economic benefits of each sowing method for a particular season defined by the user.

Other assumptions include:

inputs similar regardless of sowing method

seasonal break occurring on May 5

sowing not commencing until two days after rain

continual sowing until completion of program.

Relative yield penalties compared to conventional sowing are; direct drilling five percent; predrilling three percent, while deep banding increases production by five percent.

These production assumptions are based on five years of research (Slattery, 1995) consistently highlighting deep banding's yield and agronomic advantage over other forms of sowing and fertilisation.

Other findings of this research include:

Improved seed placement increased plant emergence by ten to twenty percent and early growth by ten to fifty percent over that achieved by wide share seeding methods resulting in yield gains of at least ten percent (Slattery, 1995). Nil emergence was seen when seeds were placed at less than twenty millimetres depth. Thirty millimetres was the optimal placement zone in most soils with dramatic variations in seeding effectiveness on poorer soils.

The use of spear points gave greatly reduced vertical and lateral variations of seed placement in loamy soils compared to lucerne and superseeder points but increased soil disturbance.

Superseeder (inverted T) points and spears worked well on lighter soils. The seed trench tended to fill with water causing seed burst, have reduced seed to soil contact and smear on heavier soil.

Press wheels improved growth and emergence on most soils, especially in combination with deep cultivation points and heavier soils, excepting superseeder points on heavy soils. Yields were increased by an average of seventeen percent compared to finger harrows.

When sown conventionally there were no yield differences with any sowing configuration.

Plants do not seek out nutrients in the soil; they grow in a path of least resistance. Deep banding creates a path of lower soil strength so roots can intercept banded nutrients more efficiently as well as having greater access to subsoil moisture. The reduced soil disturbance also increases trafficability in wet seasons on heavier soils (Slattery, 1995). Brome grass emergence was reduced by fifty percent on banded plots compared to multiple tillage treatments and rhizoctonial damage was reduced (Rainbow, 1999).

Average yield results from fertiliser research is seen in Table 119. Synergism of nitrogen and phosphorous application at depth was seen with yield increased by twelve and seventeen percent on loam and loamy sand respectively. Protein was also significantly increased.

Table 119 – Average yield response from different fertiliser treatments.

All treatments sown with 75kgs/ha of DAP	Loamy sand yield (t/ha)	Loam
No additional N or P	3.58	3.68
40kgs of N topdressed at tillering	3.77	3.89
40kg of N banded	3.92	3.93
15kgs of P with seed	3.55	3.87
15kgs of P banded below seed	3.52	3.83
40kgs of N + 75kgs of DAP banded	4.20	4.12

Given the yield results the use of a five percent yield advantage in the deep banding treatment is perhaps conservative. Sensitivity analysis will alleviate this anomaly however.

4.19.6. RESULTS

Over the complete sowing program, for all the methods compared, these losses for sub-optimal timing of sowing for each crop are specified. The simulated cropping gross incomes at the different seasonal timings are indicated below given that total growing season rainfall is 350mm.

Table 120 - Gross cropping income with the break occurring at various dates.

Sowing method	Optimal Income	April 20	May 5	June 5	July 5
Three bin airseeder	$444,360	$468,823	$425,050	$334,587	$247,043
Pre-drilling		$418,337	$377,899	$294,329	$213,454
Direct drilling		$424,979	$385,375	$303,528	$224,321
Conventional		$411,543	$369,855	$283,700	$200,324

The effect of sowing time is evident, causing gross cropping income to fall by almost half with a late break. In reality the grower has the option to sow earlier maturing varieties if the seasonal break does not occur by a pre-determined time. If an early break occurs, greater plantings of longer season, higher yield potential varieties could increase farm income over the simulated case. Canola might also be discarded if the season is late, reducing income. Even considering these complications we can draw some conclusions from the analysis that have significant impact on our understanding of adoption.

4.19.7. CONCLUSIONS

Sowing the crop quickly can have large benefits for the farming operation. Poor timeliness of operations can cause yield losses compared with yields achievable with better timing of operations. The simulated five percent yield reduction associated with direct drilling, due to greater soil disturbance, sub-optimal fertiliser placement and greater weed burdens, reduces returns to a level comparable to conventional cultivation, even though the conventionally sown crop was sown at a much slower rate.

Earlier sowing brings large income gains regardless of cropping system. This model may have underestimated the effect of sowing time on crop yield to a degree, especially at later sowing times.

The move to banding technologies is one constrained by cost, available cash flow and projected earnings. Risk will play a large part in the adoption of this method.

Adoption of conservation cropping will be greater in areas of high cropping intensity, where the need to conserve soil structure is greater. Low intensity croppers using conventional methods will only see small long-term benefits to their cash flow by the adoption of conservation cropping methods.

Over a short period the extra expense of deep banding technology on large, high cropping intensity operations may be able to be justified. Increased variability in the timing of seasonal breaks increases the importance of sowing timeliness. The potential benefits of purchasing deep-banding equipment will hence be greater.

If the assumption is made that there is no yield response associated with sowing method, the income differences associated with the various cropping options are reduced, as seen in table x below. In essence the analysis becomes a test of yield loss due to the time of sowing.

Table 121 – The effect of seasonal break timing on cropping income if growing season rainfall is

Sowing method	Optimal Income	April 20	May 5	June 5	July 5
3 bin airseeder	$444,360	$446,498	$404,810	$318,655	$235,279
Pre-drilling		$431,275	$389,587	$303,432	$220,056

Direct drilling		$447,346	$405,658	$319,503	$236,127
Conventional		$411,543	$369,855	$283,700	$200,324

This is also illustrated in Figure 115, where income decreases at the same rate as the yield decline due to late sowing.

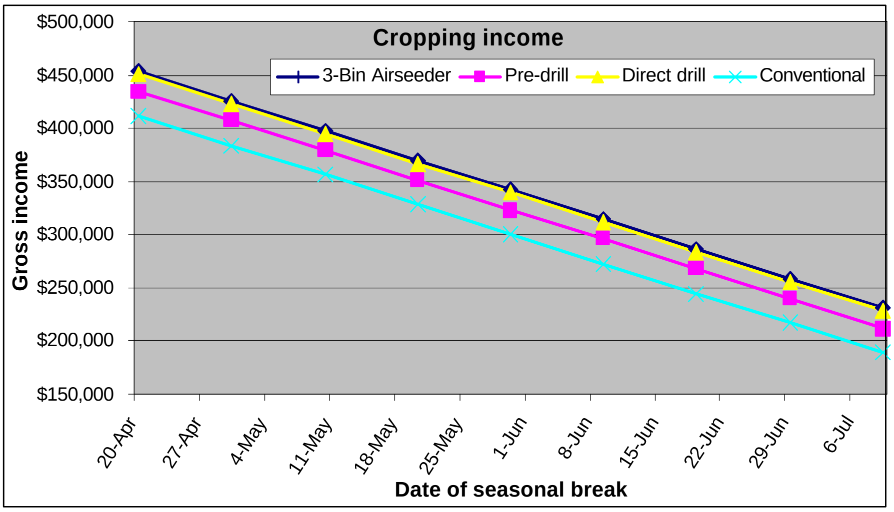


Figure 115 – the effect of sowing method on cropping income.

4.19.8. OTHER FACTORS TO CONSIDER

Machinery size

From the above, it follows that any factor that increases the rate at which the crop is sown, such as increasing the width of the spray unit or seeder, would reduce sowing time and hence increase farm income in a typical year. This follows from the assumption that yield decreases at a set rate per week in comparison to the yields achievable if sowing is done at the optimal sowing time. This may not be a reflection of reality due to seasonal vagaries. These decisions have to be balanced against the increased cost of the larger machinery. The benefits of increasing seeder or spray width in a typical year are seen below.

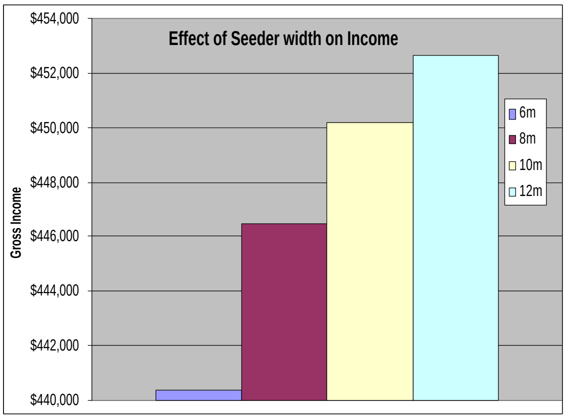


Figure 116 – The effect of seeder width on simulated farm income.

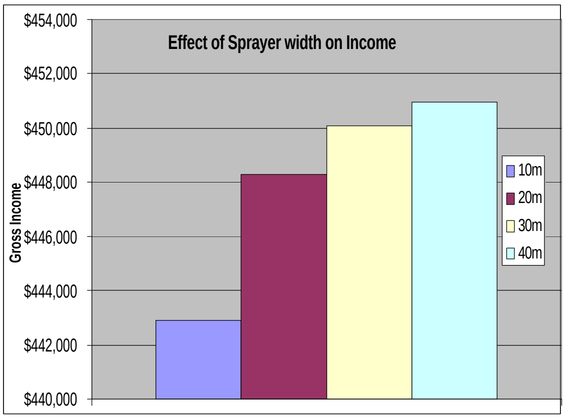


Figure 117– The effect of seeder and sprayer width on simulated farm income.

As shown in the simulated year, increasing seeder width will only bring marginal benefits to the one thousand hectare farm. Increasing width from six metres to ten metres will increase the simulated farm income by around $10,000. It would take a number of years to repay the extra capital investment in larger seeder capacity, and perhaps a larger tractor to pull it, given this efficiency gain. The cost of increasing machinery size can be seen in Table 125 below. The same can be said for an investment in greater spraying capacity. Increasing boom width in a farming operation of this size from ten metres to forty metres has little effect simulated farm income, increasing it by around $8,000 per annum.

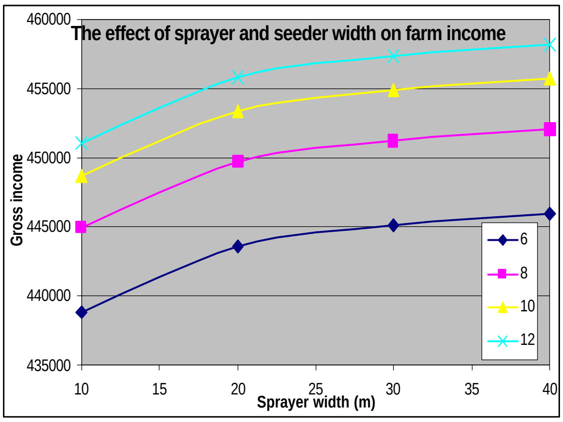


Figure 118– The effect of seeder and sprayer width on farm income.

The combined effect of increasing sowing and spraying width on the gross income of the farm is seen in figure x above. Different coloured lines indicate different seeder widths. Again the combined efficiency gains are not large.

4.19.9. INCREASED SCALE OF OPERATION

Figure 117 and Figure 118 are for a 1000ha cropping operation. If we increase the size of the cropping operation to 2000ha the marginal gains from sowing in a more timely manner change considerably.

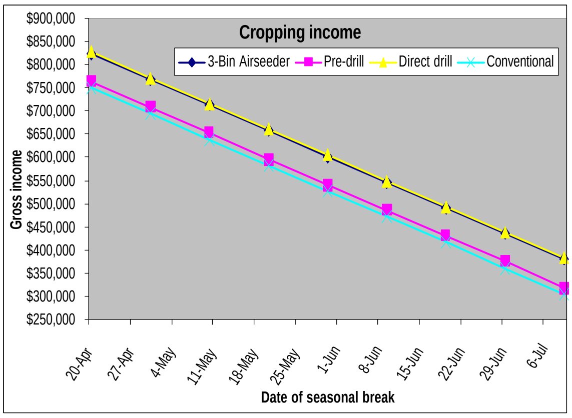


Figure 119 – Simulated impact of seeding method on 2000ha farm income.

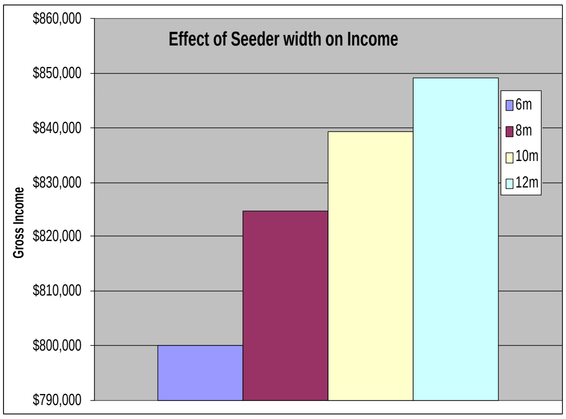


Figure 120 - -Simulated impact of seeder size on 2000ha farm income

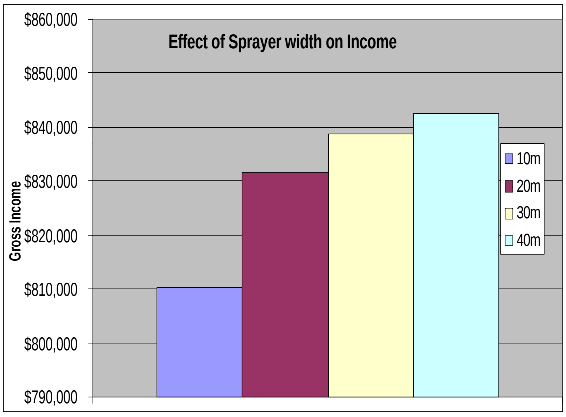


Figure 121 - Simulated impact of boom spray size on 2000ha farm income

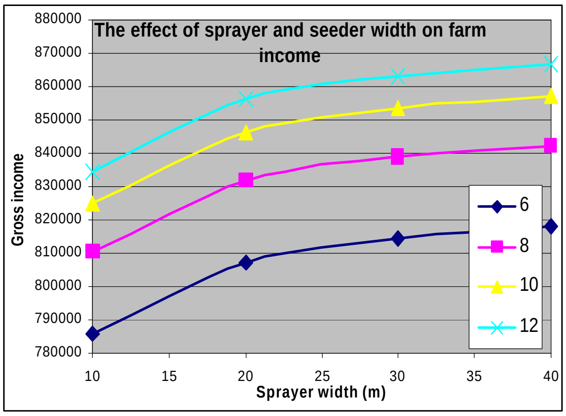


Figure 122 - Simulated impact of seeder and spray size on 2000ha farm income

As is predicted from management economic theory marginal gains from increasing machinery capacity are much greater with a greater acreage to be cropped. This principle is well known though precise monetary effects of scale need to be worked out for particular cases. Increasing seeder width from six metres to twelve metres has the potential to increase the income on the simulated two thousand hectare farm by around $50,000, an amount that makes the decision to invest in larger machinery relatively easy to justify. This situation is similar for the partial budgeting analysis of banding fertiliser that is carried out below. The same can be said of increased boom spray width where increasing the size from ten metres to thirty metres potentially increases income by around $30,000. Increasing the machinery from a six metres seeder and ten metre boom spray to a twelve metre seeder and a thirty metre boom spray potentially increases simulated income by $80,000.

4.19.10. SUBSTITUTION OF CAPITAL WITH LABOUR

If longer hours are worked then the benefit from increased machinery capacity is reduced considerably. This is represented in the graph below.

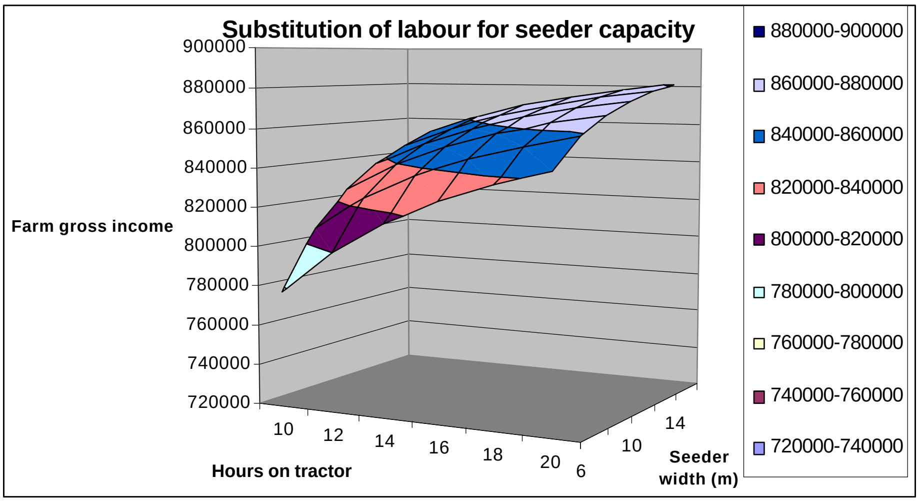


Figure 123 – Effect of substituting labour for increased seeding capacity on the simulation farm.

If twenty hours per day are worked on a two thousand hectare sowing program the marginal gain from increased seeder capacity is much less in terms of gross farm income than a situation where only ten hours per day are worked. This is evidenced by the slope of the surface area, which increases as hours of labour decrease, indicating greater marginal gains from the substitution of capital for labour.

4.19.11. CONCLUSIONS

The permutations could continue to be shown ad infinitum but the principles are clear with regard to the potential benefits of conservation cropping and larger machinery.

Farmers have substituted minimum-tillage crop establishment techniques in place of increased machinery requirements. This has offset capital requirements in many situations where the cropping intensity has increased.

Many farms have now reached a scale where improved machinery capacity has the potential to improve cropping timeliness and can be justified in terms of improved yield and net returns. These are the properties more likely to be investing in improved machinery.

Smaller scale properties do not have the timeliness, and hence yield, gains over smaller cropping programs to justify increased machinery expenditure in many cases. Substitution with labour is a more economic option.

All of these factors combine to make the transition to alternative sowing techniques harder to justify for the smaller grower. This is the type of adoption that we have seen in conservation cropping in south-eastern Australia. The large scale cropping operations in Western Australia are a major reason are a major reason for crop farmers in WA being at the forefront of sowing technologies. The purchase of higher capacity machinery is much easier to justify on these properties than a medium sized mixed farming operation in south eastern Australia. The much more defined season also increases the likely benefits in the Western Australian environment.

As the above points hint at, with the adoption of conservation cropping and increased cropping intensities, the smaller the enterprise the less to be gained from adoption - but if adoption does take place on the larger farms there is greater ability to crop intensively over greater areas, in turn generating higher cash flows and placing smaller operations under greater pressure if they wish to expand.

4.19.12. MOVING TO FERTILISER BANDING

The economies of scale associated with airseeding and deep banding are an interesting analysis in their own right. The price of a range of airseeders and seeder bars, as reported by the Kondinin Group and Power Farming magazine over time, are displayed in figure x and x. Increased seeding capacity produced a relatively linear relationship. Each cubic metre of bin capacity cost a relatively similar amount. Variation within bin sizes were related to bin position (trailing, mounted or in front of seeder) and number of bins. Trailing bins with more wheels cost more than other boxes. Three bin boxes cost around $10,000 more than comparable two bin airseeders at mid range capacities.

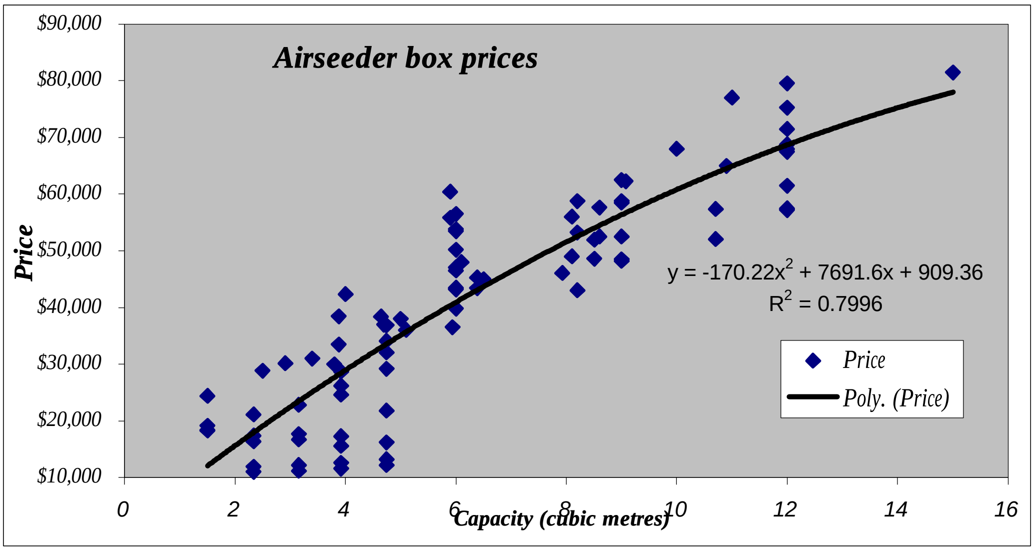


Figure 124 – Air seeder box prices from various manufacturers.

An analysis of seeder bar cost is significantly different however. The large number of models and variation in construction found in today's seeding technology (breakout pressure, ground clearance, tine configuration, use of press wheels and coulters etc) creates a situation where costs can diverge in similarly sized machines. Irrespective of complications however, a reasonable R^2 value was observed. Without the inclusion of disc seeders and highly priced brands, such as Flexicoil and Conservapak, the relationship is stronger. Again the conclusion we should make is that increasing seeding capacity increases reasonably linearly but the cost of increased width will vary greatly with manufacturer. Deep banding will require higher breakout pressure, increased horsepower and heavier duty frames.

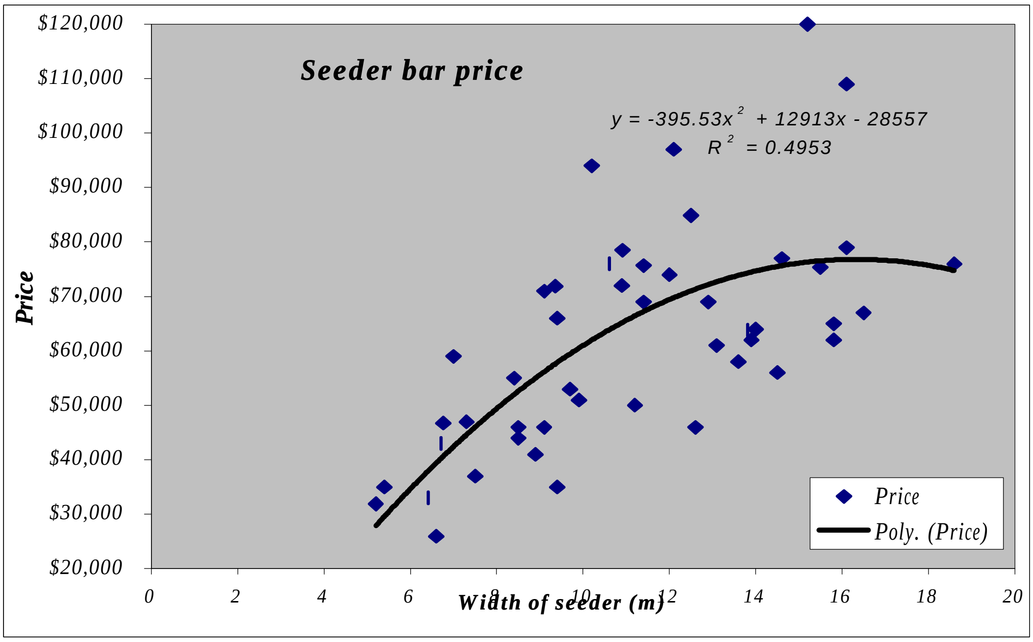


Figure 125 – Seeder bar prices of various manufacturers

Despite the fact a reasonably linear relationship was seen in airseeding technology the transition to increased sowing capacity is harder to justify for the smaller grower. The smaller grower has to choose between airseeding or using conventional sowing methods, which are less capital intensive. This has undoubtedly contributed to the adoption phenomena seen in conservation cropping in south-eastern Australia. Western Australia's large cropping programs have made increased sowing capacity much more justifiable than medium sized mixed farmers in south eastern Australia. Lower draft in the sandy soils of the west also reduce tractor horsepower requirements and the cost of using deep banding.

An economic analysis of a move into deep banding has been undertaken. It was assumed that the farmer was already looking to purchase new sowing equipment and was deciding whether to spend the extra money required to allow deep banding. The medium sized operation in southern NSW was looking to purchase a trailing, 6000 litre airseeder capable of holding 2.2 tonnes of seed and a total of 2.9 tonnes of fertiliser. The three-bin model costs $50,000. The two-bin model costs $40,000. In addition, alteration to the sowing kit is needed to cater for more fertiliser hoses, different boots and points. These changes cost $5000. To pull the deep banding machine, extra horsepower is required from the tractor. A tractor of similar condition to that presently owned, but with fifty more horsepower, costs $30,000. This machine will use $5000 a year more fuel to put the crop in. All up, the changes to capital items to cater for banding cost $50,000. Variable fertiliser costs are the same regardless of the system but variable fuel costs are said to increase. Pre-drilled crops will have some nitrogen put under the crop prior to sowing and some top-dressed, direct drilled and conventional crops will have it all top-dressed post-sowing and the deep banded crops will have the majority of put under the seed at sowing.

The analysis uses growing season rainfall (GSR) deciles from Walbundrie's rainfall history in southern NSW. As seen in the analysis above, there are timeliness benefits associated with deep banding technology. If relative yield advantage is added, what is the likely impact on income over a ten year planning period?

Table 122 – Probability of growing season rainfall totals at Walbundrie, Southern NSW.

Historical Probability	Decile	GSR (mm)
10%	1	175
20%	2	232
30%	3	283
40%	4	323
50%	5	352
60%	6	383
70%	7	423
80%	8	462
90%	9	527
100%	10	733

The budget below is based on results from the time of sowing analysis and compares deep banding to the use of pre-drilling sowing methods.

Table 123 – Partial budget for changing systems from pre-drilling to deep banding fertiliser given no yield advantage.

Partial budget		**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Increased income c.f. predrilling		$14,236	$18,413	$10,177	$3,824	$24,531	$16,060	$20,707	$12,530	$7,177	$36,650
Yield advantage	0%										

Decile year	5	7	3	1	9	6	8	4	2	10
Rainfall	352	423	283	175	527	383	462	323	232	733
Total extra income	**$14,236**	**$18,413**	**$10,177**	**$3,824**	**$24,531**	**$16,060**	**$20,707**	**$12,530**	**$7,177**	**$36,650**
Seeder modification	$5,000									
Extra cost of three bin air delivery	$10,000									
Extra horsepower requirement and fuel	$35,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Increased depreciation	$5000	$5000	$5000	$5000	$5000	$5000	$5000	$5000	$5000	$5000
Total extra costs	**$55,000**	**$10,000**	**$10,000**	**$10,000**	**$10,000**	**$10,000**	**$10,000**	**$10,000**	**$10,000**	**$10,000**
Net effect on income	**-$40,764**	**$8,413**	**$177**	**-$6,176**	**$14,531**	**$6,060**	**$10,707**	**$2,530**	**-$2,823**	**$26,650**
Total extra income/cost	**$19,306**									
NPV	**$1,338**									
IRR	**7%**									

Over the course of the planning period the average date of the break was assumed to be May 15. Given similar yield assumptions to the analysis above (1000 hectares of crop based on a cereal, canola and legume rotation and conservative price estimates) it was found that yield can be reduced in the new system and positive net present values can still be obtained due to the efficiency gains at sowing time. If yields were increased to any extent the investment became very profitable.

Table 124 – NPV of system given altered yield advantage.

Yield advant.	NPV
-5%	-$ 116,054
0%	$ 1,338
5%	$ 152,786
10%	$ 304,235

Given yield responses of five to fifteen per cent obtained in research on similar soils in South Australia, the investment in deep banding capability appears to be a profitable one. Once quantification of various other benefits are included in the equation, the system appears to be even more financially attractive. These include reduced competitive ability of weeds, better trafficability at sowing time and improved efficiency of fertiliser use. In this analysis, account was taken of increased depreciation costs and increased fuel costs. Pre-drilling of fertiliser will also incur greater machinery and fuel costs but these were not quantified. With this in mind it would appear that the investment in banding could be profitable in many cases because of improved operational timeliness and the prospects of increased yields.

The partial budget reveals that even if no yield advantage is seen with pre-drilling methods, sowing is more timely. This produces overall yield benefits for the farmer. An internal rate of return (IRR) of seven percent is unlikely to result in adoption due to the risk involved. However, if a five per cent yield advantage is factored in, the IRR increases to 107 percent and the net present value of the cash flow is

$152,786. This result creates a significant incentive to buy the deep banding technology instead of a two-bin airseeder configuration.

The large amounts of money at stake for the farmer increases the risk of the decision. A move to a technology that can increase production by small amounts is easily justified in most situations. This yield increase has to be demonstrated clearly before adoption however as, similarly, a small reduction in yield over the cropping program could disadvantage the grower substantially. The large amounts of investment involved in seeding technology increase the riskiness of the decision. Investigation of the economics of seeding technology are hence of great importance to many farm operations.

Table 125 – Example costs of airseeding machines.

Seeder Bar Manufacturer and size of model	**6 metre**	**8 metre**	**10 metre**	**12 metre**	**14 metre**	**16 metre**
Walkers Triple Disc of Merredin *Triple discs $1250 per sowing row*			10.2m bar without discs $52,110 plus $42,500 in discs equals $94,610			15.2m bar w/o discs $56,750 plus $63,330 equals $120,080.
Ezee-On (cultivator)		3500 model, five bar high breakout 7.36m $47,700	9.75m model $53,600		13.86m model $63,800	15.54m model $75,300
Rogro Groundhound planter (Coulter, depth wheel with tine and press wheel on parralellogram @ 1m spacing)			9.14m planter (24 row marker arm) $70,990 3 point linkage $52,370			
MFS multiplanter	6.4m model $33,000	(parralellogram and hydraulic press wheel)		12m model $74,000		
Forward Engineers		Single fold 7.5m model $37,282		2800 model 12.9m $68,739	13.6m model $57,772 Double fold 13.9m $61,836	16.5m with low breakout tines $66,687 16.1m $79,108
Case Concord Ribbon seeding		8.5m model $44,200			14.6m unit $77,500	

Horwood Bagshaw	Fixed frame 5.22m $18,950, 6.66m $26,450	350 bar, folding wing 8.9m model $41,383			14m bar $63,943	
Conserva Pak	7m, 3-bar $59,000		10.6m, 3-bar $76,000	12.1m, 4-bar model $97,000		16.1m 3-bar model $109,000
Gason (4100hd and 5100 models)	5.4m model $35,000	8.4m folding unit $55,000	9.4m $35,100	12.6m model $46,110	14.5m unit $56,000	15.8m unit $61,710
Janke			9.1m, low breakout $45,916, high breakout $48,124, medium breakout with increased clearance $51,224			High breakout 15.8m $64,884 15.8m with increased clearance $69,369
Flexicoil		820 high breakout 8.5m model $46,511				18.6m unit $76,110
Deep Blade System (DBS) Auseeder Parralellogram deep penetration with hydraulic breakout 3 bar machines		26 (tine) – 260 (row spacing) model 6.76m $42,750	36-260 9.36m model $65,550 42-260 10.9m $71,900	38-300 11.4m $68,900	48-260 12.48m $77,500	
Alfarm			Vertical fold 9.9m $51,520		Horizontal fold 13.14m $61,140	14.22m $59,240 18.54m $77,290
Airseeders and size of model in cubic metres	**2 m^3 capacity**	**4 m^3 capacity**	**6 m^3 capacity**	**8 m^3 capacity**	**10 m^3 capacity**	**12 m^3 capacity**

Case airseeders – 2-bin unless stated		1100 model 3.9m³ $38,450		2300 model 8.1m $53,250		3400 12m $68,000 3 bin, 3503, 12m $75,280
Gason		1830 3.4m $31,330	1850 5.1m $36,580	1880 8.2m $43,080 1880, 3 bin, 8.1m $49030		
Horwood Bagshaw					10m $67,887	11m, 3 bin $76,512
Bourgault		4.7m, 3165 model $37,000	6.5m, 3225 $45,000			
Flexicoil			1720, 6.12m $48,317	2320 8.13cum $56,264		
Alfarm		350, 3.8t model $30,000	A550 5t model $38,000			

5. -SUMMARY OF FINDINGS

The choice of the best cropping system to use in any particular paddock on any particular farm at any particular time by any particular farming family depends on a complex mix of many factors that can be broadly categorized as being of a human, technical, economic, financial, risk, institutional and social nature.

This study is about growing broad-area crops in South-Eastern Australia. It is about the many choices of methods crop farmers have for growing their crops. Many methods of growing crops exist along a continuum from the traditional method – the many-cultivations methods – to the variations involving less tillage, known collectively as conservation cropping methods.

In this study, conservation cultivation methods are investigated using the whole farm approach. The whole farm approach involves looking at a farming question from a number of important angles and a number of dimensions. A farm business can be characterized as comprising of human, technical, economic, financial, risk, institutional and social elements, with theoretical and practical dimensions to each of these angles.

Thus the perspective of this study is that of the management of whole cropping farms. Information has been gleaned from a wide array of sources – from the scientific research literature; from canvassing of the knowledge, experiences and judgements of crop farmers across a wide geographic spectrum; and from detailed case studies of crop farmers who have practiced conservation cropping methods over a considerable run of seasons.

Overall, an important message from the scientific research into conservation cropping, and from farmers who practice conservation cropping techniques, seems to be that in terms of the technical, economic, human, risk, institutional and social criteria that are important to the sustainability and profitability of crop-farm businesses, in many paddocks of many cropping systems on many farms in many of the cropping areas, conservation cropping methods can be made to work as well according to the major criteria of farmers as alternative, cropping methods based on more cultivation than the methods generally termed conservation tillage.

Significantly, depending on the particular situations, changes in cropping systems from heavy reliance on cultivation to less reliance on cultivation can facilitate increased cropping intensity and reduce some of the cropping risks of crop farm businesses. Conservation cropping methods can result in less structural degradation of soils than actually happens or potentially could happen with cropping systems based on numerous tillage operations. Improving the long-term crop-soil environment makes it possible to meet the twin imperatives of being profitable and sustainable - remembering that farm businesses have to be profitable to be sustainable, and have to operated in sustainable ways to be profitable.

In this study, scientific research results, behavioural studies of farmers, and case studies of crop farm businesses have been canvassed and carried out. Evidence from these investigations lead to the following main conclusion:

In many paddocks, cropping systems, and farm businesss, with sound crop establishment, crop nutrition, choice of rotation, weed and disease management – that is, with sound crop farm management - conservation cropping systems can be as profitable in the widest sense over the medium term as are other cropping systems.

Studies of adoption of changes in cropping methods by farmers have found that while conservation cropping is increasingly being carried out in many of the cropping regions of south-eastern Australia, different factors influenced the decisions to adopt, or not to adopt, conservation cropping in different cropping areas.

Common important barriers to adoption, varying in importance depending on the cropping region, were machinery limitations, risks if increasing herbicide resistant, weed control, disease problems and perceived increases in production and business risk. Improvements in soil health and reduction in susceptibility of soils to erosion have been widely reported by adopters of conservation cropping. As well, adopters commonly considered that technical and economic efficiency of their cropping system has been maintained or improved. Agronomic advisors who were surveyed cited a definite increasing trend toward conservation cropping, although problems were found to exist in Mallee soils.

A range of complex social, human, technical, economic and risk-related factors affect the adoption and success of conservation farming systems on farms. Ultimately the complex mix of factors of each case determines what farmers decide to do. The starting point to understanding why farmers operate their farms the way they do is an understanding of the goals, hopes and aspirations of the farm family. Important goals include earning enough income, improving wealth, business survival, satisfaction and enjoyment, recognition of peers, wish to improve the status of resources controlled, and so on.

Considering and adopting conservation farming involves understanding, accepting and managing a whole system of land management that is made up of many interacting parts. The more complex the farming system, the more understanding and management skill is required. When adopting no-till methods, the aims of maintaining required soil moisture and structural, nutritional, weed and disease status have to be pursued by means that may be more complex and less convenient than is the case using alternative cropping methods. Thus factors such as the stage of life, motivation and the knowledge base of individual farmers thus have a major impact on rates of adoption. Modern conservation farming requires knowledge of crop varieties, rotations, chemical use, fertility, weed and disease control, soil management, and so on. Technology that can be divided into component parts allows partial adoption and sequential evaluation. Success of components is likely to lead to complete adoption over time. As a technological innovation conservation farming tends to lack divisibility. Conflicting messages as to the applicability, effectiveness and net benefits of adopting modern technology in particular farm situations also enhance uncertainty and resistance to change. New methods and technologies that limit the ability of farmers to respond to the vagaries of commodity prices or weather also face greater resistance to adoption, for sound business management reasons. Broad views favouring the *status quo* in the farming community may influence some individual farmers to conform, and can have the effect of increasing resistance to adoption of new technology until there is sufficient acceptance within the community.

More precisely, in practical terms, there are many factors that are important in the establishment and acceptance of a cropping system using less cultivation than has traditionally been used. Decreased soil disturbance cannot be implemented at the expense of accurate seed placement, optimal tilth and soil-moisture contact. Adequate nutrition and placement of nutrition is vital to crop growth. Placing nutrients where roots will use it has increased yield on a range of soil types. Effective weed and disease management is vital in any cropping system. The removal of cultivation and danger of herbicide resistance heighten the need for advanced knowledge of chemicals and integrated weed management techniques. Crop sequence has the potential to alter weed populations greatly, while also having an impact on disease.

A major perceived barrier to adoption is the potential for weeds to develop resistance to herbicides. The integrated use of range of control methods could profitably maintain adequate weed control in intensive, conservation-cropping systems, even in the presence of herbicide resistance. The interaction between sowing time and sowing method over farm cropping programs, the advantages of deep fertiliser banding and the impact of seasonal conditions helps explain adoption phenomena in areas such as Western Australia. The technology to increase rotation length and grow crops that independently vary in price has allowed growers to widen the range of choices facing crop farmers about what to grow and when to grow it. One result has been increased adoption of continuous and high intensity cropping in many areas. Conversely, in areas where crop choices remain limited, entrenched farming systems prevail.

Adoption of new technology invariably involves added risk, as growers are dealing with a system which they have had little experience and the likelihood of various possible outcomes cannot be known well before the event. Risk associated with a change to conservation cropping include both the risk about whether it will work or not, and any change in risk of the introduced system compared with the pre-existing level of risk with the current cropping system. Farmers in precarious business situations either may not have the cash available in the short-term to purchase new technology, or a change may be perceived as imposing on the business extra production risk. Conversely, a business in a stronger economic position may be able to afford the perceived production risk in the short term, with the aim of achieving medium to long-term benefits, including business growth. In the case of conservation farming, after an initial adoption phase where only better placed or risk accepting growers adopt, more risk averse growers then adopt the change if the methods are demonstrated to be successful (Pannell, 1999). Increased diversity of crop activities, such as substitution of canola and high-value legume crops in place of wheat, can alter the risk position of cropping businesses. The increasing ability of growers to sell product forward has also changed the risk profile of Australia's croppers. Altered marketing methods have reduced price risk for many grains, in turn, reducing business risk and significant adoption technology.

From an economic point of view, expected profitability is a primary determinant of choice of farming system and of adoption of new technology; while choice of farming system and adoption of new technology are key determinants of the profitability and likelihood of the sustainability of the farm business. *Case studies of farmers who have practiced conservation cropping methods in their businesses for a reasonable run of years reveal that these businesses have earned a return on capital over time that is commensurate with what these same resources could have earned if used in different, alternative systems of farming.*

In many ways, in the past most crop farmers were not in a sound position to adopt conservation cropping methods until other related technical requirements of conservation cropping systems were met and economic circumstances favoured such a change. Nowadays, an expanded range of chemicals, choices of crops and crop rotations, choices of tillage systems and equipment such as controlled traffic machinery, the continued cost-price squeeze in farming, and a decline in the livestock industries, have combined to make conservation cropping methods worthy of more serious consideration by more farmers in south-eastern Australia than ever before has been the case.

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