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Abstract

Economic benefits that arise from conservation farming practices need to be assessed over several years to account for improvements in soil structure and nutrient levels. A gross margin model was used to assess benefits over the eight-year period 1999-2006 for 12 regions in the central west of NSW. The annual benefits from improved soil structure ranged from $2.46 to $12.82 per hectare (ha). A reduction in tractor power produced annual savings in the range of $0.60 to $4.05 per ha. The cost of soil compaction by livestock grazing on crop areas ranged from $3.41 to $14.90 per ha. The break-even time to pay back costs for the conversion of machinery for no-till seeding was two to three seasons.

Key Words

No-till, conservation, farming, tillage, cropping systems

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Introduction

The objective of this research was to analyse the costs and benefits of the adoption of conservation farming practices for the Central west region of New South Wales (NSW). A major cost is that associated with upgrading the machine used for seeding. The benefits include savings in tractor capital and operating costs, decreased fertiliser inputs and increased yields due to an increase in water availability over time.

Conservation farming methods that previously focused on reducing tillage practices have progressed to include management of stubble, weeds, moisture conservation and soil health (Lawrie, Murphy, Packer and Harte 2007). The primary benefits of improved conservation practices arise from the retention of and access to soil moisture. Soil moisture availability can be increased through managing water entry and exit from the farm system (Semple and Johnson 2007). Methods to increase moisture retention include retaining stubble, increasing soil bulk density through minimising soil compaction and increasing soil biota and organic matter (Charman and Roper 2007). Soil compaction, which reduces water absorption and root penetration, can be minimised by reducing the number of machine passes over farmland and by restricting traffic to dedicated pathways (or tramlines) (Tullberg 2003). Knowledge of soil biota and their role in soil health and plant yield potential is increasing; however, the actual benefits to the farming system in yield terms have not been quantified sufficiently to include in this research.

Many of the reported benefits to conservation practices arise from an increase in water holding capacity, which depends upon the soil type and climate of a particular region. There has been a considerable amount of conservation research conducted in the Toowoomba region of Queensland, areas in western Victoria, and Western Australia; however, the soils of those regions, the mix of crops, rainfall, temperature and humidity does not transfer readily to the Central West of New South Wales.

Kingwell (1996) has shown the importance of sowing time with variation in cereal variety and soil type to returns from investment in seeding machinery. The model used in his analysis assumes that the majority of the variation in yield and therefore return on investment was due to planting time, cereal variety or soil type. In areas of Australia, which may exhibit less reliable rainfall relative to parts of Western Australia, factors such as water holding capacity and in-crop rainfall may need to be included in investment models. Kirkegaard *et al.* (2007) for example, found that water use efficiency after anthesis was three times that typically expected for total seasonal water use for cereal crops in southern NSW, which implies the end of the growing cycle is more important for yield than earlier periods.

In this study geographic areas within the Central West were treated separately to account for the influence of environmental variation. The agronomic model APSIM (CSIRO 2008) includes environmental variables that could have been used to assess farm level data; however, using that model would have required a detailed knowledge of agronomic traits over time to predict crop inputs and yields. Discussions with various researchers and extension officers indicated that the necessary data would not be readily available for areas of the catchment that did not have crop research facilities. The trade-off was to examine catchment and regional level costs and benefits using regional historical rainfall and yield data in a scenario modelling approach to explore potential gains over eight cropping seasons.

Purpose

In this paper it is argued that the benefits and costs of conservation farming practices should be assessed over periods of five to ten years rather than one or two years to account for soil quality improvements that can lead to increased crop yields and higher revenues. The argument relies on the following logic:

1. income can be increased by increasing crop yields
2. crop yields can be increased by increasing soil water availability
3. soil water availability can be increased (on soils other than heavy clay) by increasing soil organic matter
4. soil organic matter can be increased by stubble retention, crop rotations, minimising soil disturbance during sowing, and minimising soil compaction through controlled traffic and through grazing management.

Conservation farming can also reduce costs over time. The argument for cost minimisation relies on:

1. a reduction in synthetic nutrients (fertiliser) due to the increased activity of soil biota due to increased organic matter;
2. crop rotations that include legumes that fix nitrogen save on the fertiliser cost of sowing a subsequent crop (canola still requires a sulphur supplement);
3. an increase in soil organic matter reduces the bulk density of soil which reduces tractor power requirements and/or time required to sow crops. Theoretically the farmer could maintain tractor size and pull wider seeding equipment or alternatively pull the same seeding equipment with a smaller tractor. In most cases it is more cost efficient to reduce tractor size when it is due for replacement, which reduces capital costs, depreciation and operating costs.

Some costs are assumed to increase with the adoption of conservation practices. The cost of purchasing new or used seeding machinery for no-till farming is more expensive relative to traditional machines due to the requirement for higher initial breakout pressures on tines, stronger bars or frames to support the new tines, and the costs of more precise seed metering and delivery systems. The increased cost of purchasing improved seeding equipment can be off-set to some extent through the sale of redundant tillage equipment such as disc ploughs or chisel ploughs. Increasing organic matter through stubble retention requires that straw be spread over a wider area during harvest and this may require the fitting of straw spreaders to harvesting machinery.

A description of the Central West catchment is next provided prior to the presentation of research to support the above logic. The gross margins model and results are then provided along with the conclusions.

Central West Catchment

Climate and topology

The Central West catchment of NSW includes the central tablelands locations of Bathurst and Orange; the slopes regions including Mudgee, Wellington and Cumnock; and the plains extending west toward Peak Hill, north to Nyngan, east to Coonamble and southeast to Coonabarabran. The most limiting resource for cropping in the west of the catchment is rainfall, which may average 438 mm per year at Nyngan to 888 mm at Orange. The catchment elevation commences at 173 metres at Nyngan rises to 948 metres at Orange. This change in elevation produces a wide fluctuation in temperatures from an average annual minimum of 6.2°C at Orange to 11.9°C at Peak Hill. The rainfall, temperature and elevation for selected regions in the Central West catchment are shown in Table 1.

Table 1 Rainfall, temperatures and elevations by district within the east or west region of the central west catchment

District **West Region**	Total Rainfall mm	Average Max Temp °C	Average Min Temp °C	Average Elevation m
Nyngan	438.8	25.7	11.6	173
Tullamore	486.1	24.5	10.0	239
Trangie	492.0	24.5	10.7	215
Coonamble	501.6	26.6	11.6	180
Warren	515.8	25.3	10.4	198
Dubbo	551.5	24.4	10.1	284
Gilgandra	557.2	24.7	9.9	282
Peak Hill	560.1	24.4	11.9	285
East Region				
Dunedoo	614.6	23.9	9.5	388
Wellington	614.7	24.4	9.4	305
Mudgee	638.0	22.5	8.0	471
Gulgong	649.4	23.0	9.5	475
Molong	701.3	22.3	6.2	565
Coonabarabran	747.0	23.7	7.4	505
Bathurst	750.0	20.1	6.7	745
Orange	888.0	17.6	6.2	948

Source: Australian Bureau of Meteorology (2008).

Soils types

Soils in the region are primarily comprised of red-brown earth (44 per cent), cracking clays of various depths (28 per cent), yellow solodic soils (15 per cent), sandy yellow earth (8 per cent) and euchrozems (4 per cent) (Department of Land and Water Conservation 2002). The soil types by estimated percentage for each region in the catchment are shown in Appendix 1. The red brown earths are weakly structured on the surface and contain sodic subsoils (Murphy, Elderidge, Chapman and McKane 2007 p. 141). The clay soils have a greater shrink-swell capacity that enables them to recover from tillage and compaction more quickly relative to the red-brown earths (Murphy, *et al*. 2007 p.142). In general the soils in the Central West are susceptible to surface crusting and compaction.

Tillage and seeding

The 2001 Agricultural Census indicates that 16 per cent of the cropping land in the catchment was sown with a single pass seeding operation; 51 per cent was sown with one or two cultivations prior to sowing; and 33 per cent was sown using the traditional practice (ABS 2001). Approximately 25 per cent of the cropland was fallowed in the 2001 season (ABS 2001).

The Agricultural Census also revealed that the majority of farmers (46 per cent) in the Central West region ploughed stubble back in while only 14 per cent retained it and direct drilled back into it. Approximately 24 per cent of farmers burnt stubble using either a hot (12 per cent) or cold (11.7 per cent) burn. Few farmers reported removing stubble by baling or heavy grazing (7.2 per cent) (ABS 2001). The low incidence of stubble grazing by livestock would limit the potential for damage by soil compaction due to treading. Agricultural Census data for the region are presented in Appendix 2.

Progressive farmers in the region use knifepoints, limited tillage passes, chemical fallows and stubble retention. Soil moisture retention practices have been more widely adopted in the drier north-western areas of the catchment in which larger farms operate relative to the south-eastern areas where the average rainfall increases and property size decreases.

Crops

Cereal grains comprise approximately 90 per cent of the crops reported in the Agricultural Census for the Central West; oil seeds represented six per cent and legumes four per cent (ABS 2001). The dominant three crops were wheat (78 per cent), barley (6 per cent) and oats (4 per cent). The planted areas, tonnages and yields for other crops produced in the region are shown in Appendix 3. The small proportion of oil seed and legume crops relative to cereals indicates that the crop rotation system was not adequately balanced to naturally replace nutrients.

Water Holding Capacity

Farmers can exercise some control over water infiltration rates by improving soil structure. The aim is to capture and hold available water for use during the growing season to increase plant yield. Water that enters the soil profile can exit through evaporation, transpiration or deep drainage. The presence of organic matter in soil enhances its cat ion exchange capacity, a property related to clay content, which influences clay aggregation, nutrient availability and water holding capacity. This property is also important in holding nutrients against leaching and thus it is of particular significance in lighter soils (Charman and Roper 2007). Increased organic matter content after long-term direct drilling has also been associated with lower bulk density and tensile strength after compaction (O'Sullivan 1992). Various options exist to increase soil organic matter and the simplest is to retain stubble as opposed to burning it.

Lawrie, Murphy, Packer and Harte (2007) argue that stubble retention can be used to:

> 1) increase breakdown of stubbles during the fallow period without treatment;
> 2) improve soil friability and moisture retention for timely sowing regardless of seasonal conditions;
> 3) improve weed control from the stubble mulch effect and weed seed predation from improved soil biology; and
> 4) increase soil organic matter nutrients (slow release fertilisers) which have been estimated to be equivalent to 30 kgs/ha/year of nitrogen (p.304).

Stubble can also be used to minimise evaporation through shading soils, decrease soil compaction through increasing soil organic matter (relative to burning) and provide wind protection for emerging crops (Crovetto 2006). Stubble can increase water infiltration through minimising water and soil runoff (Rosewell 1993). Stubble thus aids in increasing water availability though capturing more runoff, decreasing evaporation and storing more water in the profile by minimising deep drainage.

Semple and Johnson (2007) show that up to 10 per cent of water inflow is lost through evaporation; up to 10 per cent due to deep drainage; and 70 to 100 per cent is lost due to evapotranspiration through plants. Evapotranspiration is the largest source of water loss to the farm system. Stubble aids in minimising evaporation of young plants by reducing wind speeds and providing shade, which reduces plant and soil temperatures.

Soils that are in poor structure due to compaction increase the likelihood that plants will suffer more stress due to their inability to extract water from the soil. Wilting point is defined as the soil water capacity "at which most crop plants will wilt under near zero transpiration conditions" (Milthorpe and Moorby 1986 p.20). The wilting point is equivalent to a pressure of approximately 1500 kPa.

Field capacity of soil is defined as the point where "all pores with an effective diameter not exceeding about 30 microns are filled with water" (Milthorpe and Moorby 1986 p.20). Field capacity is equivalent to a pressure of approximately 10 kPa. More simply, field capacity represents the remaining water by volume after it has drained for 48 hours. Compaction of soil by tractors, harvesters and livestock reduces the number of pores and thus reduces the capacity of the soil to absorb and hold water.

Available water storage capacity (AWSC) is defined as "the volume of water that can be stored by soil that is available to plants" (Geeves, Craze and Hamiliton 2007 p.182). Water holding capacity is a function of particle size and distribution, type of clay, amount of organic matter and the bulk density and structure of soil (Hazelton and Murphy, 2007, p. 9). A central west sandy loam soil that is well structured can hold up to 265 mm/m of water, whereas a poorly structured sandy loam might hold only 146 mm/m (Williams 1983 in Geeves, Craze and Hamiliton 2007 p.182). The yield response of wheat to available soil water varies from 18 kgs/ha/mm (Kirkegaard *et al.* 2001) to 25 kgs/ha/mm (French and Shultz 1984). Thus the difference in water holding capacity between a soil in bad and good structure could result in a yield difference of 2.1 to 2.9 tonnes per ha. This difference in capacity equates to 26 per cent relative to15 per cent water by soil volume. The difference in water holding capacity for a poorly structured soil to a well-structured soil is then 11 per cent. To repair poor soils to a good structure using no-till seeding and stubble retention could take more than ten years (Lawrie, Murphy, Packer and Harte 2007). In the gross margin model presented below a 1 per cent per annum increase in yield was projected to represent an increase in soil structure over the eight-year modelling period.

The improvement of soil structure provides benefits in terms of annual production associated with increasing yields and reduced input costs and these benefits flow through to asset values of farms. Sinden and King (1996) show that potential land owners can and do place an economic value on environmental attributes of farms. They argue that technology is now available to track soil fertility, vegetation growth rates, overgrazing and erosion.

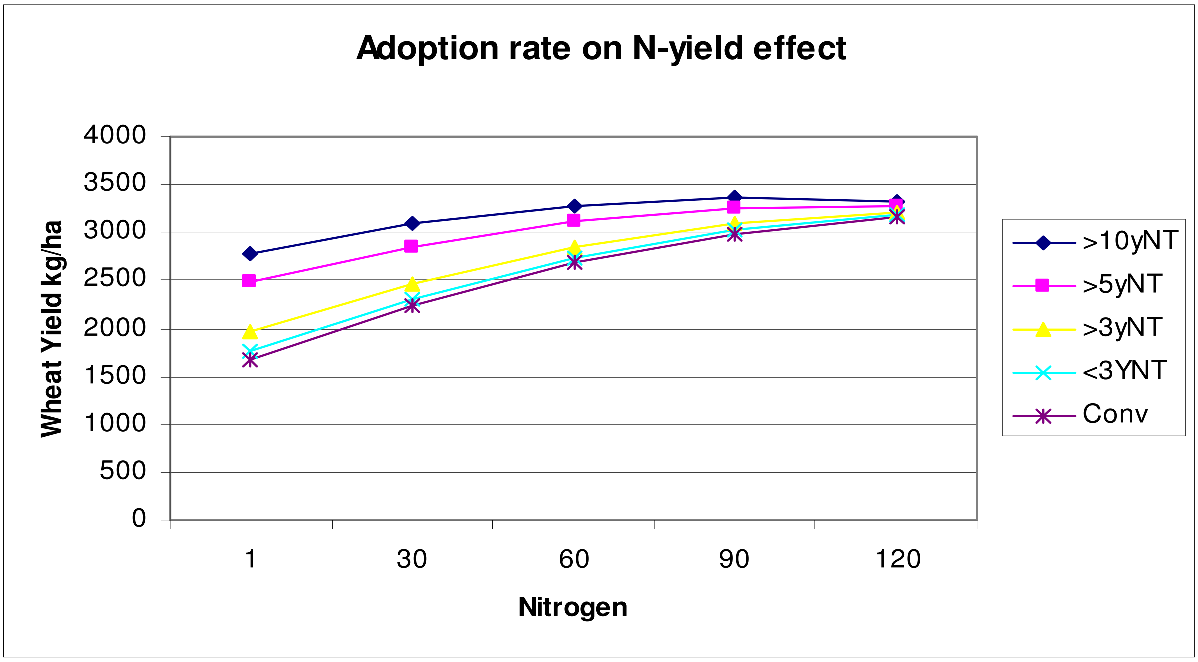
Improvement in soil structure also increases the public good. Reducing the capacity of soil to be blown or washed away provides public benefits in terms of water and air quality. Improving soil structure may reduce silting of major waterways or reduce algal blooms. Packer, Hamilton, and Koen (1984) reported that a traditional farming system might displace 290 kilograms per hectare of soil relative to 200 kilograms for reduced tillage or 15 kilograms or direct drill or low till practices. Society may also benefit from the sequestration of soil carbon associated with improved soil structure or suffer when it declines. Capital values of land assets and public good improvements were not valued in this analysis.

Soil Fertility

Soil fertility relates to the supply of nutrients available to plants. The degree of naturally produced plant-available nutrients depends on available water, organic matter, temperature and soil structure. Cereal crops use large volumes of nutrients and most traditional farming practices have applied synthetic fertilisers to boost the natural system. One tonne of wheat removes 19.5 kg of nitrogen, 3.1 kg of phosphorus, 4.3 kg of potassium and 1.5 kg of sulphur (Schultz and French, 1976). Soil nutrients may be increased through incorporating legumes in rotations and minimising stubble integration into the topsoil (Peoples and Baldock 2001). In low-till farming systems nitrogen levels may initially decline due to stubble retention as the soil biota adjusts to the new levels of energy provided by the carbon stored in the crop residue (Charman and Roper, 2007) p 282. Over time nitrogen fertiliser input may be reduced by 30 kgs/ha/year (Lawrie, Murphy, Packer and Harte 2007).

Lafond and Halford (2002) have shown that higher crop yields can be achieved with no-till farming relative to conventional farming and that higher yields can be attained with lower nitrogen inputs in the no-till system over time. Figure 1 shows the yield response for five fertiliser rates comparing conventional seeding practices with fewer than three, more than three, five and ten years of no-till farming. Their results show that there was no significant difference between conventional farming yields versus no-till yields for the first three years; however, there were significant differences in the years that followed when the fertiliser rates were less than 60 kg/ha.

Figure 1 Wheat yield response to year of adoption of no till farming with varying nitrogen inputs



Source: Lafond and Halford (2002)

In the gross margin model presented below the NSW DPI recommended nitrogen inputs (40 kgs of urea and 60 kgs of MAP for wheat) were reduced by one per cent per annum (total 28 % over eight years) to reflect the accumulation of nitrogen available through improved soil structure.

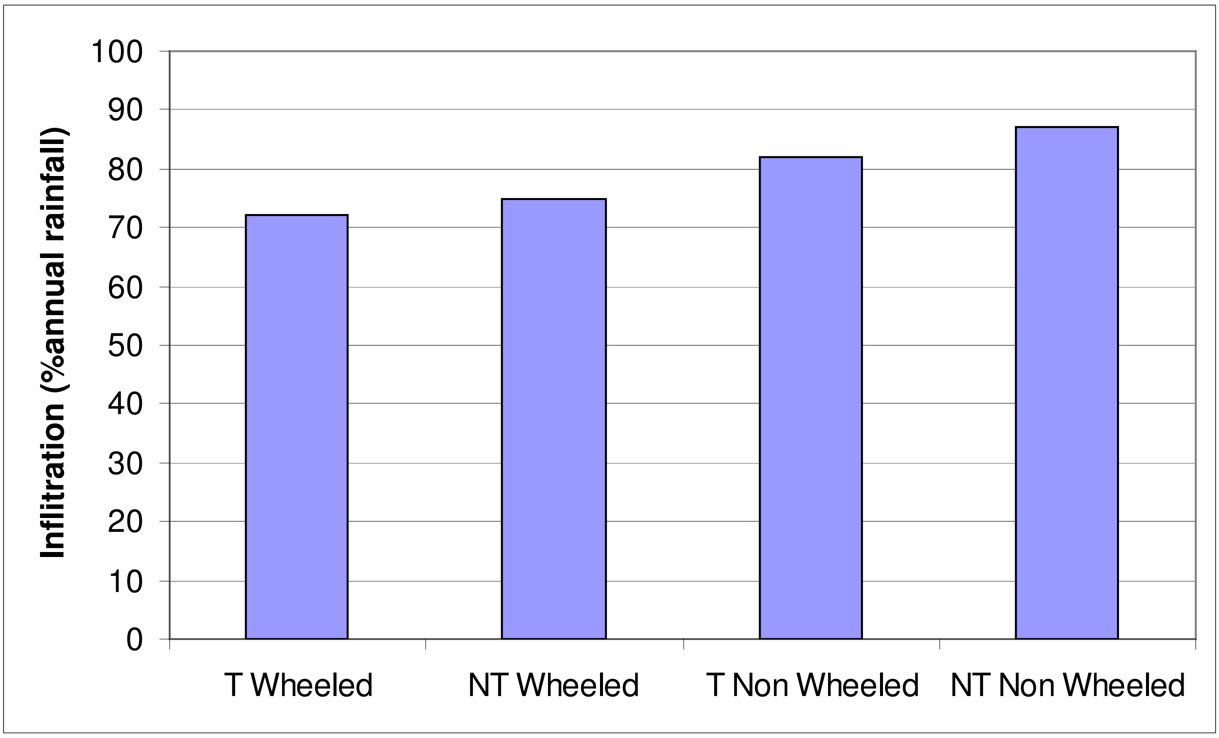
Controlled Traffic

Research on the benefits of controlled traffic has been reviewed by Spenceley and Phelps (2006). In their review they report a study by Blackwell (2004) who found farmers who used digital global positioning devices with auto steer saved 10 per cent of their total costs and those without auto steer saved approximately seven per cent of their costs. In addition to the cost savings with inputs there is also a benefit in terms of reduced compaction due to a reduction in traffic.

> The total coverage of tractor and [seeding] plant wheels over the soil surface during a crop preparation period can be surprisingly high. A traditional tillage system will cover approximately 82 per cent, a no-till system 46 per cent and a controlled traffic system 14 per cent for the paddock in one year (Walsh 1998 p.315)."

Tullberg (2000) reports that the draft tractor power requirements on tracks versus non-tracks were 1.6 to 2.2 kilowatts more efficient. Tracks also caused less compaction relative to wheeled tractors and the resulting water infiltration percentages are shown in Figure 2. In that figure it can also be observed that no-till devices enabled approximately 5 per cent more water to infiltrate relative to the traditional-till methods (T= Tilled, NT=No-Till).

Figure 2 Cumulative effects on water infiltration of wheeling and tillage in Australia



Source: Tullberg, Yule and McGarry (2003).

The increase in grain yield in response to increased water infiltration was 3.4 t/ha wheeled tilled, 3.7 t/ha wheeled no-till, 3.8 t/ha non-wheeled tilled and 4 t/ha non-wheeled no-tilled (Tullberg, Yule and McGarry, 2003). These results reveal a 5 per cent increase in yield by employing no-till methods versus tilled methods and a 9 per cent increase in yield when comparing wheeled with non-wheeled (tracks) methods. In the gross margins analysis below a potential yield increase due to the use of tracks and no-till was represented by an increase in water holding capacity over the eight-year period. The benefit from using guidance technology alone was analysed via a direct 10 per cent cost savings across all inputs in each year following Blackwell (2004).

Chisel Plough Versus Spray Costs

A number of farmers in the region use chemical fallows to improve soil structure and reduce tractor hours. In this analysis the benefit of chemical spraying versus a chisel plough operation was assessed. A budget was constructed for five chisel plough widths and the tractor power requirements were calculated following Kelly and Reeder (2000). The fuel efficiency levels at the 87 per cent load level required to meet the calculated power requirements were obtained from the Nebraska Tractor Test Laboratory (2007). Working speeds were calculated and this enabled the calculation of fuel demand per hectare. Other costs such as depreciation and labour were added to produce a cost per hour for the tillage operation. Depreciation was calculated on hours used plus number of years following Tozer (2003). The spray costs and machine hours were calculated from the application rates and costs in the NSW DPI budgets, described below, for a single pass with Garlon and Glyphosate. The chisel plough costs ranged from $35.26 for an 8.5 metre machine to $40.59 per hectare for 5.5 metre machine. The spay operations ranged in cost from $16.31 to $18.32 per hectare. The range in tillage versus spray cost savings was $17.95 to $24.11 per hectare. These results are reported in Table 2 below. The net benefits for each district are shown in column 4 of Table 3.

Table 2 Tillage versus spray costs

		Machine width				
	Metres	5.50	7.31	8.53	10.60	12.19
Tillage	**PTO Kw (HP)**	106 (142)	141 (189)	164 (220)	204 (274)	254 (341)
Ltrs / hr (Nebraska Test 87% load)#		28.31	38.32	43.04	65.47	66.73
ha / hr		4.24	5.64	6.56	8.00	10.16
ltrs / ha		6.68	6.79	6.56	8.18	6.57
$ / ltr (after rebate)		1.00	1.00	1.00	1.00	1.00
Fuel $ / ha		6.68	6.79	6.56	8.18	6.57
Depreciation $ per ha		29.19	28.20	25.65	29.52	31.88
Labour $20 /hour		4.72	3.55	3.05	2.50	1.97
Total Tractor Costs $/ha		**40.59**	**38.54**	**35.26**	**40.21**	**40.42**
Spray						
Garlon	0.1L/ha@$49/L	4.41	4.41	4.41	4.41	4.41
Glyphosate	1.2L/ha@$5/L	5.40	5.40	5.40	5.40	5.40
Application including labour		8.50	8.00	7.50	7.00	6.50
Total Spray Costs $/ha		**18.31**	**17.81**	**17.31**	**16.81**	**16.31**
Spray benefit $/ha		**22.28**	**20.73**	**17.95**	**23.40**	**24.11**

\# Nebraska Tractor Test Laboratory (2007).

5. Gross Margins Model

To assess the net benefits of converting to a conservation farming system a gross margin model was used to simulate the income and costs savings for a period of eight years for twelve districts in the Central West of NSW. The catchment was divided into two regions on an east west axis to represent the tablelands and slopes, and plains regions respectively. The NSW Department of Primary Industries publishes annual gross margin budgets for cereal, oil and pulse crops for both regions. In this analysis the 2007 crop budgets were used to simulate input levels and costs; however, the area planted and yields in the budgets were substituted with historical estimates for districts within each region that were compiled by district agronomists for the period 1999 to 2006. The numbers of hectares planted and thus included in "area planted and fallowed" were derived from the respective district agronomists for each of the eight seasons. As discussed above, the yields for each crop and each location were projected to increase by one per cent per year to reflect the potential benefit available from soil water accumulation and these in turn increased returns and the gross margin. Similarly the nitrogen applications were reduced by one per cent in successive seasons to reflect a potential savings in fertiliser due to crop rotations and improvements in organic matter. All variable inputs were reduced by ten per cent to reflect a possible reduction in inputs gained from using controlled traffic systems. The model includes a calculation of hours of machine and tractor operations, and costs and time required to spray crops.

The results from modelling the three scenarios are shown in Table 3. In that table the benefit from increasing water holding capacity ranged from $2.46 per ha in the high rainfall region (Bathurst) to $12.82 in the low rainfall plains region (Coonamble). The benefit from increasing water holding capacity increases as rainfall becomes scarce (rainfall was reported by region in Table 1).

Table 3 Estimated average values for the eight-year period 1999-2006 for increasing water holding capacity (WHC), nitrogen accumulation, overlap reduction and increased spray versus tillage operations by district within region

	District	WHC $/ha	Nitrogen $/ha	Reduce Overlap $/ha	Spray versus Tillage $/ha	Total Benefits $/ha
West	Tottenham	8.19	2.20	18.12	24.11	52.62
Region	Peak Hill	8.19	2.20	18.12	24.11	52.62
	Coonamble	12.82	1.42	11.07	24.11	49.42
	Nyngan	4.54	0.94	13.32	24.11	42.91
	Gilgandra	12.09	1.67	16.08	23.40	53.24
	Warren	12.62	1.67	16.08	23.40	53.77
	Dubbo	8.34	0.86	12.67	23.40	45.27
East	Tooraweenah	6.43	0.41	10.73	23.40	40.97
Region	Cumnock	7.71	0.41	11.72	17.95	37.79
	Coolah	6.09	0.46	12.48	23.40	42.43
	Bathurst	2.46	0.19	4.32	22.28	29.25
	Mudgee	2.98	0.21	4.93	20.73	28.85
	Average	8.13	1.13	13.16	22.86	44.09

WHC=water holding capacity (yield increased by 1%pa), Nitrogen=nitrogen accumulation (inputs decreased by 1 %pa), Reduce overlap (all inputs reduced by 10% pa), Spray versus tillage (decrease tillage pass by 1 pa and increase spray pass by 1).

The benefit from accumulating nitrogen ranged from $0.21 per ha at Mudgee to $2.20 per ha at Peak Hill and these are shown in Table 3. The difference between areas in the western and eastern model was due to the mix of crops used in the model as each crop in each region has a different nitrogen application. Thus the benefits of including a natural source of nitrogen such as pulse crops in the rotation are greater for districts in the western region relative to districts in the eastern region. Eastern districts to some extent have a more diversified crop mix relative to western districts.

The benefits from reducing input costs through minimising overlap by 10 per cent was $4.32 per ha at Bathurst to $18.12 per ha at Peak Hill. The benefits for other regions are reported in Table 3. Those benefits are not net benefits as they exclude the cost of guidance equipment. GPS guidance systems start at around $5000 for basic units, and increase to $50,000 for standard GPS with steering devices, to well over $100,000 for more complicated systems. The breakeven number of hectares for a $50,000 auto steer unit, with a cropping benefit of $13.16, would be 3,800 in one year or 380 hectares over 10 years.

The calculation of spray versus chisel plough benefits are shown in Table 2 and the results are reported by region in column 4 of Table 3. The benefits range from $17.95 per ha at Cumnock to $24.11 per ha for most districts in the western region. These values are primarily the result of the crop mix driving chemical application costs and tractor size driving tillage costs.

Seeding Machine Conversion Costs

The costs to convert a traditional seeding machine into a machine suitable for conservation farming were calculated for a range of machine widths from 5.5 to18.9 metres. Conservation-seeding machines require the capacity for high break-out tine pressures, accurate seed and fertiliser placement, minimal soil disturbance, good stubble clearance, stubble flow and a covering device that does not disturb the inter-row space. The specifications for seeding machines were determined from data held by the Central West Catchment Management Authority. Prices for a range of used machines were sourced from The Land newspaper over a period from April to June 2007. The costs for a range of coulters, tines, openers and press wheels were sourced directly from manufactures of the various components. Two hours of labour per tine at $25 per hour were budgeted to disassemble and reassemble the tines and components. The costs to convert machines ranged from $24,443 ($9.78 per ha per annum) for a 5.5 metre machine to $101,105 ($5.06 per ha per annum) for a 14.6 metre with hydraulic tines and these are reported in Table 4.

It is economical to upgrade machines if producers own the frames or they can obtain frames at low cost. New seeding machines in the less than 7 metre range retail for approximately $35,000 to $40,000. Once the machine width increases above 10.6 metres it is cheaper to buy a purpose built used machine or new machine. As the market for purpose built machines increases the benefit for machine conversion will decrease, as there will be more used equipment on the market driving prices down.

Table 4 Seeding machine purchase and conversion costs

		Frame width						
	Metres	5.5	7.31	8.53	10.6	12.19	14.6	18.9
Machine/Frame/Bar	Purchase price	$	$	$	$	$	$	$
International 511		4,000						
Connor Shea Seeder			15,000					
John Shearer Scaribar				24,200				
Napier bar and box					22,200			
Alfarm						22,500		
Shearer 5160							24,000	
Flexicoil								48,500
Row space	Metres	0.26	0.26	0.26	0.26	0.3	0.26	0.3
Number of tines		21	28	33	41	41	56	62
Coulter $/unit								
Brand		214						
Primary Sales Single				755.7				
Tine $/unit								
Multiplanter tines		500	500	500				
Horwood Bagshaw edge-on					1150	1150	1150	1150
Points $/unit								
PR 96 DB-ATW Super Seeder		62	61.5	61.5	61.5	61.5	61.5	61.5
Press Wheel $/unit								
Janke Press Wheels		330	330					
Manutec Single				345	345			345
Primary Sales Single						539	539	
Labour $/unit								
2 hr/tine @ $25/hr		50	50	50	50	50	50	50
Total Attachments *		24,443	26,471	56,200	65,496	73,160	101,105	99,603
Hectares / year		250	500	750	1000	1500	2000	2500
Cost per ha per year		**9.78**	**5.29**	**7.49**	**6.55**	**4.88**	**5.06**	**3.98**

* Note: does not account for boots, hoses, connectors or modifications that include some attachment devices, spreading rows or altering clearance of machine

Source Data: Prices from The Land, various issues, March 2007 to June 2007.

Tractor Capital Cost Savings

A calculator was developed to analyse the power requirements of tillage and seeding machines on different soil types within the Central West region. The power functions were derived from Kelly and Reeder (2000). Testing of the calculator with various soil types, seeding speeds and machine widths indicated that tractor PTO power requirements could be reduced with conservation tillage. A table was constructed to show the power requirements with a chisel plough pass versus a zero-till machine pass. The power requirements for seven seeding machine widths were analysed and the difference in power requirements was recorded for each machine width. The economic value of the difference in power requirements was established by subtracting the purchase price of a new tractor with the power requirements for a seeding machine pass from the purchase price for a new tractor with the power requirements for a chisel plough pass for each width of machine. The capital savings, as shown in Table 5, ranged from $9,122 to $47,653 for Case IH tractors over tractor sizes from 100- 250 kilowatts (kws). The benefit including depreciation and interest when calculated on an annual per hectare basis ranged from $4.05 for a 500 ha farm to 60 cents for a farm with 2500 ha's of arable land.

Table 5 Tractor capital cost savings

Tractor Capital Savings	Seeding Machine Width						
Metres	5.5	7.3	8.5	10.6	12.2	14.6	18.9
Tractor PTO KW (HP)							
No- till seeder *	105 (142)	140 (189)	164 (220)	204 (273)	203 (272)	281 (376)	310 (415)
Chisel plough *	114 (153)	152 (203)	177 (237)	221 (296)	254 (340)	304 (407)	334 (448)
Difference	8 (11)	11 (14)	13 (17)	17 (23)	51 (68)	23 (31)	24 (32)
New Holland New 4WD	$	$	$	$	$	$	$
No- till seeder #	145,959	169,202	185,920	234,880	271,163	267,050	298,000
Chisel plough #	155,081	194,492	195,920	256,050	318,816	298,000	316,790
Difference	9,122	25,290	10,000	21,170	47,653	30,950	18,790
Hectares / year	250	500	750	1000	1500	2000	2500
Capital savings $/ha pa	3.65	5.06	1.33	2.12	3.18	1.55	0.75
Depreciation/ha (10%pa)	0.36	0.51	0.13	0.21	0.32	0.15	0.08
Interest/ha (7%pa)	2.55	3.54	0.93	1.48	2.22	1.08	0.53
Total benefit $/ha/pa	**2.92**	**4.05**	**1.07**	**1.69**	**2.54**	**1.24**	**0.60**

Source: * Estimated from Kelly and Reeder, (2000). # SpecCheck Tractors (Spring 2006).

Soil Compaction by Livestock

Livestock grazing on stubble may cause compaction if stock numbers are high, soil organic matter is low and the soil is wet. Sheep may compact soil to a depth of between 5-10 centimetres, and cattle can affect soil to a depth of 8-12 centimetres (Greenwood 1996).

Table 6 Stock compaction cost by district

District	$/ha
Tottenham	10.53
Peak Hill	10.68
Coonamble	14.90
Nyngan	5.65
Gilgandra	14.05
Warren	14.72
Dubbo	9.94
Tooraweenah	7.72
Cumnock	8.54
Coolah	7.29
Bathurst	3.41
Mudgee	5.30
Average	9.39

A standing sheep places approximate 66 kpa of pressure on soils and cattle 138 kpa, whereas tractor tyres produce between 74-80 kpa and tracks 58 kpa (Blunden *et al.* 1994 in Greenwood

1996). Livestock pressures increase when stock are running (Greenwood 1996). The levels of compaction produced by livestock may be estimated by the inverse of the benefit for increasing water holding capacity and nitrogen accumulation as a result of minimising tractor traffic as compaction negates these two benefits. The costs for each district are shown in Table 6 and range from $3.41 per ha at Bathurst to $14.90 per ha at Coonamble with a regional average of $9.39 per ha.

Net Benefits

Table 7 shows the net benefits, excluding livestock compaction, for farms located in the Bathurst, Gilgandra and Nyngan districts in the Central West. The benefits from Tables 3 and 4 included water holding capacity, nitrogen accumulation, overlap reduction and spray versus till calculations on a per hectare basis. The costs for 5.5, 10.6 and 18.9 metre machines were shown in Table 5 for machinery conversion. The calculation for GPS steering costs were estimated for GPS units ($45,000, $50,000 and $115,000) that would be used within the region with their costs spread over 10 years for 250, 500 and 2500 ha respectively.

Table 7 Net benefits for three regions in the Central West catchment

	Table number	Bathurst	Gilgandra	Nyngan
Benefits		$/ha	$/ha	$/ha
Water Holding Capacity	3	2.46	12.09	4.54
Nitrogen	3	0.19	1.67	0.94
Overlap reduction	3	4.32	16.08	13/32
Spray versus till	3	22.28	23.40	24.11
Tractor capital	4	2.92	1.69	0.60
Total Benefits		32.17	54.93	30.19
Costs		$/ha	$/ha	$/ha
Machine conversion	5	9.78	6.55	3.92
GPS system		18.00	5.00	4.60
Total Costs		27.78	11.55	8.52
Net Benefits $/ha/year		4.39	43.38	21.67

In this analysis the costs and benefits were primarily spread over ten years and the net benefits were shown to be positive for the three regions in Table 7. The sensitivity analysis (not shown) reveals that the break-even time to convert to no-till practices was between two to three seasons. The largest gains were available from minimising tractor use for weed control operations. Farmers who have invested in no-till machinery, GPS steering systems, retained stubble, sprayed crops rather than tilling them and who operated in the western region would have received the largest benefits in the range of $21 to $43 per hectare per year for the eight seasons modelled in this analysis. Farmers located on the tablelands (such as Bathurst) could have gained net benefits of $4.39 per ha. Farmers on the tablelands were also more likely to operate livestock enterprises and such enterprises may be negating the benefits ($4.39-$3.41 = $0.98) available from no-till farming practices. Farmers on the tablelands region need to weigh the net benefits of income risk management with livestock against livestock compaction costs.

Conclusions

It has been argued in this paper that benefits from the adoption of conservation farming need to be assessed over a period of at least eight years, and preferably 10 to 12 years, to account for the improvement in soil quality and the corresponding capacity to increase crop yields through an increase in water holding capacity and a reduction in soil nitrogen. The use of guidance and steering technology has been reported to reduce costs by up to ten per cent and increase soil moisture by increasing infiltration and thus increasing yields by between five to eight per cent.

It is economical to convert seeding machines that are less than seven metres in width, due to their relative cost to new machines. Conversely purpose-built machines greater than 10.6 metres are relatively less expensive to purchase used or new. It is expected that the benefit of converting small machines will erode as the number of purpose-built machines in the new and used market increases over time.

Benefits accrue from switching from a chisel plough fallow to a chemical fallow, which reduces direct input costs and has a positive effect on soil structure. As soil structure improves over time with low-til practices then tractor power can be reduced at the time when tractors are replaced which has the effect of reducing annual capital costs and depreciation.

Sheep and cattle may cause soil compaction and thus negate any benefits obtained through conservation farming practices; hence, the cost of compaction can be accounted for by using the reciprocal of the benefit for improving soil structure. In this study this was the reciprocal of the benefits achieved from increasing water holding capacity and accumulating nitrogen over time and a reduction in the capital cost savings from a reduction in tractor size.

Benefits and costs vary considerably for districts within the Central West region due to the wide variation in soil types and environmental conditions including temperature and rainfall. The mix of crops also has an impact on the levels of benefits due to variation in the input and output requirements. It is recommended that the model be validated with more precise tools such as APSIM and that agencies aim to collect relevant data from farmers to assess changes in soil conditions over time from a number of districts in the catchment, preferably with a good distribution of soil types.

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Appendix 1 Estimated percentage of soil type by region in the Central West region of NSW

Soil Type	Cracking Clays	Lithosols Shallow Soils	Shallow Cracking Clays	Euchrozems	Sandy Yellow Earth	Red Earths	Red Brown Earths	Non-calcic Brown Soils	Yellow Podzollic Solodic Soils	Yellow Solodic Soils
Soil Symbols	CC, II	Fz,LK,Pd	Kb,Kd,Ke	Mb,Mg,Mm, Mo,mm	Ms	Mx,Mr,Mu Mw,My,Mz	Ob,Oc,Od	Qb,Qc,Qd, Qr,Ra	Tb	Ub, Va
Tottenham	0.33						0.33			0.34
Peak Hill		0.08					0.60	0.02		0.30
Coonamble	0.60		0.30				0.10			
Bathurst						0.30		0.50	0.20	
Mudgee								0.25	0.50	0.25
Dubbo				0.30	0.40		0.30			
Yeoval								0.70		0.30
Warren	0.85						0.15			
Narromine						0.30	0.60			0.10
Gilgandra					0.40		0.60			
Curban	0.60						0.40			
Coonabarabran			0.50	0.20	0.30					
Nyngan	0.40					0.40	0.20			

Source: Author's estimate of soil type combinations derived from data and maps published by the Department of Land and Water Conservation, Central West Region, Resource Information, February 2002.

Appendix 2 Stubble management practice with the Central West catchment

Stubble Management Practice	**Hectares**	**%**
Stubble ploughed into soil	373,997.54	46.69
Stubble left intact (no cultivation - crops direct drilled)	112,530.03	14.05
Stubble removed by hot burn	96,260.46	12.02
Stubble removed by cool burn	94,185.37	11.76
Most stubble removed by baling or heavy grazing	58,187.97	7.26
Stubble was mulched	44,058.07	5.50
All other methods	21,830.79	2.73
Total stubble area treated	801,050.23	100.00

Source: Australian Bureau of Statistics (2001).

Appendix 3 Cropping area and production for the Central West region for the 2001 season

Crop	Hectares	Tonnes	Yield	% Ha's
Cereals				
Wheat	788,709	1,200,807	1.52	78.024
Barley	67,320	104,717	1.56	6.660
Oats	41,624	39,963	0.96	4.118
Sorghum	7,887	18,920	2.40	0.780
Triticale	5,701	9,575	1.68	0.564
Maize	1,022	6,129	6.00	0.101
Millet	94	91	0.96	0.009
Oil seeds				
Canola	57,566	80,512	1.40	5.695
Safflower	593	241	0.41	0.059
Sunflower	388	235	0.61	0.038
Legumes				
Lupins	18,736	16,722	0.89	1.853
Chickpeas	15,257	8,711	0.57	1.509
Field peas	2,377	1,017	0.43	0.235
Faba beans	1,611	1,342	0.83	0.159
Mung beans	1,435	763	0.53	0.142
Soybeans	536	1,112	2.08	0.053
Total	1,010,855	1,490,860	1.47	100

Source: data compiled from Australian Bureau of Statistics census data for the 2001 season.