Conservation cropping – the long-term experiment at Harden

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Conservation cropping, the practices of reduced tillage and stubble retention, started 40 years ago, following development of the first knockdown herbicides. These practices meant a change from conventional cultivation, which at the time consisted of stubble burning and several passes with tines or discs to control weeds and produce a seedbed.

Adoption of conservation cropping was slow until the oil shocks of the 1970s increased fuel cost and hence the cost of cultivation. After the late 1970s the environmental value of conservation cropping became more widely recognised after soil scientists showed that reduced tillage and retained stubble led to improved soil structure and less soil erosion. Machinery manufacturers developed seeders with high break-out tines that could operate in high-strength soils. Farmer groups promoted conservation tillage and no-till cropping. Many farmers enthusiastically adopted minimum tillage, which consisted of a single cultivation before sowing, generally with a chisel plough, sometimes combined with application of urea or anhydrous ammonia, followed by seeding with a trashworking combine. Conventional cultivation, involving up to 7 passes, had largely disappeared by the mid 1980s.

By the late 1980s, adoption of full cut-out direct drilling, i.e. no tillage at all, was enthusiastic in some regions but not in others. Farmers in semi-arid areas with sandy soils could direct drill into light stubbles with few problems. The heavier stubbles and hard-setting soils of south-eastern NSW provided more significant obstacles. True direct drilling was, and is still scarce in this region. Many farmers continued to burn heavy stubbles in late autumn and sow after a one-pass cultivation. Few took the additional step to direct drilling until airseeders became common in the mid 1990s.

Experiments started in Australia and elsewhere during the 1970s and 1980s to compare various conservation cropping systems with conventional cultivation. These experiments confirmed the environmental and soil benefits of conservation cropping but gave inconsistent yield results. Some showed increased yield with direct drilling or reduced tillage, some no difference and some decreased yield. The reasons for the different responses were not understood at the time.

By the late 1980s, the relevance of these experiments was questionable. The multiple passes used in the "conventional" treatments were no longer relevant to farm practice and many experiments were based on continuous wheat, which imposed a yield penalty on stubble retention because of the carry-over of leaf-borne diseases. At about that time well adapted broadleaf crops became available and farmers were aware of their value as break crops for wheat.

The Harden long-term experiment started in 1989 to investigate the effects of tillage and stubble management on soil conditions and crop productivity. The 20 years of this experiment spans half the life of conservation cropping in Australia.

From the start, our intention was to build on the lessons of earlier research, in particular by not repeating studies of the well known environmental advantages of conservation cropping. None of the treatments examined conventional cultivation which had become obsolete by the late 1980s. The intended crop sequence of wheat alternating with a break crop was successfully followed over the course of the experiment to minimise the problem of stubble-borne disease. We aimed for a high standard of crop management with early sowing, a high level of weed control and optimum fertiliser management. While there were some lapses over the 20 years, the mean wheat yield of 4.8 t/ha for the highest yielding treatment gives confidence that the results are relevant to productive cropping systems. Appendix 1 contains the yields of all crops but the following papers concentrate on wheat. The core treatments compared direct drilling with minimum tillage, and stubble retention with stubble burning. These treatments stayed the same for 20 years (Table 1).

Plots at the Harden long-term experiment.

> Table 1. Treatments in the Harden long-term experiment.

		Stubble treatment	Cultivation treatment
1	Burn / Cultivate	Stubble burnt in April[1]	Tine cultivation after burning[2]
2	Burn / Direct drill[3]	Stubble burnt in April[1]	No cultivation
3	Incorporate stubble	One or two offset disc operations after rain in late summer	
4	Bash[4] / Cultivate	Stubble flattened in JanuaryApril	Tine cultivation after burning[2]
5	Standing stubble / Direct drill[3]	No stubble disturbance	No cultivation
6	Mulch[5] / Direct drill[3]	Stubble broken down with a rotary mulcher in April	No cultivation
7	Bash[3] / Direct drill[3]	Stubble flattened in January	No cultivation

[1] Stubble Burnt plots were placed together in each replicate with a narrow firebreak on one side and the Incorporate Stubble plot on the other side. The statistical analysis accounted for this arrangement

[2] Cultivation was with a scarifier using 7 cm-wide points in one pass to 10 cm depth

[3] Direct drilling was with lucerne points (~ 1 cm wide) until 1994, after which sowing was with 7cm "narrow" points.

[4] Stubble bashing was with a Coolamon stubble-bashing harrow with dimension 6 m x 2 m, consisting of a 20 cm square grid made from 13 mm metal rod.

[5] Stubble mulching was with a Nobili rotary mulcher. Treatment 5 and 6 were discontinued in 1992 after yields in the first three years showed no difference between treatments 5, 6 and 7. After 1992 all three were managed as Bash/Direct Drill.

Experimental notes
Four replicates. Plot size 30 m x 6 m, plots aligned down a 2% slope. Stubbles were not grazed. The experimental area was limed in 1989, 2000 and 2008. Annual phosphorus application was 20 kg/ha as triple superphosphate. Nitrogen application was by tactical topdressing depending on crop status and soil water status.

The core treatments are 1, 2, 4 and 7. These show the main effects and interactions of cultivation and stubble management. Treatment 3 provided a non-commercial treatment to rapidly break down stubble.

Background

Established as a part of CSIRO Land and Water Care Project in 1990, the experiment became a focal point of collaboration and discussions with local farmers, consultants and the Harden Murrumburrah Landcare Group, and annual field days have been held at the site. Since the initial funding by Land and Water Care ceased in 1994, the site has been maintained by CSIRO in collaboration with other research groups interested in sampling the site, and basic soil and agronomic data has been taken throughout this period.

Peer-reviewed publications from this research will ensure that the results are not forgotten and will lead to further progress (Appendix 2). Research at the long-term site has led to other CSIRO research in the region such as deep drainage and growth of canola through wheat stubble. The most recent is Clive Kirkby's study of the prospects and costs of soil carbon enhancement. The HMLG has its own productive program of paddock-scale experiments which build on the plot scale research at the long-term site.

1990 – 1994	CSIRO Land and Water Care (John Angus, John Kirkegaard)
1995 – 1997	CSIRO Biodiversity Projects (RIRDC Funded)
1997 – 2000	CSIRO, NSWAg, Organisms associated with poor vigour (GRDC DAN316)
1998 – 1999	CSIRO High vigour wheat for overcoming DD constraints (Greg Rebetzke)
1998 – 2002	CSIRO/CSU Wheat stubble impact on canola (GRDC CSP244) Sarah Bruce
2000 – 2001	CSIRO Developing a simple drainage meter (Paul Hutchinson GRDC CSO201)
2001 – 2005	CSIRO Inhibitory bacteria on DD wheat (Michelle Watt GRDC CSP329)
2003 - 2004	CSIRO Simulation of water use and drainage (Julianne Lilley)
2005 – 2007	CSIRO Soil organic C and N under different tillage systems (Terry Bolger)
2008 - 2010	CSIRO/CSU. Impact of nutrients on humus production (Clive Kirkby)

Key results

- Stubble retention and reduced tillage increased microbial biomass, microbial activity and the number and the diversity of microorganisms and soil fauna represented by earthworms, nematodes and springtails.
- Despite these changes, early crop vigour decreased with conservation cropping in every year of the experiment and crop yield decreased in years of average or above average rainfall.
- For wheat crops, the package of stubble retention and direct drilling reduced yield, on average, by 10%. Stubble retention was responsible for three-quarters of the decrease and direct drilling for one-quarter. The impacts did not diminish with time.
- Diseases and inhibitory microbes were responsible for the negative effect of conservation cropping on growth and yield, even in a crop sequence that included break crops. The inhibitory microbes infected the roots of direct drilled crops when their growth was impeded in high-strength soil. The yield penalty of conservation cropping was greatest in wet seasons and least in dry seasons.
- Early sowing, deep soil disturbance, dry springs and low stubble loads overcame the reduction in seedling vigour.
- Retained wheat stubble reduced yield of canola through physical effects on microclimate. Using sowing techniques to push stubble away from the rows of emerging seedlings can alleviate this problem.
- Conservation cropping increased drainage below the root zone, apparently because of more infiltration following reduced evaporation during winter, improved soil macroporosity and more residual soil water following reduced uptake by previous crops.
- Averaged across all treatments, soil carbon decreased by at least 30% over the course of the experiment. The decrease was most rapid since 2001 when input of residues was low because of drought. The effects of cultivation and stubble management on carbon levels were small, with cultivation leading to lower levels than direct drilling while stubble management had no significant effect.
- Stable soil organic matter (humus) at the Harden site contains carbon, nitrogen, phosphorus and sulphur (CNPS) in predictable and constant proportions which are consistent with the proportions at many other sites worldwide. Accumulation of more soil carbon may be limited by the amount and cost of N, P and S.
- Over the twenty years, there was no significant difference between mineral N content of soils in the burn-minimum tillage and stubble retain-direct drill systems. However the percentage of soil and fertiliser N recovered by the crop was significantly greater by burn-minimum tillage crops, apparently because of their greater yield potential.

Perspective

Conservation cropping can have significant impacts on productivity in the high-rainfall cropping region of Harden that are not obvious in lower rainfall areas. Many of these effects of direct-drilling can be overcome with strategies revealed in the experiments, while leaf diseases can be reduced by varietal selection and use of fungicides. In wet seasons it is likely that the problems reported in Harden will show up elsewhere. The results indicate that occasional tillage and stubble reduction through a late burn in a conservation cropping system will not lead to soil degradation.

The impacts on productivity should be balanced against the benefits of reducing erosion, improving soil properties, earlier sowing and lower costs of labour and machinery. Most growers will judge that the benefits outweigh the costs. However the lack of significant response of crop yield to the improved soil conditions under conservation cropping remains a puzzle and is an important topic for further research.

There are still opportunities of increasing yields under conservation cropping in general and with retained stubble in particular. Advances could come from breeding crops specifically for conservation cropping, and from further development of high-precision guidance to sow between the rows of previous crops. As in other improvements in crop productivity, a combination of breeding and changed crop management is likely to lead to the most rapid progress.

Acknowledgements

The experiment would not have been possible without the generosity, patience and support of the O'Connor family over the past 20 years. The late Mr Justin O'Connor greatly encouraged us at the start of the project. Since then Mr Peter O'Connor and Mr Pat O'Connor provided access to the land, were tolerant of our many requests for assistance in managing the site, and provided stimulating discussions and ideas about the direction of the research. We acknowledge the contribution of Mr Jim Wright in identifying the experimental site and for his wise counsel before and during the project. We also acknowledge the technical assistance of Mr Geoff Howe (now retired) who managed most of the agronomic, monitoring, measurement and soil and plant analysis at the site throughout the 20 years of the experiment.

Staff at CSIRO Ginninderra Experiment Station provided expert field technical assistance throughout the 20 years of the experiment.

Financial support for management of the experimental site, individual research projects and sponsorship of the 20 year workshop came from the agencies and companies whose logos appear on the back cover. We thank them for their support.