Chapter 2

Conservation agriculture in Australia: 30 years on

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Introduction

In this chapter we present a national overview of current use of conservation agriculture-related practices by Australian grain growers and the trajectories of this practice change over the past three decades. The shift to no-tillage farming represents one of the most substantial landscape changes in Australian agriculture. From initial investigations into the potential for conservation farming in Australia during the 1960s (Belotti and Rochecouste 2014, Thomas *et al.* 2007), the long process of transformation from a traditional cropping system initially involving multiple cultivations of typically fragile soil has continued into the current decade.

The importance and extended time frame of adoption of conservation agriculture-related practices in Australia means that it has received extensive research and review attention in efforts to understand and learn from the change (Cornish and Pratley 1987, Freebairn *et al.* 1993, Crabtree 2010). The aim here is not to review these studies, or the associated international literature, but to look at the more recent status of conservation agriculture application and the path it is taking across Australian cropping zones as the extent of use continues to reach its high plateau in some agro-ecological zones. Together with this ongoing establishment of no-tillage as an extensive practice in some later-adopting agro-ecological zones, we concurrently see established no-till and stubble retention acting as a platform for further major advances in cropping practice. This is the foundation for suites of practices that are together increasing water use efficiency and general management efficiency at increasing farm scales (Kirkegaard *et al*. 2014b, Fletcher *et al.* 2016) and leading to sustained levels of strong production in the face of an increasingly challenging climate (Gobbett *et al*. 2017).

The adoption of conservation farming methods is recognised as a multi-faceted, information and learning-intensive process (Young 2003, D'Emden *et al.* 2007, Gray 2010, Rochecouste *et al.* 2018), and this has been reflected in the unique role of farmer-led groups in its development and extension. We end this chapter with an examination of the associated transformation of the farm advisory network over this period of remarkable cropping change and the legacy this has left for future farming systems innovation.

Data

The chapter draws upon a mix of published and unpublished data collected from two national surveys of Australian grain growers. The main data set (from the data collection described in Llewellyn *et al*. 2016) represents 13 agro-ecological zones across northern (including northern New South Wales and Queensland), southern (including southern New South Wales, Victoria, South Australia and Tasmania) and the western zone (Western Australia), while the second data set (from Llewellyn and Ouzman 2014) represents 12 agro-ecological zones (AEZ) across southern and western Australia. This second data set is used in a supplementary manner; examining relationships with advisory support and adoption of other cropping technologies by Australian grain growers.

Data collections in both surveys involved phone interviews run in conjunction with a specialist survey data collection company, with an extensive national grower database. Growers were randomly contacted from the database until the quota for growers meeting the criteria in each AEZ was met. In both studies respondents needed to be identified as primary cropping decision makers and were screened based on their farm's crop area being greater than 500 ha of crop, with the exception of the High Rainfall Victoria and Tasmanian zones in the 2016 study, where this was reduced to 250 ha to reflect the commonly smaller farm size in that region. In the 2016 study, the completion rate was 44%, based on the total number of primary cropping decision-makers directly approached for participation, and the

602 grower responses represent a total arable area of 2.0 million hectares. In the earlier survey study, the completion rate was 45%, with 573 growers participating.

A relatively broad definition of NT seeding is used in this chapter and the main studies cited. The working definition of NT is based around seeding with low soil disturbance and no prior cultivation, including crop seeding using either low disturbance points or ‘zero-till’ (with disc machines). The other major component of conservation cropping systems, full retention of crop residue, has been considered separately. The data present practice-change over time, showing the trends in CA-related practices, together with related factors including use of consultants and engagement with farmer groups over the last 30 years. The diffusion curves show the cumulative adoption levels based on stated times of first use by growers at the time of the study. They reflect the practice changes undertaken by the population of growers at the time of the study rather than the typically larger grower population that may have existed at the time of first use. Where possible, supplementary area-based data from the most recent farm practices survey conducted in 2016 by the Grains Research and Development Corporation (Umbers 2017) are used by way of a comparison.

Adoption and extent of use of conservation agriculture in the Australian grains industry

In this section we begin by looking at adoption and use of NT (and/or ZT practices) by Australian grain growers over the past 3 decades. Stubble retention and the use of burning is then explored as the second major component of conservation agriculture.

Adoption of no-tillage cropping

The most recent available farm practices survey data (Umbers 2017) show that the proportion of Australian grain crop area sown using no-till or zero-till reached 74% in 2016. Although this shows that NT practices have typically become ‘conventional practice’, a national perspective on time of adoption shows that growers shifting to NT for the first time has been an ongoing process into the current decade. Figure 1 shows the cumulative proportion of grain growers who have used at least some NT. It highlights the long time-frames involved in reaching peak adoption across a geographically diverse and heterogeneous population of potential adopters. At this national level, evidence of a plateauing of adoption has only become apparent in the past decade.

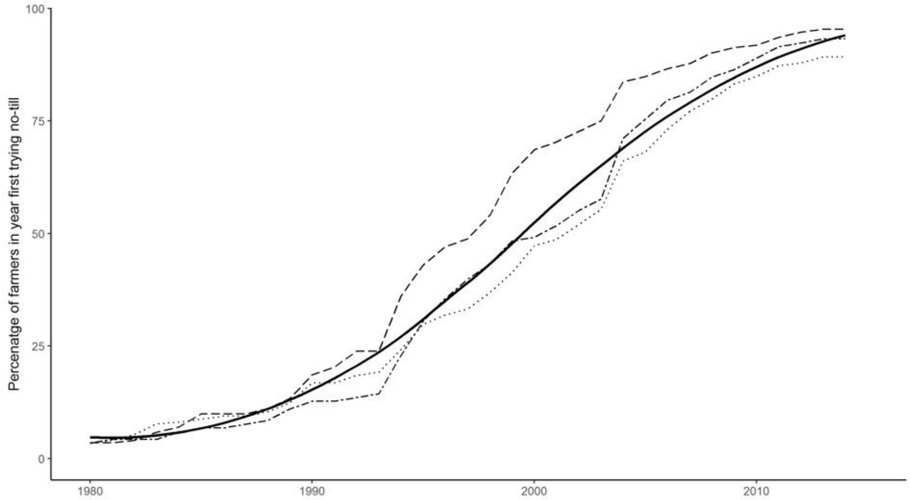

Figure 1. The cumulative proportion of Australian grain growers who had used some no-till (or zero-till) by year (solid line is national smoothed data, based on 2014 grower population, two dash line is northern, dotted is southern and long dashed is western).

When looking at the regional level, the data show the substantially faster rate of adoption of NT in Western Australia through the 1990s and an earlier slowing of adoption rates in that state (Figure 1).

Continued high adoption rates in the northern and southern regions after 2000 have led to a closing of those regional differences. Later starts to the increase in NT adoption in some agro-ecological zones such as the low-rainfall SA-Vic Mallee (including Upper Eyre Peninsula) region, and steadier rates of adoption relative to the more rapid surges in adoption experienced in agro-ecological zones such as the WA northern region, help to explain some of the regional differences and the extended period of adoption (Figure 2). Ultimately, the very large differences between agro-ecological zones in the proportion of growers who have adopted NT that was evident during the late 1990s (Figure 3) have largely disappeared, with most regions now exceeding 90% (Table 1).

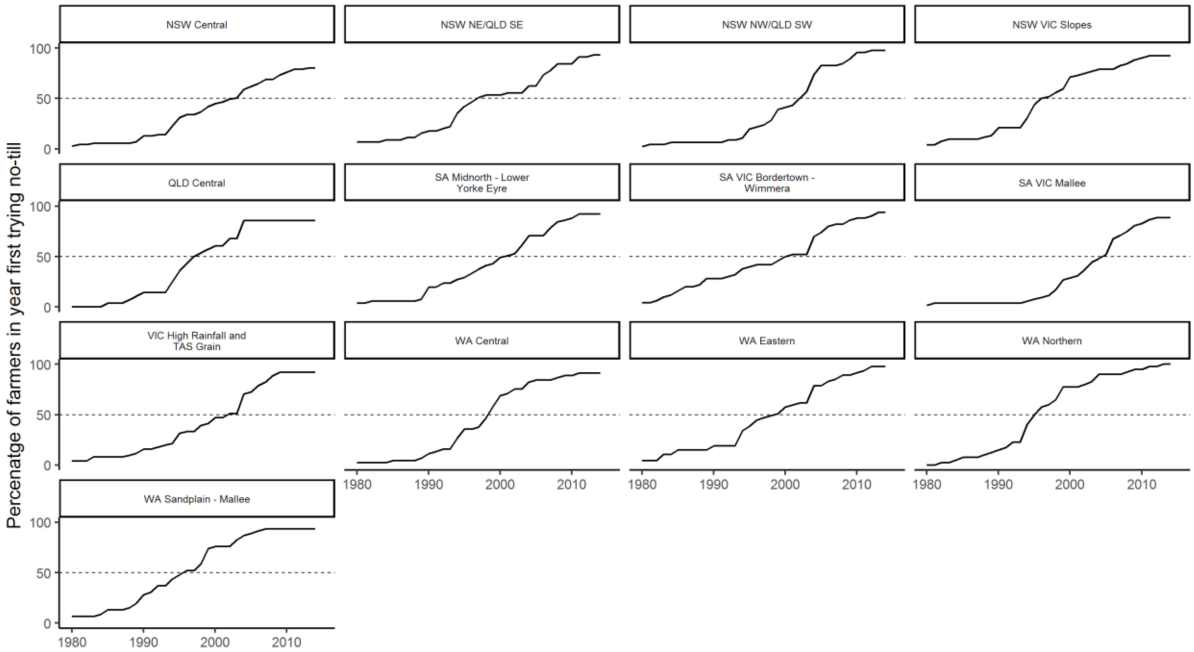

Figure 2. The cumulative proportion of grain growers by agro-ecological zone who have used some no-till (or zero-till) by year.

The extent of use of tillage

While the proportion of growers using at least some NT is typically plateauing at over 90%, the area of crop under NT (or undergoing some cultivation) still reflects more substantial differences (Table 1). On average, these 2014 season figures show 15% of cropped area sown following a prior cultivation pass. A comparable study (Umbers 2017) indicates an average 16% of the national grain crop area had received a prior cultivation pass over the years 2011-2016 with no significant change in this figure over this period. In contrast, there has been a significant reduction in the proportion of cropped area sown 'direct-drill' (causing greater than 30% soil disturbance in the seeding pass), indicating that gains in the crop area under NT/ZT over the past decade have come from new adopters and a shift to reduced disturbance in single pass sowing operations.

Although only small, the increases in extent of use demonstrate that the adoption process for NT adoption still may not be complete in some areas. This is more than three decades after NT began to be adopted under Australian farm conditions. The results also demonstrate that some form of tillage on relatively small areas is likely to remain a significant part of Australian cropping practice. Reasons for continued use of some tillage are explored in the next section.

Use of cultivation

While NT has become the increasingly dominant seeding system across all regions, nationally 10% of growers still choose to cultivate at least some of their land at or prior to seeding (Table 2). As a result, approximately 15% of crop area is cultivated in a particular season (Table 1). Growers choosing to perform some level of cultivation cited weed management as a main reason for cultivation prior to or

Table 1. Adoption of no-till/zero-till by Australian grain growers and extent of use

	Percentage of growers	*Average percentage of crop sown with* ***no prior*** *cultivation*		*Average percentage of crop sown with* ***prior*** *cultivation*	
	Used no-till or zero-till in the past	Sown with no- till or zero-till	Sown with full- cut seeding pass	Sown with no- till or zero-till implement	Sown with full- cut seeding pass
Northern	93%	80%	2%	9%	8%
Qld Central	86%	80%	0%	7%	13%
NSW NE/Qld SE	93%	82%	4%	8%	6%
NSW NW/Qld SW	98%	79%	2%	12%	6%
Southern	89%	73%	6%	10%	9%
NSW Central	76%	52%	8%	17%	21%
NSW Vic Slopes	92%	74%	6%	17%	3%
SA Midnorth – Lower Yorke Eyre	92%	85%	4%	5%	6%
SA Vic Bordertown – Wimmera	94%	76%	0%	12%	8%
SA Vic Mallee	88%	72%	10%	8%	8%
VIC high rainfall and Tas grain	92%	77%	7%	4%	12%
Western	96%	91%	2%	4%	3%
WA Central	91%	88%	1%	2%	8%
WA Eastern	98%	93%	3%	4%	0%
WA Sandplain – Mallee	93%	91%	2%	3%	5%
WA Northern	100%	93%	0%	6%	0%
Total / National	92%	80%	4%	8%	7%

'Percentage of growers' is expressed as percentage of all growers per region/zone. 'Average percentage of cropping land' is the average nominated proportion of cropping land (stated by the grower) sown in 2014 using this practice. Due to rounding, area numbers may not sum to 100%.

at seeding. Cultivation in the fallow period to control weeds is most common in the northern regions with 66% of growers undertaking this practice on at least some land and, on average, just under a third of their cropping land.

The application of strategic tillage (Dang *et al*. 2015, Kirkegaard *et al*. 2014a, and see Chapter 7) and the recent increase in interest and uptake of soil amelioration practices such as deep disturbance of sandy soils (Scanlan *et al.* 2019, and see Chapter 8) has further demonstrated that Australian grain growers will continue to be willing to apply targeted tillage practices where it can help to sustain a profitable cropping system. Although flexible and adaptive, Australian grain growers are also continuing to demonstrate that NT seeding systems will remain central to modern farming systems. Timeliness advantages have always been an important driver of NT adoption decisions (D'Emden *et al.* 2006) and the labour and machinery-use efficiency required for timely seeding on increasingly large farms is becoming more important (Fletcher *et al.* 2019).

Table 2. Percentage of growers cultivating at or prior to seeding in 2014 and percentage who cite weed management as main reason for cultivation.

	Southern	**Western**	**Northern**
Proportion of growers cultivating at or prior to seeding (%)	15	4	8
Cropping land cultivated prior to or at seeding (*i.e*. not under no-till) (%)	27	9	20
Average area to be cropped that is cultivated during the fallow by users of tillage (%)	31	19	28
Growers using cultivation of fallows primarily for weed control (%)	37	30	66
Growers who cite weed management as main reason for cultivation prior to seeding expressed as proportion of all growers (%)	29	15	28

Use of burning

As with tillage, despite the major shift to CA principles, use of burning as an agronomic tool is on-going on targeted areas. While highly seasonal-dependent, over 10% of cropped land has been burnt in southern and western regions (Table 3). Similarly, the GRDC farm survey report found less than 10% of total crop area was burnt in 2016 (Umbers 2017). An increase in use of narrow windrow burning over the past decade for weed control purposes in some cases served to reduce whole-of-paddock burning but the extensive use of this practice is also likely to have led to an increase in the overall area on which some level of burning takes place, reaching 29% of crop area in the western region in 2014 (Table 3).

Nationally, burning stubble on some cropping land is common practice with over 40% of growers engaged in this practice (other than narrow windrow burning) (Table 3). The practice is most common in the southern region and less common in the northern region with 12% doing so on a small portion of their land (3%). Growers are burning crop residues for multiple reasons including: managing heavy stubble, aiding seeding and managing pest and diseases. However, for many farmers it is primarily performed for weed control, with approximately two thirds of all growers in the southern and western regions who burn stubble citing weed management as the main reason to do so (Table 3).

The evolution of narrow windrow burning has meant that burning has become more targeted and effective. Narrow windrow burning is a practice whereby chaff is placed in narrow windrows at harvest and is later burnt; the practice can remove approximately half of crop residue (Walsh and Newman 2007). Narrow windrow burning has had a rapid rise in use from a low base in early 2000 and is particularly common in the western region (Table 3, Figure 6). Although many farmers undertake narrow windrow burning in the Southern and Western regions it is estimated that this practice is undertaken on less than 5% of national cropped area (Umbers 2017).

Table 3. Percentage of growers burning stubble in 2014 and percentage who cite weed management as main reason for burning.

	Southern	**Western**	**Northern**
Growers burning stubble – whole paddock (%)	52	40	12
Cropping land burnt by users – not including windrow burning (%)	11	19	3
Growers who cite weed management as the main reason for burning (whole paddock) as a proportion of users (%)	68	66	29
Growers using narrow windrow burning (%)	28	51	4
Proportion of crop area treated with narrow windrow burning by users (%)	21	29	18

More recent innovation and shifts to harvest weed seed control practices that do not involve a burning activity (*e.g*. chaff lining, seed destruction) are not captured in this survey and thus may reduce the use of narrow windrow burning (Walsh *et al*. 2018). This reflects what appears to be an underlying, but pragmatically applied, objective of Australian growers (Kirkegaard *et al*. 2014a) to work towards no-till stubble retention systems and, not least important, practices involving less labour.

Recognising the challenges of no-till and stubble retention

As raised above, Australian growers have demonstrated a flexible approach to the core principles of CA of NT and crop residue retention, evidenced by the use of targeted burning and occasional soil disturbance. For example, area-based trends from 2008 to 2016 in retaining stubble at sowing indicate only a small increase in the proportion of cropped area sown with standing stubble (that has not been grazed, slashed or otherwise managed to remove or reduce it), with 49% of Australia's total cropped area retaining standing stubble in 2016 (Umbers 2017).

While growers express an ongoing willingness to return to the core principles of CA and while disadoption of NT is very rare (Llewellyn *et al.* 2014), there is recognition of the agronomic challenges of NT stubble retention systems. Many growers believe that under NT stubble retention systems compared with one involving cultivation and stubble burning, there will be more weeds, pest and disease, and inputs cost are likely to be higher (Figure 3). Almost half the growers believe the efficacy of pre-emergent herbicides is less under NT stubble retention compared with a cultivation-based system without stubble retention (Figure 3). Most growers believe that weed costs are higher under a stubble retained NT system compared with one based on cultivation, with only 17% believing costs will be lower (Figure 3).

However, despite the other agronomic challenges raised, over 50% of all growers believed that wheat yield would become more reliable, including over 70% in the more fallow-dependent northern region (Figure 3). That NT stubble retained systems now dominate the modern Australian cropping landscape shows that the benefits of increased crop reliability through improved water use efficiency opportunities, and other major benefits associated with labour efficiencies, potential for scale and erosion prevention, have clearly outweighed the ongoing agronomic complexities.

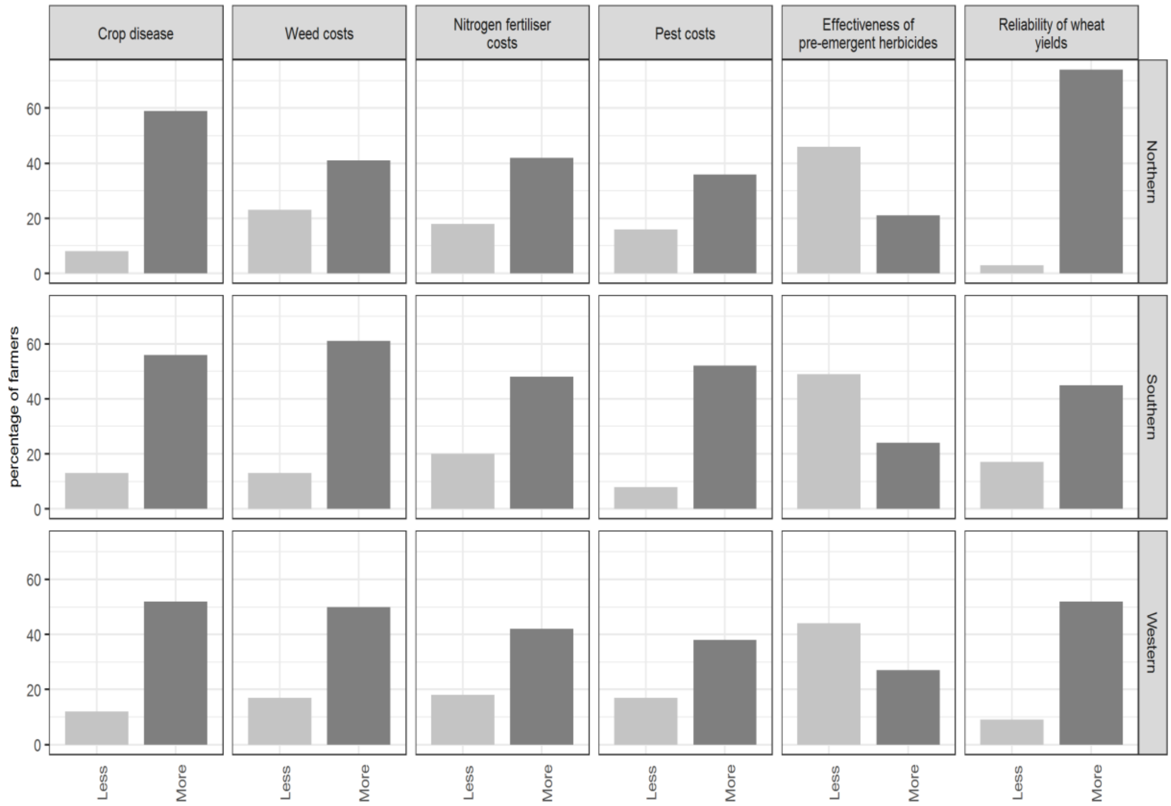

Figure 3. Grower perceptions of agronomic impacts of a no-tillage, stubble retention, continuous cropping systems compared to a cultivated system with stubble burnt on crop disease, weed, nitrogen fertiliser, weed costs, pre-emergence herbicide effectiveness and wheat yield reliability, based on 2014 responses.

Global studies have associated aridity with relatively stronger no-till performance (Pittelkow *et al*. 2015). Previous Australian studies have also shown that the likelihood of growers trying no-till for the first time rose significantly after drier than average years including droughts (D'Emden *et al.* 2007). This is attributed to: the benefits of soil water conservation; ability to seed on less rain; and erosion prevention. These aspects clearly outweighed the other agronomic challenges in those years. In the next section we explore how the farm information and advisory network has transformed to assist growers in addressing the agronomic challenges of conservation agriculture.

The changing extension environment behind the transformation to no-till

Public research agencies played a leading role in early experimentation with reduced tillage systems before farm-scale experimentation became widespread (*e.g*. Reeves 1974, Crabtree 2010, Roget *et al*. 1987, Bligh 1990). As identified by Freebairn *et al.* (1993), this early experimentation often highlighted the dilemma facing farmers: the challenge of how best to counter the negative aspects of the early conservation tillage techniques (*e.g.* variable yields) while fully exploiting the positive aspects (*e.g.* reduced erosion risk). Meeting this challenge and the subsequent transformation of Australian grain production to NT cropping systems occurred at a time of transformation of the information and support network. This included a decline in provision of farm-specific advice by state government-based extension services and the increasing influence of support for farmer-based group activity through the National Landcare Program (Marsh and Pannell 2014, Anil 2015). As part of this change there was a remarkable rise in the role of no-till farmer associations and other farmer-led groups as partners in the development, implementation and extension of NT systems. Around the same time, the growth of the agronomy consultancy industry began, also providing practical support to farmers in addressing the additional agronomic complexities of NT, stubble retention and more intensive cropping. These developments associated with the shift to NT systems led to ongoing impact on the Australian research, development and extension network and its capacity for innovation.

No-till farming associations

The rise of no-till cropping systems through the 1990s was closely associated with the remarkable rise of farming systems groups, including the no-till farming associations. Nationally, higher participation in extension including farmer groups was significantly associated with early adoption of NT (D'Emden *et al.* 2008). In Western Australia, the Western Australian No-till Farmers Association WANTFA) played an integral role in the early and rapid rise of no-till farming (Crabtree 2010, Young 2003). WANTFA formed in 1992 and recorded a remarkable 1400 members in 1999 (WANTFA pers comm). In South Australia, following the success in Western Australia, the SA No-Till Farmers Association formed in 1998 and had 1200 members by 2005 (SANTFA pers comm).

Regionally-focused farming systems groups play an ongoing and important role in the Australian grains industry research, development and extension network (Anil *et al*. 2015), together with technology-focused groups such as no-till associations and precision agriculture groups. However, it appears unlikely that the phenomenal rise of the farmer-led no-till associations will be seen again in terms of the scale of national farmer participation focused on achieving successful implementation of a particular technological change. One reason for this is the now established role of agronomy consultants on most farms.

Agronomy consultants

The use of private cropping consultants has been shown to be associated with double the likelihood of early NT adoption in Australia, although attribution of causality is difficult (D'Emden *et al*. 2006). This demand for advisory support by no-till adopters raised possible implications in regions where the ready availability of quality farm-specific advisory support was limited. An examination of the temporal relationship between increasing NT adoption and the use of paid farm advisors using data from four states (Llewellyn and Ouzman 2012) shows an interesting relationship (Figure 4).

The results show that NT adoption typically led use of paid agronomy support (Figure 5) in that the number of growers who had adopted NT was twice that of the number of growers with a private agronomy adviser. This was the case in all agro-ecological zones (data not shown), but to a greater extent in Western Australia where early NT adoption was generally ahead of the other states. In some cases this may reflect the possible availability of other information and advice sources such as retail agronomists and, initially, state government agronomists. It also demonstrates the potential 'gap' that no-till-focused farming systems groups such as no-till and conservation agriculture associations were able to fill.

As the extent of NT adoption and subsequent cropping intensity increased, and the agronomic challenges such as those raised in the earlier section mounted, the use of paid farm-specific agronomy advice typically rises. Although a highly significant association between use of an adviser and NT use was found (*e.g*. D'Emden *et al*. 2006), causality is difficult to ascribe from the available data. The results do suggest however that initial NT use on a farm most often occurred without the input of a farm adviser (with adviser use coming subsequently). Further, the rate of adoption of paid advisors followed

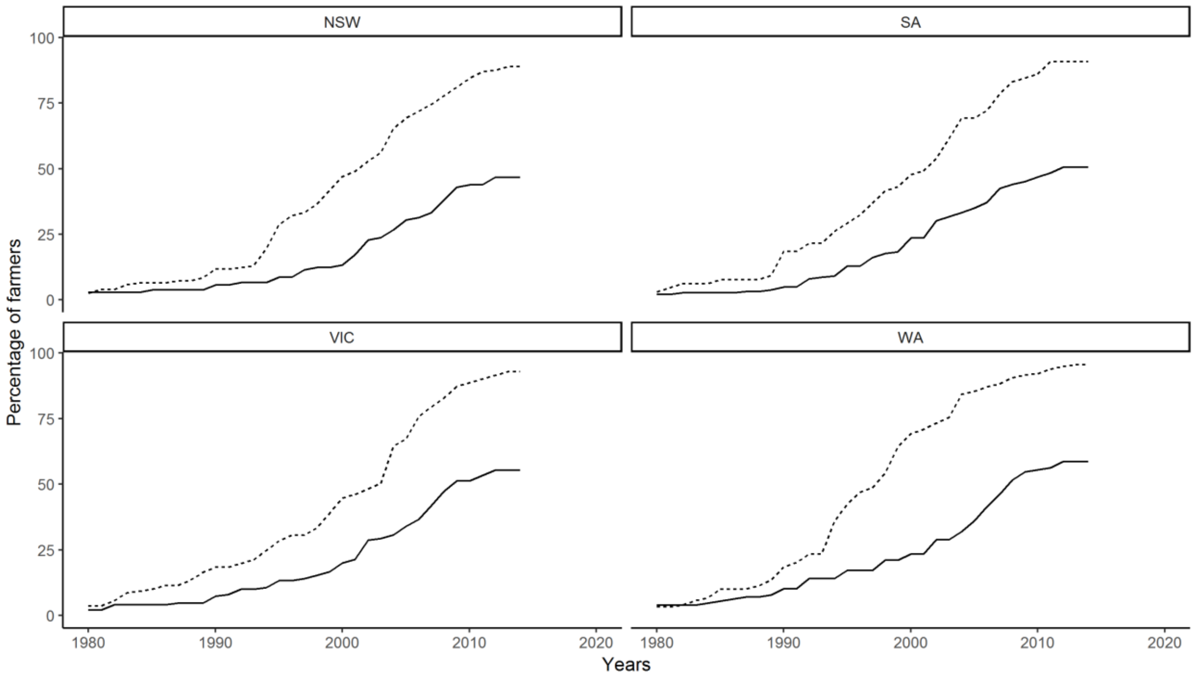

Figure 4. Percentage of farmers who have used no-till (dotted line) and use a paid agronomist (solid line) by state (no data available for Qld).

a slower rate of growth, indicating that motivation and subsequent initial farm-level decisions to adopt NT were generally not facilitated by a farm-specific advisor.

The adoption of paid agronomic advisers over the period 1990 to present has transformed how information is extended, shared and new practices introduced (Keogh and Julian 2014). By the beginning of the current decade, paid farm agronomists were the major source of farm-specific agronomic advice (Table 4).

Table 4. Major source of on-farm agronomic advice as cited by growers (showing percentage of growers citing that source in 2012)

Regions	Independent agronomist / consultant (paid)	Distributor representative agronomist (paid)	Distributor/ representative agronomist (free of charge)	State government-based agronomic adviser	Other source of advice
Southern	37	20	46	12	10
Western	51	23	36	9	16

A farm innovation and adoption legacy

Due to this rise in farm advisory services, the adoption of new practices now occurs under very different conditions from those when NT first began to be practised. In the case of current innovations, they are adopted in the presence of common on-farm agronomic advisory support. The example of the harvest weed seed control practice shown in Figure 5 highlights that, unlike the early NT adoption decision, current agronomic practice adoption decisions can now commonly be made in consultation with agronomic advisers who are in a position to learn from and share the farm experiences of a wide range of farmer clients (Kuehne and Llewellyn 2017).

The availability of cost-effective herbicide options was a major influence on the rate of adoption of NT cropping systems (D'Emden *et al.* 2006) but extensive herbicide resistance provided motivation for weed management innovation. Agronomy consultants played a key role in innovative on-farm use of herbicides (Llewellyn *et al*. 2007) and increasing attention was given to practices primarily aimed at

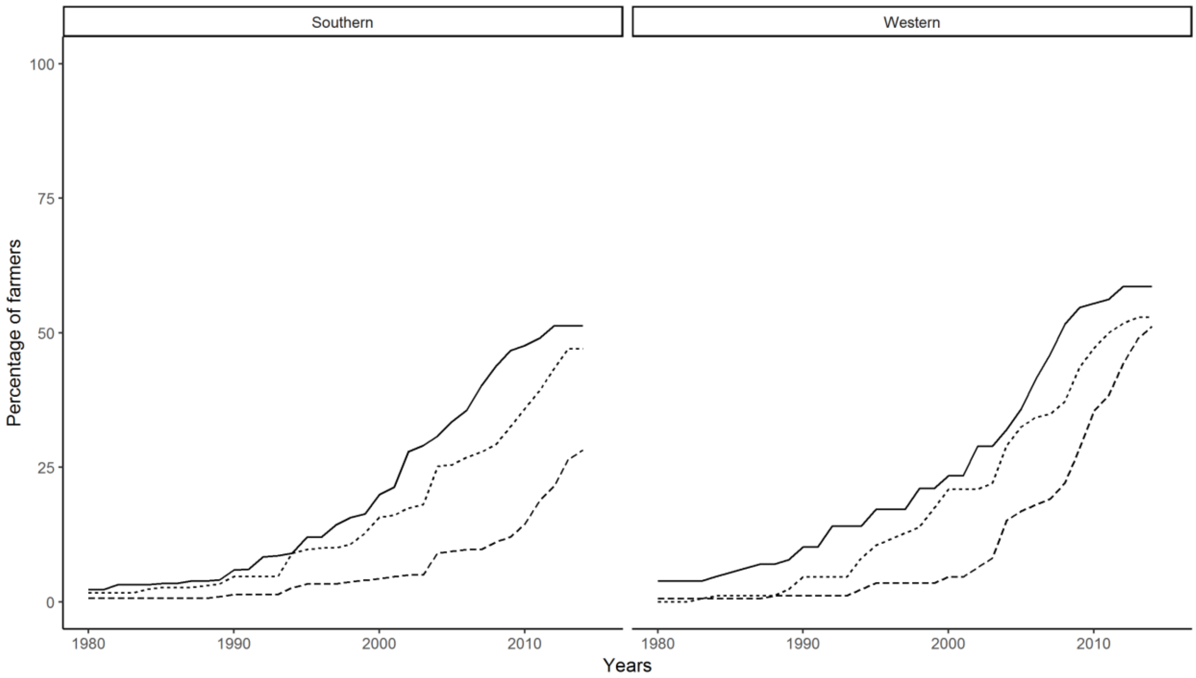

Figure 5. Percentage of farmers who have a paid cropping advisor (solid line) and harvest weed seed control practices (dotted line crop topping and dashed line narrow windrow burning)

managing weed seed set and seedbanks rather than just preventing yield loss in the year of application (Walsh *et al*. 2017).

As indicated by the cultivation and targeted burning trends described earlier, weed management demands continue to challenge some aspects of conservation agriculture practice, but at the same time are contributing to greater utilisation of more diverse crop rotations (Llewellyn *et al*. 2016) – a third key pillar to conservation agriculture. Further, Australian grain growers are recognised not only as major adopters of NT but also for their extensive and rapid adoption of harvest weed seed control practices. In many cases this has involved grower-initiated innovation in partnership with research, farming systems groups and agronomy advisers (Walsh *et al*. 2017).

Weed management provides a telling example of the farm-level innovation, adoption and extension capacity that has been developed through farmer-agronomist-researcher collaboration. The rapid rate of uptake of recent weed seed management practices shows what is now possible in the modern agricultural innovation and information network. This now also incorporates the widespread use of social media for more immediate and extensive information as well as experience sharing between farmers, their peers, advisers and researchers. Australian growers have maintained relatively low weed numbers despite severe and extensive herbicide resistance to major weeds (Llewellyn *et al*. 2009, 2016, see Chapter 10). Concurrently, they have also increased the use of early-sowing (Chapter 18) and conservation agriculture-based cropping systems in the face of drying climate trends: these are major achievements of the grains industry innovation and information system that has evolved.

Conclusion

The diffusion of conservation agriculture practices across diverse Australian cropping landscapes has been remarkable but extended. Although in some regions peak extent of use has only been reached recently, the lack of disadoption has further confirmed that NT systems are highly adoptable, adaptable, and now integral to modern cropping. Australian grain growers have achieved this through a typically flexible approach that continues to accommodate some occasional targeted soil disturbance and crop residue removal. The ongoing success of NT and its use as a platform for further major gains in agronomic and farm performance is also a result of the innovative and adaptive capacity that has developed in the grains industry over this period of change. The NT transformation involved the most powerful example of farming systems groups as agents of change, and new farmer/farmer group-researcher partnerships were forged. The emerging complexities of implementing the new cropping systems (and the declining provision of state government-based sources of on-farm advice) resulted in the emergence of the independent agronomy advisor as a key pillar in the farm research, development and extension network. These legacies of the era, together with the widespread use of new digital tools for peer-peer sharing and learning, have created an adaptive and innovative environment that has enabled the challenges of sustaining profitable, conservation agriculture-based, cropping systems to be met. Further, the combination of the NT-based cropping system and the associated farmer, research, development and extension network that formed to support it, is now the platform for ongoing innovation in Australian cropping systems.

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