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Adoption of conservation tillage in California: current status and future perspectives

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Abstract. While there have been several similarities between the development of cropping systems in Australia and California (including climate, the need for irrigation and very diverse, highly specialised crop rotations), the historical patterns of conservation tillage development in the two regions have been quite different. Current estimates indicate that conservation tillage (CT) practices are used on less than 2% of annual crop acreage in California's Central Valley. Tillage management systems have changed relatively little since irrigation and cropping intensification began throughout this region, more than 60 years ago. The University of California (UC) and United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) CT Workgroup is a diverse group of UC, NRCS, farmer, private sector, environmental group and other public agency people. It has provided wide-ranging services aimed at developing information on reduced tillage alternatives for California's production valleys. In a short span of 7 years, the CT Workgroup has grown to over 1000 members and has conducted over 60 demonstration evaluations of CT systems. While CT is still quite new in California, a growing number of farmers has become increasingly interested in it, for both economic and environmental reasons. They are now pursuing a wide range of activities and approaches aimed at developing sustainable CT systems. As successful CT systems continue to be demonstrated, the rate of adoption is expected to increase.

Introduction

Why conservation tillage?

The importance of minimising soil erosion and conserving soil resources first came to national attention during the 'Dust Bowl' period in the early 1930s, when the combination of intensive tillage, drought, crop failure and wind-driven erosion of millions of acres of farmland occurred in the Great Plains region of the US (Coughenour and Chamala 2000; Chauhan *et al*. 2006). In the decades following, several reduced soil disturbance or conservation tillage (CT) production systems emerged in the mid-west and the south-east US, to address soil loss concerns. Similarly, yet somewhat later, recognition of the importance of controlling soil erosion losses has also been a major driver for the development of CT systems in Australia (Coughenour and Chamala 2000). Because of the important role that surface cover or roughness has in mitigating soil erosion losses, the concept of CT during this time eventually became linked with the specific management goal of maintaining at least 30% crop residue on the soil surface after planting. This has been the primary characteristic used in USDA definitions of CT. Reduced soil disturbance, however, is a key element in these definitions.

Most CT systems are based on one of three reduced soil disturbance planting systems: no-till, ridge-till, or strip-till. In no-till, or zero-till, the only tillage that is used is the soil disturbance in a narrow slot created by coulters or seed openers (Conservation Tillage Systems and Management 2000) (Fig. 1*a*). The soil surface is thus generally left undisturbed, except at the time of planting. Ridge-till is a reduced disturbance planting system in which crops are planted and grown on ridges formed during the previous growing season and by shallow, in-season cultivation equipment. Ridge-till planters sweep away or shear off residues and soil in the seed line but do not disturb much of the inter-row soil surface (Fig. 1*b*). In strip-till, coulters cut residues ahead of subsoiling shanks that loosen the soil from a few to as many as 35.6 cm ahead of a planter (Fig. 1*c*). In each of these CT systems, only a small percentage of the soil surface is disturbed, unlike the 'broadcast' tillage, or land preparation operations that are typically used in conventional tillage systems.

In California, where use of the term 'conservation tillage' is much more recent, a broader paradigm has developed; it focuses more on reducing the overall number of tillage passes, rather

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than on strictly preserving surface residues. Thus, CT in California currently refers to a wide range of production practices that deliberately reduce primary, intercrop tillage operations such as ploughing, disking, ripping and chiseling. Under this definition, residues are managed in a variety of ways to permit efficient planting, harvesting and pest control. From this perspective, any production system that significantly reduces tillage operations and conserves resources (generally by more than 40% relative to what was done in the year 2000) is defined as 'conservation tillage' in California.

Benefits of CT

The success of CT in maintaining yields while reducing soil erosion has added to its popularity. Equipment innovations, herbicides, herbicide-tolerant crops (Llewellyn *et al*. 2002), widespread farmer and researcher experience have all contributed to the success of CT (D'Emden and Llewellyn 2006). In addition to reducing soil loss by erosion and runoff, CT systems have several other attributes that add to their appeal to producers. Because they aim to reduce primary, intercrop tillage operations such as ploughing, disking, ripping and chiseling, fewer tractor operations are used. The consequent reduced fuel use often improves farm profitability. In addition, NO_x and dust generation are reduced (Baker *et al*. 2005) and CO_2 losses may be decreased (Reicosky 1997). CT systems may also conserve soil water, by reducing evaporative and surface runoff losses, thereby enabling the intensification and diversification of cropping systems (Beck 1990; Freebairn *et al*. 1993). Possible benefits of CT are that it: (i) saves fuel, soil, time, labour and machinery; (ii) increases soil moisture, soil organic matter and soil biological diversity; (iii) sequesters carbon; (iv) reduces dust emissions and surface water (sediment, nutrient and pesticide) runoff; (v) improves soil and water quality; (vi) increases water use efficiency; and (vii) improves wildlife habitat.

Governmental incentives for adopting CT

The 2002 US Farm Bill provides incentives for farmers to voluntarily address environmental resource concerns using production practices such as CT. Such practices are approved through Local Work Group initiatives in county USDA Natural Resource Conservation Service (NRCS) offices. The NRCS

Fig. 1. (*a*) No-till cotton planting, Five Points, CA, 2005; (*b*) ridge-tillage planting into herbicide-killed barley, Five Points, CA, 2002; (*c*) strip-tillage corn planting following wheat forage harvest, Tipton, CA, 2005; and (*d*) CT2004 Conference farm field day at the farm of Andy Rollin, Burrel, CA (9 September 2004).

Environmental Quality Incentives Program (EQIP), for example, provides technical assistance and cost-share incentive payments to assist producers with environmental conservation improvements, such as the use of CT on their farms. In 2003, for the first time in California, CT was approved as a statewide 'cost-share' EQIP practice. In the past 2 years, several EQIP CT contracts have been implemented in the San Joaquin Valley. These were aimed primarily at air quality improvement.

Adoption of CT in California

Since 1997, more cropland acres have been farmed nationwide using CT practices than standard tillage practices (CTIC 2004). However, despite the apparent attractiveness of reduced tillage or CT systems, the NRCS estimates that less than 1% of row crop production acreage in California's Central Valley is currently farmed using CT practices (CTIC 2004). The low rate of CT adoption in California is generally thought to be the result of: (i) a lack of CT equipment being available locally; (ii) inexperience with CT techniques; (iii) the predominance of surface, or gravity irrigation systems in California; and (iv) the fact that tillage-intensive systems have been developed here for several decades and are generally quite productive.

The CT Workgroup

To respond to needs for information on reduced tillage production alternatives in California, the UC Division of Agriculture and Natural Resources and the USDA NRCS Conservation Tillage Workgroup was established in 1998. The goals of the CT Workgroup are to develop knowledge, exchange information and coordinate research and extension education programs related to CT production alternatives in California. From a handful of academics, the CT Workgroup has grown to over 600 UC, USDA ARS and NRCS, farmer, public agency, private industry and non-governmental group members. It has been active at more than 60 research and demonstration sites throughout California. The growing body of experience that CT Workgroup members have acquired during this time includes CT production systems evaluations for cotton (*Gossypium hirsutum* L.), wheat (*Triticum aestivum* L.), tomatoes (*Lycopersicon esculentum* L.), melons (*Cucumis melo*), corn (*Zea mays* L.), beans (*Phaseolus vulgaris* L.), lettuce (*Lactuca sativa* L.), and cover crops. The CT Workgroup currently has a Technical Service Provider agreement with the NRCS to provide support and education related to CT systems and has partnered with more than 30 farmers in a variety of CT evaluations throughout the Central Valley.

Farmer CT survey

In the spring of 2002, we conducted a survey of row crop producers in 11 Central Valley counties, from Kern in the south to Yolo in the north, to assess farmers' familiarity with and general perceptions of CT in California. Written questionnaires, requesting general farm information (such as crop types, farm size, predominant soil type and primary irrigation system used) and perceptions of CT, were sent to 290 farmers using mailing lists obtained from Central Valley row crop Cooperative Extension Advisors. Sixty three producers representing over 144 000 acres responded. When asked about their general familiarity with CT, 45% said they were aware of the general concepts of CT, 35% thought they were quite familiar with CT, 16% said they had limited familiarity, and 3% were completely unfamiliar with it (Fig. 2). An average of 50% of the respondents said that they had previously practiced CT. When asked about the specific form of CT they employed, two-thirds of those who had prior experience identified minimum till as the type of CT that they used.

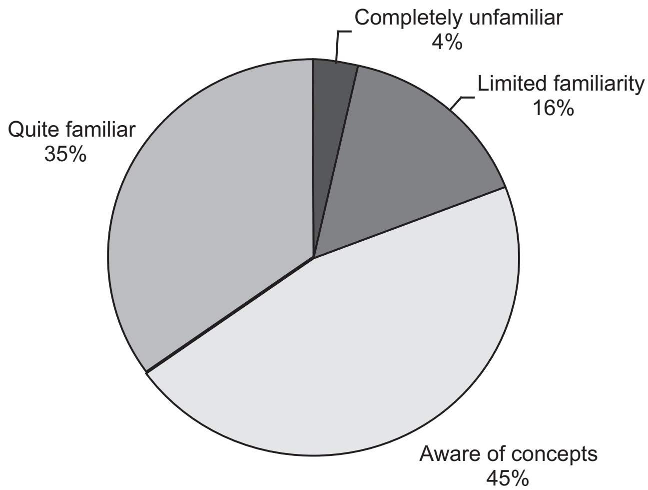

Fig. 2. Responses of Central Valley farmers polled in a 2002 mail survey, when asked about their familiarity with conservation tillage. Data represent information from 57 respondents.

While not explicitly defined on the survey itself, minimum till systems typically rely on reduced-pass, 'all-in-one' type tillage implements that either preserve planting beds, or otherwise perform intercrop land preparation with fewer operations than are used in standard till regimes. The CT

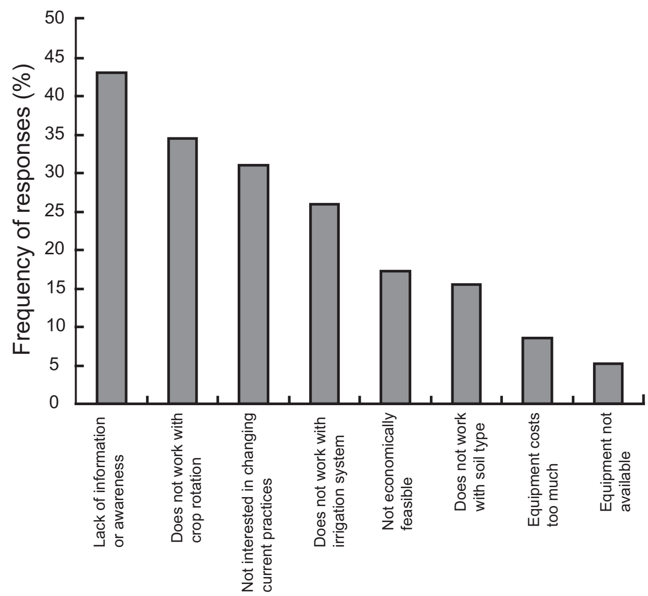

Fig. 3. Responses of Central Valley farmers polled in a 2002 mail survey, when asked to indicate obstacles to broaden adoption of conservation tillage. Data represent information from 105 respondents.

Workgroup defines 'minimum till' as a tillage system that reduces tillage passes by at least 40% relative to what was generally done in the year 2000 (J. P. Mitchell, A. Shrestha, R. Fry, R. Roy, P. Hogan, R. Vargas, K. Hembree, J. Jackson, unpubl. data). These approaches may not, however, fully meet the traditional criteria for CT because they may not preserve surface residues.

Major obstacles to broader adoption of CT by the respondents included lack of information, concerns that it doesn't work with certain crop rotations, and lack of interest in changing current practices (Fig. 3). Finally, 55% of respondents saw benefits for their crops and 68% had a favourable impression of the potential of CT (Fig. 4*a*), indicating that it is (28%) or could be (40%) a useful practice (Fig. 4*b*). This survey confirmed some of the perceived reasons for the low rate of adoption of CT in California and it also provided valuable input on the current priorities of the CT Workgroup's research and extension education initiatives and helped focus the CT Workgroup goals.

CT Workgroup research and education activities

Workgroup-sponsored CT conferences have been held annually in Five Points and Davis, CA, since 1998, with sessions focusing on relationships between soil organic matter, tillage and soil quality. The 2000 conference highlighted CT success stories from around the US. Our 2001 conferences focussed on CT equipment demonstrations; our 2002 events dealt with researcher and farmer innovation; the 2003 sessions dealt with the current state of CT in the Valley; the CT2004 conference again highlighted CT equipment (Fig. 1*d*); and the CT2005 conference was organised as tours to innovative CT tomato, cotton and dairy forage farms. Participant feedback reveals increasing interest in CT alternatives and indicates an expectation that CT will become more widely used throughout California once successful examples are demonstrated (Table 1). Recent informal polling of the CT Workgroup's farmer members suggests that, unlike other regions where CT systems have been adopted, primary motivations for these alternatives in California include cutting production costs,

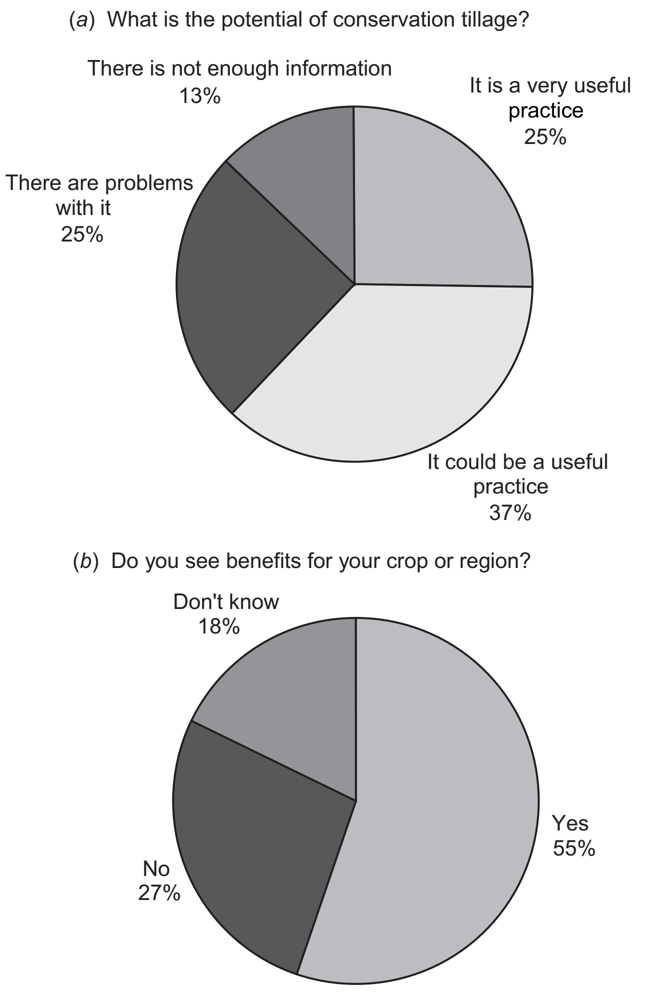

Fig. 4. Responses of Central Valley farmers polled in 2002 mail survey when asked (*a*) about the potential of conservation tillage (63 respondents) and (*b*) whether they see benefits of conservation tillage with their crops or in their region (56 respondents).

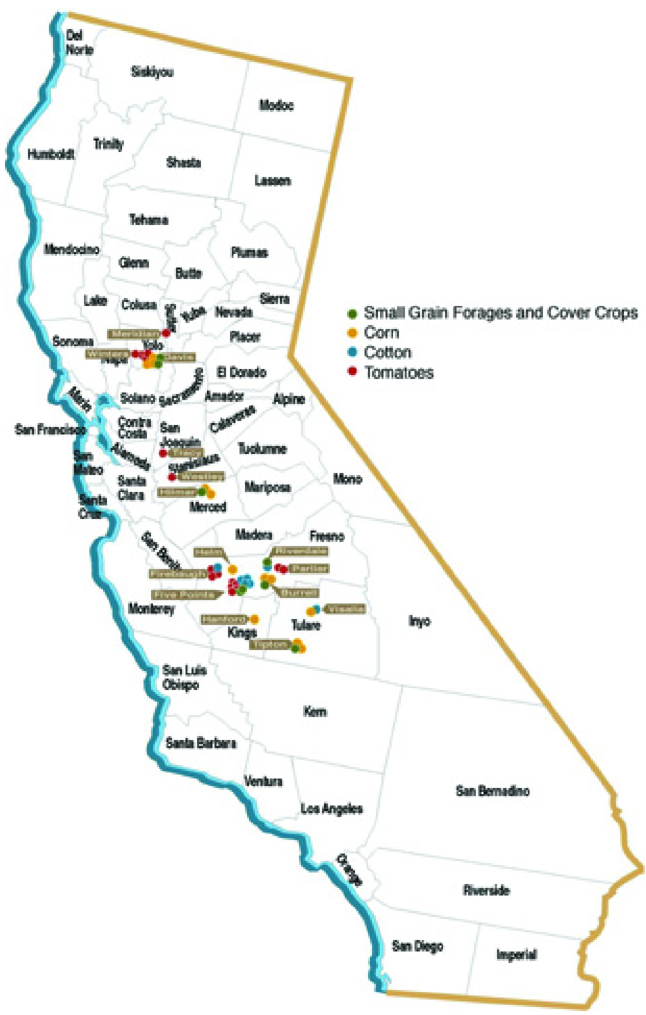

Fig. 5. Locations of Conservation Tillage Workgroup's corn, cotton, tomato and small grain forage research and demonstration evaluation sites (2000–2005).

Table 1. Participant responses to post-conference question 'What do you think about the future adoption of the various conservation tillage practices in California presented at this conference?' for 1998, 2000 and 2003 conservation tillage conferences

Values in parentheses are the percentages of respondents

	1998	2000	2003
No. of responses	54	79	48
CT practices will not be widely adopted in California	–	3 (4)	1 (2)
Adoption of CT will likely be on a very limited scale	11 (20)	11 (14)	3 (6)
CT may become more widely adopted if successful examples are demonstrated	36 (67)	45 (57)	21 (44)
It is inevitable that CT will have a far wider role in California	7 (13)	20 (25)	23 (48)

reducing dust and generally conserving society's 'common assets' – our soil, water and air resources. Examples of the types of CT studies currently being conducted by the CT Workgroup are briefly described below.

A variety of evaluation activities have been initiated to develop information on reduced tillage production options. These studies have focussed on different aspects of CT systems including: (1) opportunities and issues related to integrating cover crops in CT production systems; (2) developing and refining the ability to produce single crops using reduced till approaches; and finally (3) integrating CT principles throughout various sequences or rotations of crops. Much of this early research was done in standard research and extension centre small plot work (Herrero *et al*. 2002*a*, 2002*b*). This preliminary work was essential for subsequent larger-scale trials that have been done in conjunction with farmers. Fig. 5 indicates the crops and locations where CT practices have been evaluated.

Following these initial small-scale studies, and as the CT Workgroup acquired more reduced till equipment, several larger-scale demonstrations of CT systems were initiated with partner farmers. Farmers actually initiated several of these trials, asking for implementation support and offering land, facilities and labour to CT Workgroup partners. Several of these farmer demonstrations have been developed into case studies documented in the CT Workgroup 2003 conference proceedings and on the CT Workgroup website (http://groups.ucanr.org/ucct/, verified 4 October 2007). Others have been prepared as peer-reviewed publications (Mitchell *et al*. 2006).

The CT Workgroup, in conjunction with the California NRCS State Agronomist, also initiated a survey to track trends in reduced tillage practices throughout the Central Valley. Local CT Workgroup members conducted this survey for the first time in 2004. Data on CT acreage for major Central Valley crops were collected from local NRCS staff, UC Advisors and private sector CT Workgroup members, and will be provided every 2 years to the Conservation Technology Information Center in Lafayette, IN for compilation in their national database on CT. In this survey, a new CT category, '≥40% reduction in overall tillage relative to standard tillage practices for a given crop in the year 2000,' was used in addition to the more conventional CT classifications of no-till, strip-till/ridge-till and mulch-till. The rationale for including this category was to track 'reduced pass' practices that may achieve conservation and economic goals, but that do not necessarily conform to the '30% or more residue' requirement of the classic USDA CT definition. Results of this 2004 survey are presented in Table 2. In general, both the classic CT and the minimum till (≥40% reduction in tillage passes) systems currently represent ~2% of the total acreage for the crops and counties surveyed, with more acreage under minimum tillage than under CT.

The CT Workgroup has also instituted an annual CT Farmer Innovator Award Program to acknowledge and honour

Table 2. California Conservation Tillage Acreage Survey (2004) for tomatoes, cotton, edible dry beans, silage corn, grain corn, and small grains for grain, hay and silage

Crop	Conservation tillage (>30% residue cover after planting)				Minimum tillage (>40% reduction in total passes)	Conventional tillage (<30% residue cover after planting)	Total area (acres)
	No tillage	RT/ST[A]	Mulch tillage[B]	Subtotal			
Fresno County	2250	260	150	2660	20 830	534 411	537 071
Kern County	0	0	0	0	23 200	295 616	295 616
Kings County	0	0	0	0	2708	370 281	370 281
Madera County	0	0	0	0	800	122 163	122 163
Merced County	485	0	0	485	3735	320 071	320 556
Sacramento	650	0	0	650	2610	75 557	76 207
San Joaquin	505	0	0	505	2450	271 589	272 094
Tulare County	1375	430	0	1805	8280	381 546	383 351
Yolo County	0	0	51000	51000	0	138 683	189 683
Total	5265	690	52150	57105	54 913	2 590 235	2 647 340

[A]Ridge-till/Strip-till.

[B]Mulch-tillage is defined by the CRIC as 'full-width' tillage usually requiring only one to three tillage passes. After planting, at least one-third of the surface remains covered with residue.

pioneering leaders in the development of CT systems in California. CT Workgroup members have visited farmers and researchers in Alabama, South Dakota, Iowa, South Carolina, Texas, Oregon and Arizona in an effort to learn about successful CT systems.

The UC Division of Agriculture and Natural Resources' CT Workgroup has thus become a highly visible and effective extension education program during the relatively short time since its formation in 1998. Its membership, research and extension education programs and its contacts with producers and land managers have all increased dramatically during the 5 years of its existence. Its current members and affiliates have been involved in over 60 different research and demonstration studies and more than 1200 participants have attended its annual conferences during this time.

Future of CT in California

The development of successful CT systems in California, as in other regions, requires a 'systems' orientation and will not result from the introduction of a single technology or practice (Coughenour and Chamala 2000). New paradigms for rotations, planting, fertility, irrigation and pest management systems are needed and are now being developed and shared through connections between farmers, the private sector, non-government organisations and 'information flow' people from the University of California and the USDA NRCS. Several 'local networks' of CT cropping innovation (Coughenour and Chamala 2000) have been established and are currently being facilitated by the CT Workgroup. Many questions remain to be answered, however, with respect to the extent to which CT will be pursued in California: (i) How might CT practices be developed for California's very diverse cropping systems? (ii) Can CT contribute to water conservation in California? (iii) Will CT improve soil, water and air resource quality? (iv) What will be the long-term impacts of CT on labour and farm economies? and (v) Can adoption of CT systems in California be increased to 20% within the coming 10 years? To date, the CT Workgroup has been pivotal in initiating research aimed at answering these questions. Its success has resulted from several factors, including its timeliness in responding to the need for information on reduced tillage options within California's current production systems and economic environment, the encouragement of the University DANR and the USDA NRCS, and perhaps most importantly the recognition that public-private partnerships result in diversified teams that are an effective means for innovative program development and a dynamic organisational structure for the integration of research and education leading towards improved cropping systems.

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