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UC PEER REVIEWED

PUBLICATION 8364 / FEBRUARY 2009

Classification of Conservation Tillage Practices in California Irrigated Row Crop Systems

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Tillage has been an integral component of crop production systems since the beginning of agriculture. The process of tilling or preparing the soil was greatly refined with the invention of the first plow by the Chinese in the sixth century b.c., and since then, various types of tillage equipment and systems have been developed for seedbed preparation and cultivation. In California, many of the modern tillage practices that became common with the expansion of irrigated agriculture in the 1930s changed little during the second half of the twentieth century. However, during the past 10 or so years, a number of new tillage implements and management approaches have been introduced in California, and this has created a need for more concise tillage terminology to replace the often confusing jargon.

Some of the tillage systems that were recently introduced in California resemble well-known forms of conservation tillage (CT) such as no-tillage and strip-tillage, which were developed in other regions of the United States primarily to combat soil erosion. However, many of the new systems in California are quite different from these better-known forms. Compared with conventional plowing systems, these new approaches reduce the number of tillage operations or passes, the amount of diesel fuel that is used (Upadhyaya et al. 2001), the amount of dust that is generated (Baker et al. 2005; Madden et al. 2008), and the volume of soil that is disturbed (Mitchell et al. 2004; Reicosky and Allmaras 2003; Reicosky 2002). For this reason, the term “conservation tillage” is justified in characterizing them. However, compared with the familiar no-tillage systems, conservation tillage systems that reduce or combine passes do so generally with relatively high amounts of soil disturbance, and therefore do not protect the soil resource as well as do the no-tillage or strip-tillage approaches (Reicosky and Allmaras 2003). It is essential, therefore, to define the tillage system alternatives that constitute conservation tillage in California at this time and describe the extent of their use. This publication reports the terminology and classification of conservation tillage systems that have been adopted by the University of California Agriculture and Natural Resources (UC ANR) and USDA Natural Resources Conservation Service (NRCS) Conservation Tillage Workgroup (WG), a diverse group of over one thousand researchers, extension educators, conservationists, farmers, and private-sector partners (Mitchell et al. 2007; see also the CT Workgroup Web site, http://groups.ucanr.org/ucct/). This publication also describes a 9-county Central Valley baseline survey of acreage under various CT systems for 2004.

TRADITIONAL TILLAGE

Traditional, or conventional, tillage refers to the sequence of operations "most commonly or historically used in a given field to prepare a seedbed and produce a given crop (MWPS 2000; ASAE 2005). Conventional tillage, which varies widely among regions, has been defined by the Conservation Technology Information Center (CTIC 2002) as incorporating most crop residue and leaving less than 30 percent of the surface covered by residue after planting. Created by the National Association of Resource Conservation Districts as a nonprofit organization in West Lafayette, Indiana, to promote the adoption of conservation practices (Owens 2001), The CTIC has been an important national source of information on tillage systems, and its biennial tillage surveys have tracked tillage practices for a number of years.

Reicosky and Derpsch (2003), in an effort to dispense with "tillage system jargon," point out that rather than continue using "vague and nondescript" terms such as "conventional tillage" and "conservation tillage," greater accuracy can be achieved by providing explicit lists and descriptions of tillage equipment and operations. Examples of today's conventional tillage systems for cotton and corn in California are shown in table 1.

Table 1. Typical land preparation, tillage, and soil disturbance operations for cotton and field corn in the Central Valley in 2000

Cotton	Field corn
stubble disk (2×)	stubble disk (2×)
rip or deep chisel	subsoil
disk (2×)	disk (2×)
landplane (2×)	landplane (3×)
fertilize if needed or appl	list beds
disk (2×)	rolling cultivator or mulch beds (2×)
list beds	ring roll beds
harrow to flatten cotton beds	plant
rolling cultivator (2×)	cultivate (2×)
plant cotton	cultivate (3×)
Total number of operations: 15	Total number operations: 18

In conventional California row crop tillage systems, moldboard plowing has generally been replaced by disking and chiseling. Additionally, where surface gravity irrigation is practiced, a major function of tillage has been to prepare the land for irrigation. This is done by a series of leveling, smoothing, and furrowing operations.

REDUCED TILLAGE

Since the early 1960s, the term "reduced tillage" has generally referred to any tillage system that is less intensive and that employs fewer trips across a field than traditional tillage. Reduced tillage is a category used in CTIC surveys for systems that maintain at least 15 percent but less than 30 percent coverage by surface residue after planting; this is, however, a relatively vague term with little practical value or descriptive clarity for California irrigated annual crop systems.

CONSERVATION TILLAGE (CT)

Conservation tillage was defined in 1984 by the U.S. Soil Conservation Service (currently the USDA Natural Resources Conservation Service) as "any tillage system that maintains at least 30% of the soil surface covered by residue after planting primarily where the objective is to reduce water erosion" (MWPS 2000; Owens 2001). When wind erosion is a concern, the term refers to tillage systems that maintain at least 1,000 pounds per acre (1,120 kg/ha) of flat "small-grain residue-equivalents" (MWPS 2000; Owens 2001; ASAE 2005) on the soil surface during critical erosion periods. The term "conservation tillage" broadly encompasses tillage practices that "reduce the volume of soil disturbed" (Reicosky 2002); preserve rather than incorporate surface residues; and "result in the broad protection of soil resources while crops are grown" (Allmaras and Dowdy 1985). Conservation tillage has thus been described as a "collective umbrella term" that denotes practices that have a conservation goal of some nature (Reicosky 2002). Many different planters, implements, and general approaches have been used to achieve this goal. Because of the importance of surface residues to this early definition of CT, the USDA NRCS now uses the term "crop residue management" (CRM) rather than "conservation tillage" in their inventories of conservation practices.

In conjunction with state NRCS offices throughout the country, the CTIC has in the past conducted biennial national surveys of cropland areas farmed using different tillage systems. For these surveys, CTIC considers the four categories no-tillage, strip-tillage, ridge-tillage, and mulch-tillage as types of conservation tillage.

NO-TILLAGE OR DIRECT SEEDING

In no-tillage or direct seeding systems, the soil is left undisturbed from harvest to planting except perhaps for injection of fertilizers. Soil disturbance occurs only at planting by coulters or seed disk openers on seeders or drills (fig. 1).

Figure 1. John Deere 1590 no-tillage drill seeding sorghum-sudan hybrid into corn stubble, Barcellos Farms, Tipton, California, July 24, 2005. *Photo:* J. P. Mitchell.

Weed control is generally accomplished with herbicides. "Direct seeding" is a synonym for "no-tillage" that is commonly used in small grain production systems of the northwest United States, Canada, and Brazil.

STRIP-TILLAGE

With strip-tillage, the seed row is tilled prior to planting to allow residue removal, soil drying and warming, and in some cases subsoiling (fig. 2).

Figure 2. Orthman 1-tRIPr strip-tiller in wheat stubble prior to forage corn planting, Giacomazzi Dairy, Hanford, California, May 16, 2006. *Photo:* J. P. Mitchell.

The CTIC and the NRCS define no-tillage and strip-tillage as systems in which less than one-third of the soil surface is disturbed (CTIC 2002) (fig. 3). Strip-tillage is now quite common in Georgia, Alabama, and western Nebraska.

Figure 3. Orthman 1-tRIPr strip tilling alfalfa prior to corn planting, Helm, California, July 9, 2005. *Photo:* J. P. Mitchell.

RIDGE-TILLAGE

In ridge-tillage, the soil is also generally undisturbed from harvest to planting except for fertilizer injection. Crops are seeded and grown on ridges or shallow beds that have been formed or built during the prior growing season, generally during cultivation using implements fitted with sweeps, hilling disks, and furrowing wings (MWSFS 2000) (fig. 4).

Ridge-tillage planters employ sweeps ahead of the seed or planter shoe that effectively shear off soil and residues from the surface of the ridge, creating a clean seed row (fig. 5). Weed control is accomplished by herbicides, cultivation, or both.

Figure 4. Buffalo ridge-tillage seeder planting cotton into barley cover crop residue, Borba Farms, Riverdale, California, May 14, 2003. *Photo:* J. P. Mitchell.

MULCH-TILLAGE

Mulch-tillage, the fourth major CT category used in CTIC and NRCS tillage system acreage surveys, includes any CT system other than no-tillage, strip-tillage, or ridge-tillage that preserves 30 percent or more surface residues (MWFS 2000). Mulch-tillage uses conventional broadcast tillage implements such as disks, chisel plows, rod weeders, or cultivators, but with limited passes across a field so as to maintain plant residue on the soil surface year-round (ASAE 2005). This was probably the earliest approach to CT, and it dates back to 1930 when the first chisel plow was used.

STALE SEEDBED

Another variation of CT that is informally used but is not included in NRCS or CTIC national tillage system acreage surveys is stale seedbed. Stale seedbed production systems rely on "full-width" tillage following harvest, generally with implements similar to those used in mulch-tillage. Beds are allowed to settle and are left undisturbed until planting in the following season. Weed control is accomplished with contact herbicides. Whereas mulch-tillage preserves at least 30 percent surface residue, the stale seedbed system does not meet this standard. In fact, conventional land preparation may be done following harvest in stale seedbed production, but once that is done, no additional work generally occurs before planting. Stale seedbed production is common in Texas and south-central U.S. cotton systems. Use of the term "stale seedbed" in California has referred primarily to cotton and tomato beds that are prepared in the fall using

Figure 5. Close-up of Buffalo ridge-tillage planter showing residue-clearing hiller disk (right), sweep (center), and seed shoe and closing wheel (left). *Photo:* J. P. Mitchell.

conventional tillage and then only lightly tilled in the spring using rolling cultivator-type implements.

MINIMUM TILLAGE

The term "minimum tillage" has been adopted by the CT Workgroup as a subcategory of CT (Reicosky 2002). It refers to systems that reduce tillage passes and thereby conserve fuel for a given crop by at least 40 percent relative to what was conventionally done in the year 2000. This term defines a standard that is based on achieving the 40 percent or more reduction in the number of tillage or soil-disturbing passes (fig. 4). The use of equipment that combines tillage tools onto a single frame, such as the Optimizer (New World Tillage, Modesto, CA), the Eliminator (Wilcox Agriproducts, Walnut Grove, CA) (fig. 6), would meet the definition of minimum tillage practices. University of California researchers report a mean fuel savings of 50 percent and a mean time savings of 72 percent with one-pass tillage equipment (Incorpramaster) compared with the standard tillage program of disking and landplaning (Upadhyaya et al. 2001). As of 2004, minimum tillage is a reported category for California on the national tillage system acreage survey that is conducted by members of the CT Workgroup in conjunction with the NRCS and the CTIC every 2 years.

Figure 6. Wilcox Performer tilling wheat stubble, Kerman, California, May 6, 2007. *Photo:* J. P. Mitchell.

CALIFORNIA 2004 TILLAGE ACREAGE SURVEY

In 2004, the CT Workgroup conducted a survey of its own members to track trends in nine Central Valley counties. Questionnaires that requested estimates of the numbers of acres in a given county that were farmed using specific CT practices in 2004 were sent via the U.S. Mail to 30 CT Workgroup UCCE, NRCS, and private-sector members who had experience with current crop and tillage management practices in the counties that they represented. These sources provided local knowledge and expertise (CTIC 2004). This data collection procedure was deemed to be more efficient and accurate at this time than conducting county roadside transects and in actually visually estimating the greater than or equal to 40 percent reduction in tillage passes, or minimum tillage, category. In-person individual interviews with each of these participants were then conducted by the CT Workgroup chair and the NRCS state agronomist. The data from these interviews were compiled and compared with information on the total number of acres on which eight major Central Valley crops were produced in each of the counties surveyed. Survey responses were collected in most counties from more than one source. Data included actual CT acreage under NRCS EQIP contracts as well as additional acreage that was estimated to be under CT management in 2004. In cases in which conflicting data were received, follow-up discussions with respondents were conducted to verify and reconcile discrepancies in estimates. Data from this survey were provided to the CTIC for compilation in their national database on CT. In the 2004 survey, the new CT minimum tillage category, "≥ 40 percent reduction in overall tillage relative to standard tillage practices for a given crop in the year 2000," was used in addition to the other CT classifications of no-tillage, strip-tillage, ridge-tillage, and mulch-tillage. Results of this 2004 survey are presented in table 2.

In general, both the classic CT systems and the minimum tillage (≥ 40% reduction in tillage passes)

Table 2. California conservation tillage survey 2004 (acres)

County by crop	Conservation tillage (> 30% residue cover after planting)			Minimum tillage (≥ 40% reduction in total passes)	Total acreage
	No-tillage	Ridge-tillage and strip-tillage	Mulch-tillage*		
Fresno County					
tomatoes	—	2,000	—	3,100	104,300
cotton	—	200	—	17,000	218,333
corn silage	—	60	150	370	23,684
small grains for grain	250	—	—	360	44,850
Kern County					
cotton	—	—	—	13,500	138,596
Kings County					
cotton	—	—	—	536	159,530
corn silage	—	—	—	1,368	38,379
small grains, hay or ensiled	—	—	—	804	93,134
Madera County					
cotton	—	—	—	800	21,534
Merced County					
corn silage	485	—	—	1,735	61,545
Sacramento					
corn silage	490	—	—	2,450	5,038
small grains for grain	160	—	—	160	9,646
San Joaquin					
corn silage	505	—	—	2,450	31,950
Tulare County					
corn silage	1,375	430	—	2,180	116,752
Yolo County					
tomatoes	—	—	10,000	—	39,200
dry edible beans	—	—	1,000	—	2,037
corn for grain	—	—	5,000	—	19,628
small grains for grain	—	—	20,000	—	39,822
small grains, hay or ensiled	—	—	15,000	—	83,691
Total	5,265	690	51,150	54,913	2,647,340

Note: *Mulch-tillage is defined by the CTIC as "full-width" tillage usually requiring only one to three tillage passes. After planting, at least 33½% of the surface remains covered with residue.

systems currently represent about 2 percent of the total acreage for the crops in the counties surveyed. The higher estimates of mulch-tillage that appear in Yolo County relative to other counties indicate historical differences in the use of management practices that maintain at least 30 percent of the soil covered by residues after planting.

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Publication 8364
ISBN-13: 978-1-60107-631-1

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UC PEER **REVIEWED** This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by the ANR Associate Editor for Vegetable Crops.

pr-2/09-SB/AZ