Why Conservation Tillage?

Since the 1930’s, tillage management in California’s annual cropping systems has changed relatively little. Following the harvest of one crop, soil is typically worked or prepared through a series of tillage operations before the planting of a subsequent crop. The success of these intensive tillage systems has contributed to California’s high agricultural capacity during this time. Recently, however, a number of factors are converging that result in interest in production practices that minimize tillage operations. Rising fuel prices, farm labor shortages, and regulations targeting air and water quality and greenhouse gas emissions are among the major factors that have spawned interest in what are generally called “conservation tillage” systems.

Conservation tillage (CT) has become an important management tool in sustainable crop production systems throughout the world. The term “conservation tillage” has been defined in a very wide variety of ways during the past seventy years of its use. Throughout much of the US, it designates crop production systems that maintain a minimum of 30% soil cover after planting, or a minimum of 1,120 kg ha$^{-1}$ of flat, small grain residue equivalents on the soil surface throughout the critical wind erosion period (CTIC, 2002; Lyon et al., 2004). A number of rather well documented and publicized benefits derive from CT production systems including reduced soil loss due to water and/or wind erosion, increased water infiltration and soil water storage, reduced labor, fuel and equipment use, improved soil tilth, increased soil organic matter, and improved water and air quality (McLaughlin and Mineau, 1995).

The collective advantages of CT correspond to widespread adoption. Recent global estimates of 72-million ha were under no-till during 2001 – 2002 (Derpsch and Benites, 2003). This estimate includes about 50% of the cropland in Brazil and Argentina, 45% in Australia, and 20% in the US. Tillage system surveys in the US since 1900 indicate a general downward trend for conventional tillage and a steadily increasing trend for no-tillage (CTIC, 1990 - 2004).

Current estimates of CT adoption in California are far lower at about 2% in 2004, - up from 0.5% in 2002 (Mitchell et al., Submitted). In California, a broad and rather adaptable model or definition of CT has emerged across a broad range of crop production systems that reduce or eliminate primary, intercrop tillage operations of disk, plowing, ripping and chiseling, and that manage residues in ways to enable efficient and successful planting, pest management and harvesting. There is also an emerging portion of California’s overall crop production systems that is using the more “classic” forms of CT that are common elsewhere, - no-till and strip-till. While these production alternatives are relatively new in California, they are well
suited to forage crops that are commonly produced for dairies.

**CT in California Forage Systems**

California’s dairy industry is a huge contributor to the State’s economy. Dairy products have been California’s top agricultural commodity for a number of years (CDFA, 2004). They account for over 5 billion dollars in cash receipts, which is about 17% of the State’s overall agricultural output in recent times. California dairies require year-round availability of inexpensive, locally-produced forage materials. Common dairy forage production systems consist of winter small grains seeded either individually or in mixes in November and December. These winter forages are then harvested as “green chop” the following March through May. In conventional production systems, fields may be disked and deep-ripped a number of times following the harvest of these winter forages, disked again, relisted or bedded and then preirrigated for spring corn planting. Turnaround time between winter small grain forage harvest and spring corn planting routinely takes about two weeks. Spring silage corn is then produced for late-summer harvest. Occasionally, corn or another forage crop such as milo or sorghum-sudan, may be double-cropped after an early planted corn crop with the second crop coming off in early fall. In most current production systems, intercrop tillage and seedbed preparation is done ahead of each successive crop. Such production systems, however, lend themselves quite well to a variety of conservation tillage (CT) approaches that have been developed in other production regions, and in recent years, a number of California dairy forage producers have begun experimenting with these reduced till forage production alternatives.

The primary motivation for CT in dairy forage systems is to save time, labor and fuel (Table 1). This is accomplished by reducing primary, intercrop tillage or soil preparation operations such as disking, plowing, chiseling and ripping to the greatest extent possible while still achieving adequate productivity. In general, the earlier a crop such as corn is planted, the higher the yield. Corn stunt disease is also less severe in early corn than in later-planted corn. Minimizing or eliminating intercrop tillage can reduce the time between winter forage harvest and corn seeding from 2 – 3 weeks under conventional practices, down to 7 to 10 days or even less due to reduced time for tillage operations, and less water applied as preirrigation.

<table>
<thead>
<tr>
<th>Table 1. Possible benefits of conservation tillage</th>
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<tbody>
<tr>
<td>• saves fuel</td>
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<td>• saves soil</td>
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<td>• saves time</td>
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<td>• saves labor</td>
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<td>• saves machinery</td>
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<td>• permits timely planting</td>
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<tr>
<td>• reduces runoff</td>
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<td>• increases soil moisture</td>
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<td>• increases soil organic matter</td>
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<td>• sequesters carbon</td>
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<td>• improves habitat for beneficial organisms</td>
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<tr>
<td>• reduces PM and PM2.5 dust emissions</td>
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<td>• reduces surface water, sediment, nutrient and pesticide runoff</td>
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Phatak, S., 1999, University of Georgia

**CT Corn Systems**

There are currently three general types of conservation tillage systems that are being used in San Joaquin Valley dairy forage production fields: complete no-till, strip-till, and a one-pass operation in which several implements such as a light disk and a harrow are pulled in tandem to create seedbed conditions quite similar to conventional tillage. In no-till or
zero-till, the only soil disturbance is the 
creation of a narrow slot by coulters or seed 
openers during planting (Photo 1). In strip-
till, coulters cut residues ahead of subsoiling 
shanks that loosen the soil from a few to as 
many as 14 inches deep ahead of a planter 
(Photo 2). A strip-till implement can also be 
connected to a planter to enable a one-pass 
planting operation (Photo 3). Strip-till is 
sometimes referred to as “vertical till” because 
tillage is done in a vertical fashion in the soil 
profile, thereby preserving much of the residues 
on the soil surface. Finally, a variety of 
implements including basic disk harrows and 
other recently-introduced and more specialized 
“all-in-one” type tillers can also be used to 
accomplish the reduced pass approach. This 
latter CT system reduces the number of overall 
tillage operations while tilling the surface soil 
sufficiently to mix residues with the soil, thus 
providing seedbed conditions relatively 
comparable to standard tillage procedures 
(Photo 4 and 5). Specific examples of CT that 
have recently been used in Central Valley 
dairies are listed in Table 2.

CT Forage Corn Planting Alternatives

In the San Joaquin Valley, CT forage corn 
planting is generally done on the flat in the 
same direction as winter forage plantings using 
the same irrigation borders. Therefore, it is 
critical to optimally prepare fields in terms of 
slope or fall, and border width before 
transitioning to CT management. Slope must 
be adequate to allow water to move across a 
border check efficiently and the border width 
must be narrow enough to permit uniform 
irrigations. Irrigation is a major factor to 
consider when switching to CT. In some cases, 
where fields have not been managed properly, 
the spread or flow of water down the field has 
been a problem during flood irrigation in some 
CT forage production fields. Slight high or low 
spots and unevenly distributed clumps of crop 
residues can interfere with or impede normal 
irrigation water flow. In general, however, CT 
dairy forage producers report that fields irrigate 
faster, but irrigations tend to be required more 
frequently in no-till fields.

In no-till, the common practice is to irrigate 
before planting. Less water infiltrates a no-till 
than a disked field. So a pre-irrigated no-till 
field usually takes seven days or less for it to be 
dry enough to plant. In fact, one of the 
challenges in the no-till system is to be ready to 
plant when the field is at the proper moisture 
because the soil dries up much more rapidly 
than pre-irrigated fields that are traditionally 
cultivated. A few more days can be saved by 
planting dry and then irrigating. However, 
there have been more failures with this method, 
especially under hot conditions.

A variety of no-till planters are now being used 
successfully in dairy forage production fields. 
Extensive research conducted in the Midwest 
has indicated benefits of on-seed starter 
fertilizer applications and nitrogen applications 
2 – 4 inches from the seed line in no-till fields. 
Commercial no-till planting services now 
available in California make use of these

Table 2. Conservation tillage dairy forage 
production evaluations conducted in 
the Central Valley 2002 – 2005

<p>| |</p>
<table>
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<tr>
<td><strong>Table 2.</strong> Conservation tillage dairy forage production evaluations conducted in the Central Valley 2002 – 2005</td>
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<tr>
<td><strong>•</strong> no-till corn planted into winter small grain forage</td>
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<tr>
<td><strong>•</strong> strip-till corn planted into winter small grain forage</td>
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<tr>
<td><strong>•</strong> strip-till corn planted into burned down alfalfa</td>
</tr>
<tr>
<td><strong>•</strong> no-till sorghum-sudan drilled into corn stubble</td>
</tr>
<tr>
<td><strong>•</strong> no-till corn planted into corn stubble</td>
</tr>
<tr>
<td><strong>•</strong> no-till triticale drilled into sorghum-sudan</td>
</tr>
<tr>
<td><strong>•</strong> one-disk corn planted into winter small grain forage</td>
</tr>
<tr>
<td><strong>•</strong> no-till oats drilled into alfalfa</td>
</tr>
<tr>
<td><strong>•</strong> no-till wheat drilled into corn stubble</td>
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</table>
Photo 1. No-till drilling wheat into herbicide-burned alfalfa, Riverdale, CA, 2003

Photo 2. Strip-tilling into harvested wheat field, Hanford, CA 2006

Photo 3. Orthman 1-tRIPr strip tiller ahead of John Deere 1730 no-till planter, Mendota, CA, 2006

Photo 4. “Optimizer all-in-one tillage implement”, New World Tillage, Modesto, CA

Photo 5.
fertilization technologies on their no-till planters. The most common no-till planters currently being used plant six, eight or ten rows on 30-inch spacing. Most, if not all, use global positioning systems (GPS) to place rows most efficiently as possible to fit in between borders and for ease of planting straight. Because the winter forage is cut just a few inches above the soil surface and the entire plant is used for harvest, there is not much trash left behind for no-till planters to cut through unless heavy lodging occurred and the harvester did not pick it all up. Trash managers, such as those provided by Yetter, Marten, and Dawn have been commonly used and are effective in dealing with forage stubble, downed forages and manure clumps.

A number of San Joaquin Valley dairy forage producers have also strip-tilled ahead of corn planting. Strip-tillage relies on a coulter disk that cuts residues, a subsoiler shank that can loosen compacted layers 8 – 14 or so inches deep, and some sort of clod-busting seed bed prep tool. To date, strip-tillage has usually been done as a separate operation from planting and a GPS system is therefore a necessity in order to plant in the strips that were tilled by the strip-tiller. If strip-tillage is done before pre-irrigation, water penetrates deeper into the soil than in no-till. This may cause a delay in soil drying and thus lengthen the waiting period for planting. Strip-tillage into wet or pre-irrigated soil may be easier and require lower horsepower, but the soil loosening benefits might not be as great.

Because many forage production fields are associated with dairies, application of solid manure needs to be addressed in CT systems. Many dairy operations need or want to utilize this manure on their fields. In conventional systems, dairy corral scrapings have been spread immediately after winter forage harvest and incorporated with disking operations. When spread in a completely no-till system, manure is never incorporated. In a strip-till system, there is limited incorporation in the strip. In the “single pass” system with some sort of “all purpose implement,” manure is incorporated to some degree over the entire surface. In several fields, there have been no known negative impacts from manure left on the soil surface in terms of planting with a no-till planter or drill or in terms of plant growth. However, potential concerns of volatilization of ammonia and nuisance from flies or smell, may necessitate different manure management strategies if regulations against this practice are introduced in the future. In one recent trial in which corn followed wheat planted on beds, clumps of surface spread manure applied before corn planting interfered with water movement in the furrows and this required an additional pass with furrowing-out shovels to push the manure aside. Future CT systems for manure management may make use of various injector technologies common in other dairy regions.

A common observation comparing conventional plantings to no-till is that no-till plantings are often less uniform in appearance and shorter early in the season. These differences, sometimes very pronounced and other times very subtle, often continue into the elongation stage. However, in most cases, by the time of tassel appearance the no-till corn looks uniform and of equal height to conventional plantings.

**Weed Management in CT Forage Systems**

Most no-till forage corn plantings for California dairies have utilized Roundup Ready (RR) varieties. With the numerous and varied preplant and post-emergence herbicides registered on corn, conventional varieties could also be used. The major reasons for growing RR varieties seem to be the ease of weed control operation and cost effectiveness. Research in the Midwest US has shown that timely weed control with postemergence herbicides can be an effective alternative to soil-applied herbicides in corn (Carey and Kells, 1995; Gower et al., 2002). Dairy corn
growers generally apply glyphosate alone or tank-mixed with another herbicide one time during the first few weeks after corn planting. In many situations, this strategy has worked but in some it has been a problem. Although, a single postemergence application of glyphosate can be successful (Myers et al., 2005), timely application of herbicide is critical to avoid crop yield losses and weed escapes. Studies in the northeast US have suggested that glyphosate should be applied by the V3-V4 stage of corn. Glyphosate applied at the V5-V6 stage resulted in 20 to 25% loss in dry matter (Cox et al., 2005). Similarly, the probability of weeds escaping the herbicide application may be greater if they are bigger or at an advanced growth stage. These weed escapes may not only compete with the crop but produce seeds and increase the weed seed bank. Timely application could be of concern to corn growers who rely on contract custom herbicide applicators for weed control. Further, glyphosate has been noticed to provide inadequate control of some weeds such as annual morningglory (Ipomoea sp), nettles (Urtica sp), horseweed and hairy fleabane (Coneza sp.), and cheeseweed (Malva sp.). Reliance on glyphosate alone may cause weed shifts by increasing the prevalence of these species. Therefore, if only postemergence control is preferred, one strategy could be tank mixing other products with glyphosate that may give adequate control of these species (Refer to UC Pest Management Guidelines for corn for possible options). Another strategy could be to plant corn in narrow-row spacing so that the corn canopy closes earlier than in wide-rows and the weed escapes are shaded earlier. However, the effectiveness of narrow row spacing on reducing weed competition has had inconsistent results and in many cases not resulted in yield benefits. Another weed management strategy that may have utility in forage corn systems but that is currently not used would be to apply preplant herbicides following winter forage harvest and then use the preirrigation to incorporate the herbicide prior to corn seeding. In systems using herbicide-tolerant corn varieties, careful long-term planning and management strategies are required to avoid herbicide resistance. It is important to rotate herbicides that have a different chemical mode of action.

A weed management option that has not yet been widely used in California CT forage corn systems to date is cultivation. In Canada, Swanton et al. (2002) found that shallow interrow tillage was a viable option for weed control in CT grain corn provided that the timing of cultivation was adequate. The challenge may be to time the cultivation as soon as the field is dry enough after irrigation and not let the weeds get too big. In fields were weeds like annual morningglory escape the glyphosate treatment, as seen in the Central Valley dairy corn systems, cultivation may be the only option to remove these weeds. A variety of high residue crop cultivators are available and have been used in CT systems in other regions (Grisso and Jasa, 1995). Cultivators used in CT fields that have considerable residue must allow these residues to flow through the implement without clogging. In addition, extra penetration force may be required in cultivating CT fields relative to traditionally tilled fields. Experiences from other regions where CT is more extensively used indicate that combining mechanical and chemical weed control may be both economical and effective because weed control does not rely exclusively on one strategy (Grisso and Jasa, 1995; Swanton et al., 2002). CT cultivators tend to be heavier and more robust than standard cultivators, and rather than using multiple knives or shovels as on standard till implements, CT cultivators typically rely on a single wide sweep with a coulter mounted in front to cut residues (Figure 1).

Successful No-Till Crop Rotations

Extensive information has been developed throughout the Midwest and eastern US on the relative ease of no-tilling a particular crop into
A summary of this information is given in Table 3. These ratings represent a considerable research and experience base for the major crops in these other regions and reflect a variety of management goals including the need for residue conservation to reduce soil erosion, soil temperature requirements at planting time, as well as the relative ease of no-till planting a given crop into particular residues. We currently have far less experience with no-till planting sequences in California.

A variety of CT forage planting sequences have, however, been successful at a limited number of sites and generally as single-season trials. We currently lack information on continuous CT forage plantings, CT alfalfa planting into various residues, and CT planting into cover crops such as annual or cereal rye, which have recently begun to be promoted in several other US regions. There is also currently no experience on the impacts of sustained CT production on surface irrigation efficiency which could conceivably be negatively impacted due to residue buildup and problems associated with not performing routine soil leveling as is done routinely in current conventional tillage systems.

Compaction in CT Forage Systems

A common concern in sustained no-till systems is soil compaction that is caused by the movement or traffic of vehicles, livestock or humans over the surface of the soil. Soil compaction is the consolidation or packing of the solid portion of the soil which is composed of varying proportions of sand, silt, clay and organic matter, into the soil’s pore space (Kinsella, 1995). The reduced pore volume and size can then negatively impact agricultural production “by limiting root growth, reducing water infiltration and availability, increasing erosion, reducing beneficial microorganism growth and activity, and reducing nutrient availability and uptake” (Kinsella, 1995).

Conventional tillage systems generally seek to minimize the risk or potential of soil compaction by temporarily adding pore space through the use of various types of implements. Usually, however, conventionally tilled soils “recompact” because their structure has been lost and their humus content has been reduced. “Tillage farming” has thus been described as “a series of packing and loosening events” (Kinsella,
Table 3. Ratings for the ease of no-tilling a crop into the residue of a prior crop*

<table>
<thead>
<tr>
<th>Crop planted</th>
<th>Crop residue planted into (1 = least, 5 = most challenging)</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Corn</td>
<td>fall killed alfalfa or grass hay</td>
</tr>
<tr>
<td>Alfalfa/grass</td>
<td>corn silage (some residue may be removed)</td>
</tr>
<tr>
<td>Soybeans</td>
<td>corn grain</td>
</tr>
<tr>
<td>Winter small grain</td>
<td>corn silage</td>
</tr>
<tr>
<td>Spring small grain</td>
<td>soybeans</td>
</tr>
</tbody>
</table>

*Adapted from Duiker, S.W. and J.C. Myers. 2005. Steps toward a successful transition to no-till. Penn State College of Agricultural Sciences.

1995) aimed at periodically breaking up compacted layers. However, because of the inevitable loss of soil structure and humus that accompany conventional tillage, a “tillage treadmill” becomes established. “Tillage begets more tillage; the more we do, the more we need” (Kinsella, 1995).

The bulk of soil compaction research has been done on tillage systems. Reducing the impact of soil compaction under no-till is different compared to standard tillage systems (Duiker and Myers, 2005a, b). Kinsella (1995) identified a strategy for the critical and often difficult transition or conversion period to no-till. The objective of this strategy is “to maintain yields while allowing the soil to build humus and regain its structural stability so that it will reestablish pore space and be able to resist greater compaction forces long term” (Kinsella, 1995). Over time, soils under no-till management tends to have higher SOM in the surface layer, biological activity including earthworms tend to be higher, and a firm but resilient soil matrix with macropores for air and water movement develops that can better support traffic without being compressed than a soft, tilled situation. An example of this process of soil porosity decline and subsequent increase following sustained no-till management is seen in Figure 2.

Overall, research suggests that soil compaction can be a significant problem in no-till systems (Duiker and Myers, 2005a, b; Kinsella, 1995). A number of preventative as well as remediating management strategies have been
Figure 2. Changes in porosity larger than 0.5 mm diameter in the surface soil from Coshocton, Ohio, after beginning no-till management (Norton and Schroeder, 1987).

identified, however, to minimize or alleviate the risk of soil compaction in no-till, particularly during the transition years. The first principle is to limit traffic to times when the soil is dry. Prior to converting to no-till, an evaluation of the soil profile for yield-limiting compaction should be done using an inexpensive soil penetrometer, or by examining root growth. If roots avoid areas or are restricted or flattened, there may be potential for yield loss if the situation is not corrected (Kinsella, 1995) using vertical tillage implements that loosen the compacted soil layer but that also preserve residues and macropore systems in the surface layers. Other considerations for avoiding soil compaction include staying off the soil when it is wet, using dual wheeled, or track tractors, taking weights off tractors, and using GPS guidance systems to achieve controlled traffic farming. To date, however, controlled traffic CT dairy forage production systems have not been fully tested or developed in California.

Studies and experience in other regions indicate that successful transitions to no-till management typically take a number of years to accomplish. The strategy for a no-till transition with respect to avoiding soil compaction is “to improve soil structure so the soil is better able to resist the surface traffic of planting, spraying, fertilizing and harvesting” (Kinsella, 1995). In a local study comparing CT controlled traffic systems with standard tillage after four years of a cotton / tomato rotation in Five Points, CA, no differences in soil compaction (0 - 45 cm) were seen (Veenstra et al., In press). We currently have, however, no data on the risk of compaction in continuous no-till dairy forage systems in California.

Other factors need to be considered when thinking about switching to reduced and no-till corn. Irrigation is a key component and how it will be managed in CT will be important. The width between borders and the size of borders will be dependent on soil type, the volume of water applied, slope (both down the field and across the field), and whether or not there is a return system. Growers may have to experiment on their own to determine the best set up for their fields. In addition, one needs to consider the number of rows on the planter and the harvest choppers for maximum efficiency. GPS guided systems are extremely helpful in reduced and no-till systems. They allow for strip-tillage to be in the correct spot so that the planter will be planting in the strip-tilled area. It allows for the accurate positioning of borders so that the minimum loss of planted areas occurs.

Summary

Since about 2003, use of a variety of conservation tillage systems in Central San Joaquin Valley dairy forage production fields has expanded significantly, making this cropping system the most rapidly growing CT sector in California today. Many questions regarding the long-term feasibility of sustained CT forage production are now beginning to be answered, however, many questions remain. Two key areas that require additional research and evaluation are weed pest and soil compaction management. Additional information on CT forage systems is available
at the website of the CT Workgroup
(http://groups.ucanr.org/ucct/).

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