

# Improving soil health in irrigated intensive vegetable production

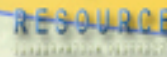
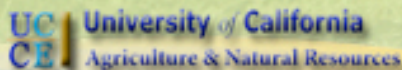
**Jeff Mitchell**

Department of Plant Sciences, University of California, Davis



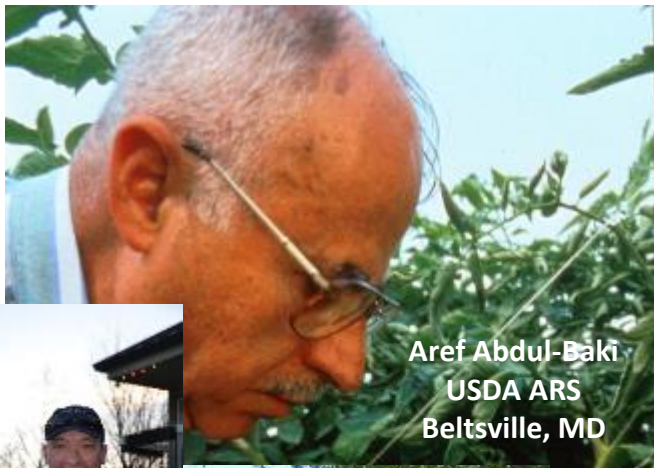
**USDA Natural Resources Conservation Service  
Conservation Webinar Series  
Science and Technology Training Library  
September 12, 2017**

Special thanks to Dr. Zahangir Kabir for  
the very special invitation to be with  
you today.



# Outline of Discussion

- Provide background on California's phenomenally productive annual crop systems
- Point out some of the sources of experience and knowledge
- Lay out some of the rationale for our work with conservation agriculture systems
- Describe some of the advances and progress of California farmer innovators with conservation agriculture systems, and end by
- Encouraging questions and discussion



Aref Abdul-Baki  
USDA ARS  
Beltsville, MD



Dwayne Beck  
SDSU  
Pierre, SD



Jay Fuhrer  
NRCS  
Bismarck, ND



Jerry Hatfield  
USDA ARS  
Ames, IA



Brendon Rockey  
Center, CO



Dick and Sharon Thompson  
Boone, IA



Suat Irmak  
Univ NE  
Lincoln, NE



Steve Groff  
Lancaster County  
Pennsylvania

Ron Morse  
Virginia Tech  
Blacksburg, VA



Andy McGuire  
Moses Lake, WA



John Landers  
Cerrado Region  
Brazil



John Luna  
Oregon State  
University  
Corvallis, OR



Karl Kupers  
Rearden, WA



Sharad Phatak and Rick Reed  
UGA and USDA NRCS  
Tifton, GA



Mike Peterson  
USDA NRCS  
Greeley, CO



Rolf Derpsch  
Paraguay

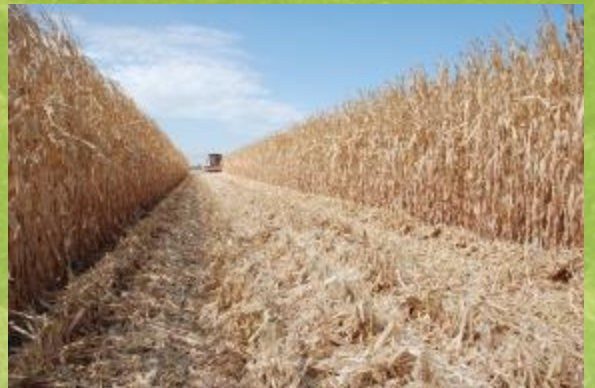


Don Reicosky  
USDA ARS  
Morris, MN



John McPhee  
Tasmania  
Australia







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UC Davis  
COLLEGE OF AGRICULTURAL  
AND ENVIRONMENTAL SCIENCES

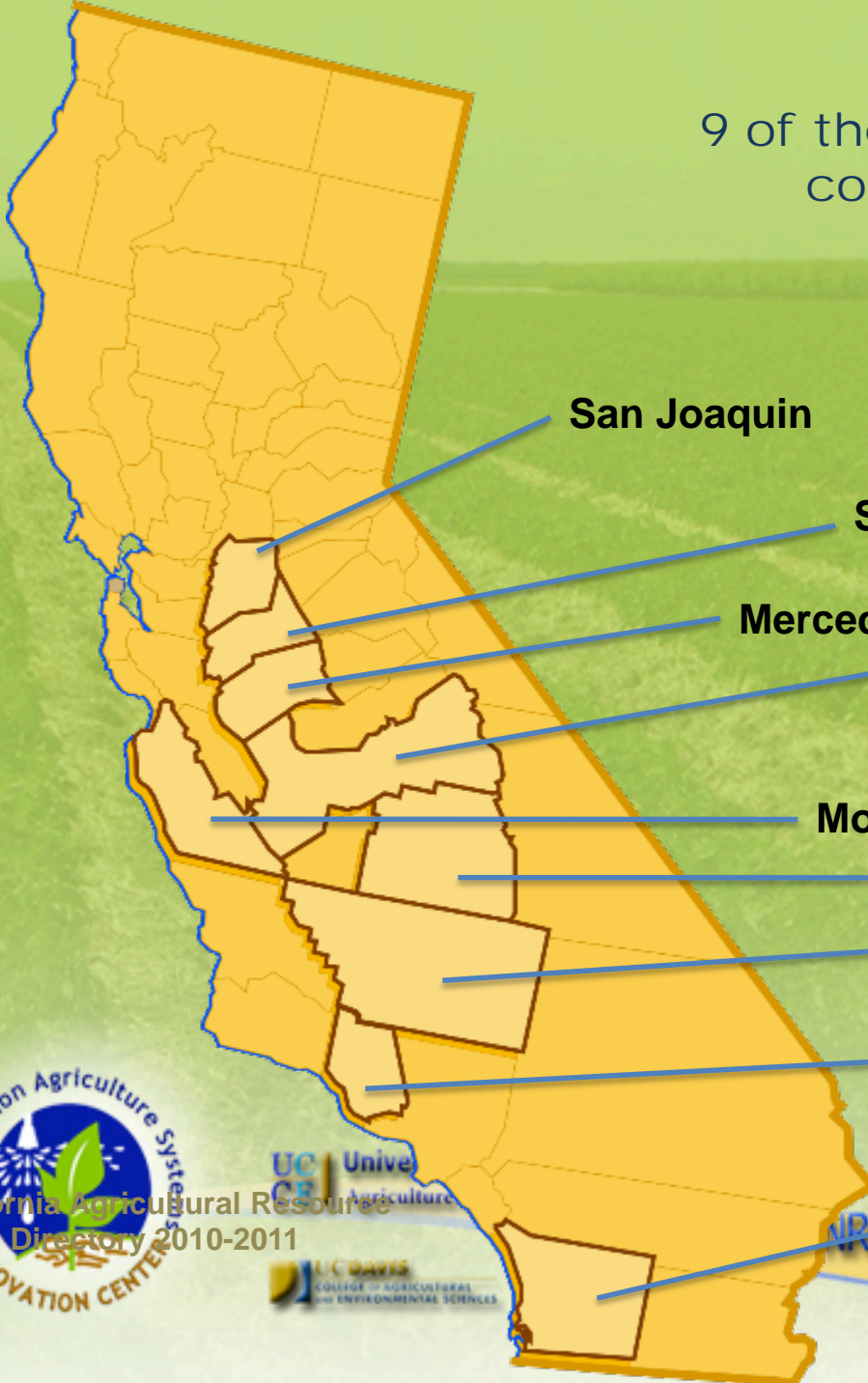
UC Davis  
DEPARTMENT OF PLANT SCIENCES



Sustainable Conservation



9 of the nation's top 10 producing counties are in California



**San Joaquin**

**Stanislaus**

**Merced**

**Fresno**

**Monterey**

**Tulare**

**Kern**

**Ventura**

**San Diego**



# Crop and Livestock Commodities in which California Leads the Nation

## Almonds

Apricots

## Artichokes

Asparagus

Avocados

Beans, Dry Lima

Bedding/Garden

Plants

Broccoli

Brussels Sprouts

Cabbage, Chinese

Cabbage, F.M.

Carrots

Cauliflower

Celery

Chicory

Cotton, Am. Pima

Daikon

## Dates

Eggplant

Escarole/Endive

## Figs

Flowers, Bulbs

Flowers, Cut

Flowers, Potted

Plants

Garlic

## Grapes, Raisins

Grapes, Table

Grapes, Wine

Greens, Mustard

Hay, Alfalfa

Herbs

Kale

## Kiwifruit

Kumquats

Lemons

Lettuce, Head

Lettuce, Leaf

Lettuce, Romaine

Limes

Mandarins & Mandarin

Hybrids

Melons, Cantaloupe

Melons, Honeydew

Milk

Milk goats

Nectarines

Nursery, Bedding Plants

Nursery, Crops

## Olives

Onions, Dry

Onions, Green

Parsley

Peaches, Clingstone

Peaches, Freestone

Pears, Barlett

Peppers, Chile

Peppers, Bell

## Persimmons

Pigeons and Squabs

## Pistachios

Plums

## Plums, Dried

Pluots

## Pomegranates

Raspberries

## Rice, Sweet

Safflower

Seed, Alfalfa

Seed, Bermuda Grass

## Seed, Ladino Clover

Seed, Vegetable and

Flower

Spinach

Strawberries

Tomatoes, Processing

Vegetables, Oriental

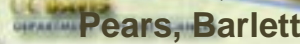
## Walnuts

Wild Rice



RED - >99%

USDA, National Agricultural Statistics Service, California Field Office  
California Agricultural Statistics, Crop Year 2016





**Overhead irrigation of carrots  
Bakersfield, CA**



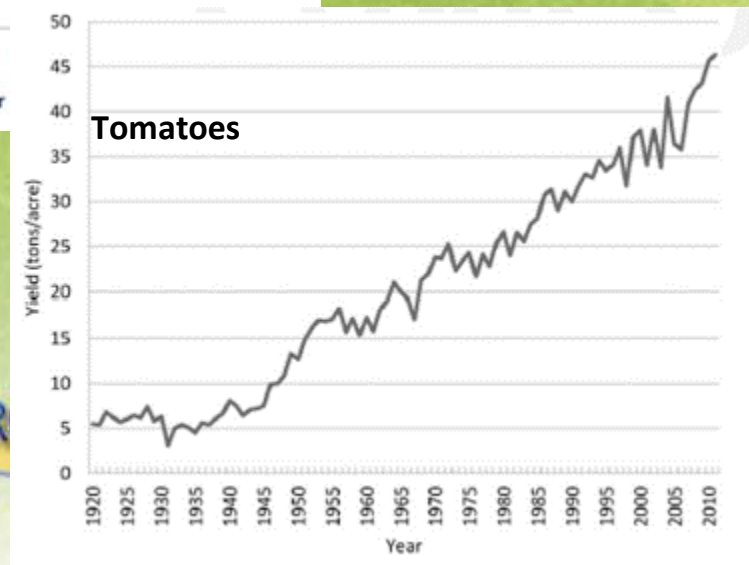
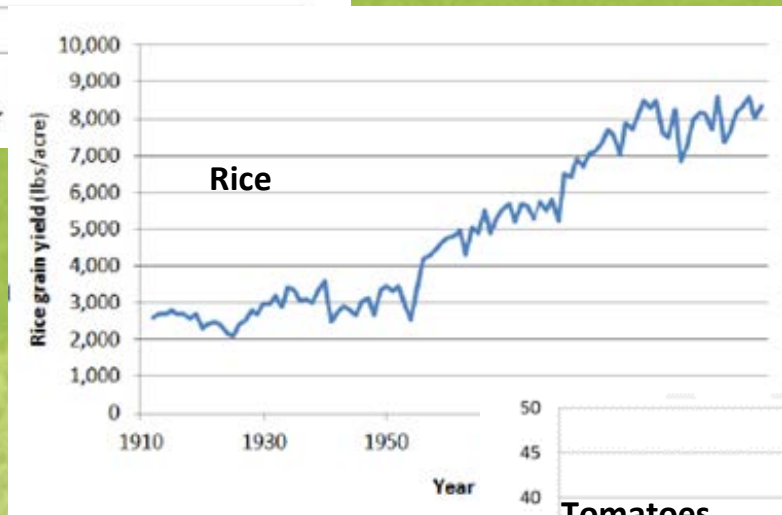
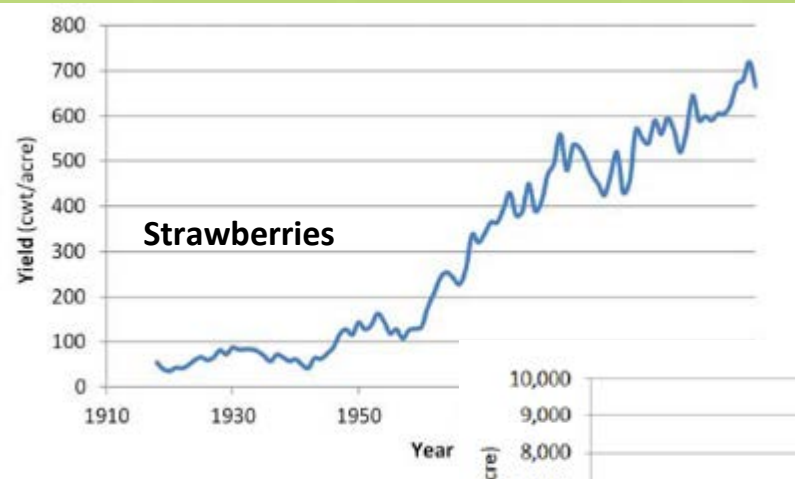
**Processing tomatoes  
Five Points, CA**

**Installation of surface drip tape  
in cotton during drought  
Fresno, CA**





**Harvesting of rice  
Sacramento, CA**



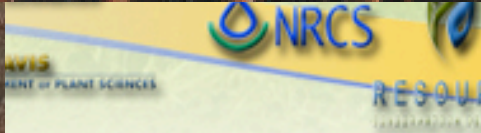
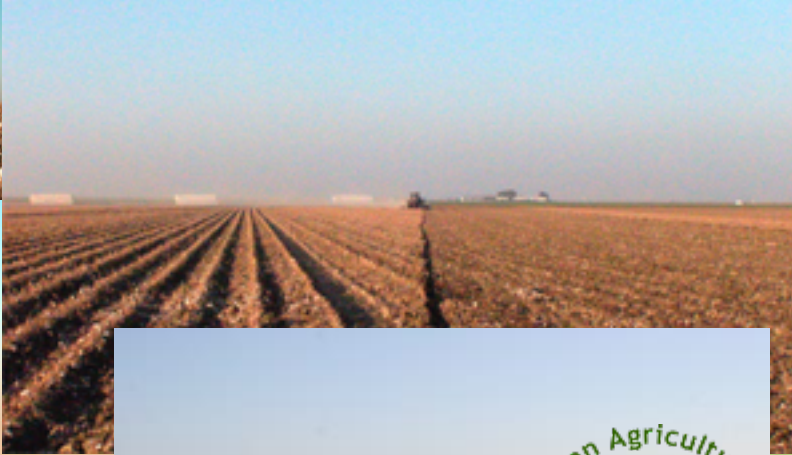
Geissler et al., 2012



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U.C. Davis DEPARTMENT OF PLANT SCIENCES







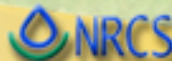


## Managing for soil health ...

- Minimizing soil disturbance
- Maximizing the diversity of plants in rotation / cover crops
- Keeping living roots in the soil as much as possible, and
- Keeping the soil covered with plants and plant residues at all times



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Unlock the Secrets in the Soil

<http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/>

## Mother Nature...

- harvests the maximum amount of sunlight
- leaks very few nutrients including CO<sub>2</sub>
- has diversity
- does not export nutrients
- makes maximum use of water and nutrients by having highly developed porosity and VAM webs
- does not do tillage



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Summary of comments made by Dr. Dwayne Beck, SDSU,  
at 2014 Winter Conference of No-till on the Plains, Salina, KS



RESOURCE  
LABORATORY CENTER



Sustainable Conservation

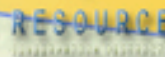
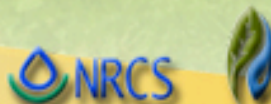


EDISON

**Conservation tillage practices have increased by 300% in the Midwest during the last decade.**

**In California however, less than 0.3% of crop acreage is farmed using conservation tillage practices.**

*(Conservation Technology Information Center, Lafayette, IN, 2002)*



“We’ve been doing some conservation tillage and cover cropping for about eight years. With minimum tillage we can cut fuel costs, compaction of the soil and labor costs ...”

— Bob Prys, agronomy manager for Borba Farms Inc. in Riverdale



PHOTOS BY RICHARD DABBS — THE FRESNO Bee  
Nick Madden of University of California at Davis checks how well a cultivator is “getting the weeds” at a field in Five Points.

## SMARTER TILLING

Farmers seek to cut labor and fuel costs while maintaining soil.

By DENNIS POLLOCK  
THE FRESNO BEE

As sleek as a piece of machinery with the intriguing name “sharedder-boader” probably said it best: “saves soil, oil and toil.”

No, this is not an endorsement for that one particular item that was showcased at Conservation Tillage 2001, a demonstration of equipment and talks by growers and researchers Tuesday at the University of California West Side Research and Extension Center in Five Points.

But it was clear that much of the in-crowd interest in the new tillage systems is aimed at cutting labor costs, saving fuel costs and maintaining the viability of the soil.

The main use of the word “tillage” may cause the average person’s eyes to glaze over. But the concepts — aimed



A tour for Valley farmers stops at a conservation tillage demonstration tomato plot.

at cutting down the number of trips across a grower’s field — are opening some eyes for farmers in the West who see the prospect for saving money and time.

Among about 100 participants in Tuesday’s conference was Bob Prys, agronomy manager for Borba Farms Inc. in Riverdale, who is becoming a believer: “We’ve been doing some conservation tillage and cover cropping for about eight years,” Prys said. “With

minimum tillage we can cut fuel costs, compaction of the soil and labor costs and cut down on the amount of equipment we need. We’ve encountered some skepticism. There’s some concern about planting into a cover crop of barley, but the test is going to be in this year’s harvest.” Conservation tillage, which also can boost organic matter and trap helpful carbon in the soil, has been used for about three decades in  
Please see TOUR, Page C1



# More Profit With Less Tillage

Ernest E. Behn



Iowa, 2001



Alabama, 2001



Washington, 2007



Iowa, 2001



Georgia, 2001



Brazil, 2007



Nebraska, 2007



Brazil, 2004



Strip-till cotton into rolled rye cover crop  
Tifton, GA 2005



Ron and Robert Rayner  
No-till cotton  
Goodyear, AZ



Patos de Minas, Brazil  
2007



**Strip-till seeded onions in wheat cover crop  
Moses Lake, WA  
2010**





**Processing tomatoes  
Patos de Minas  
Goiania,  
Brazil  
2005**

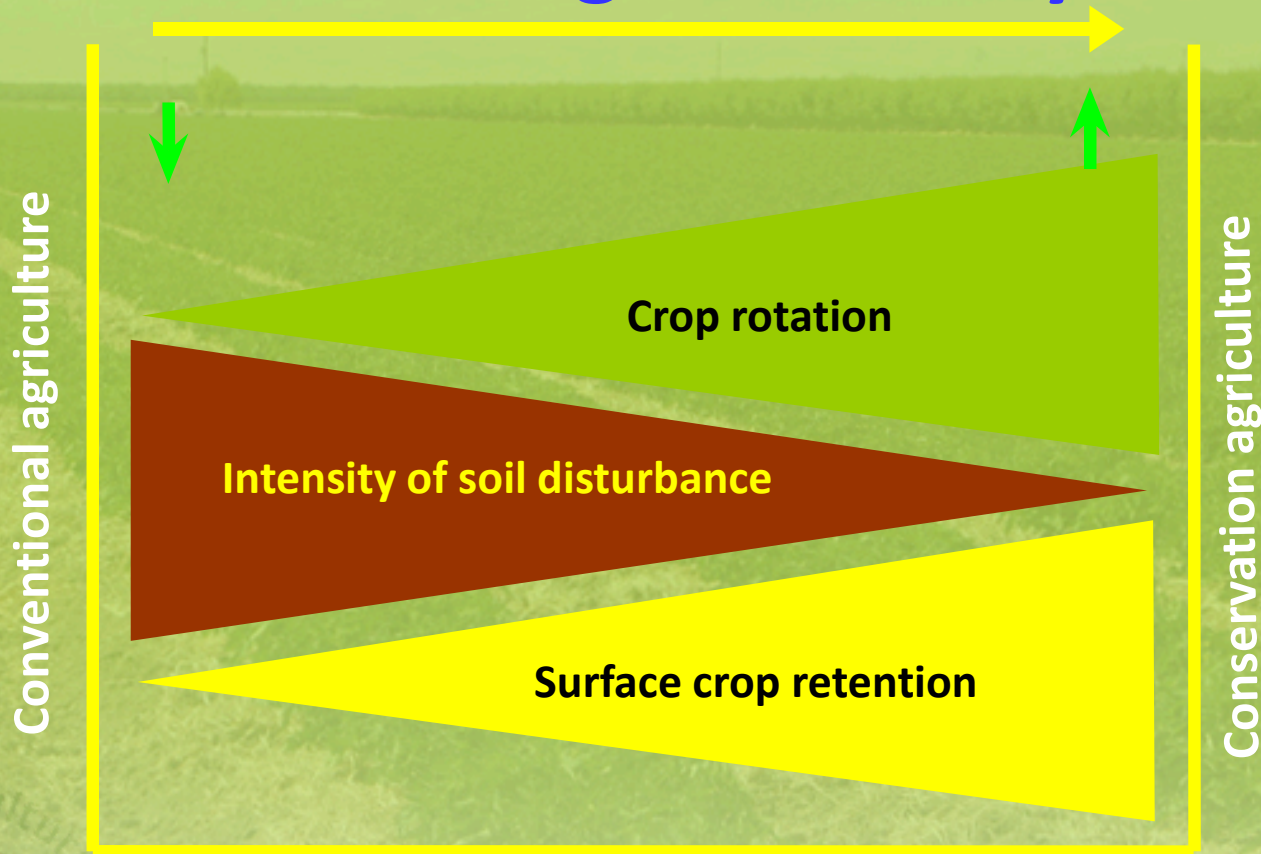


Tomato transplanting following silage wheat chopping  
Turkey  
2009



**No-till onion experimentation  
Patos de Minos, BRAZIL  
2006**

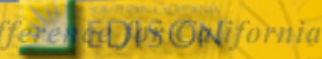
# Conservation Agriculture Systems



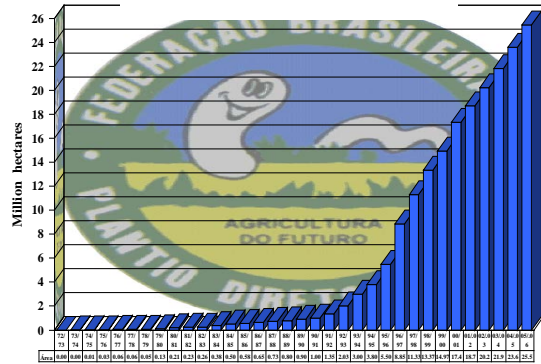
**Conventional**

**Minimum  
Tillage**

**Direct  
seeding**

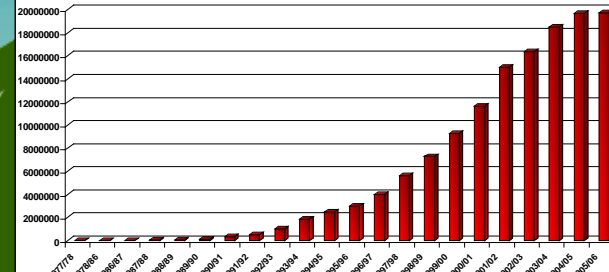


Brazil - Area under CA from 1972 to 2006



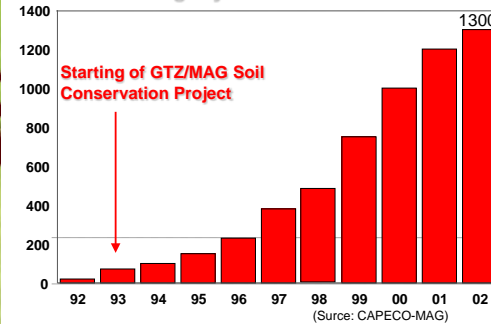
Fonte: EMATER-RS, EPAGRI-SC, EMATER-PR, CATI-SP, FUNDAÇÃO MS, APDC (Cerrado)

Argentina - CA from 1977 to 2006



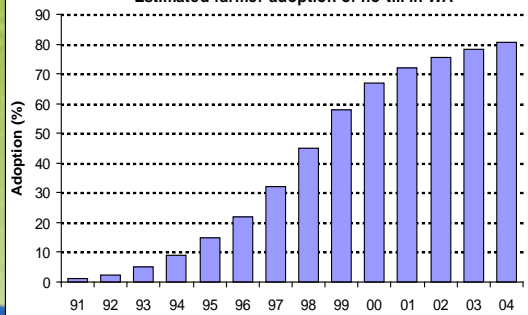
CA globally - history and adoption

Paraguay - CA area 1992-2001



(Source: CAPECO-MAG)

Estimated farmer adoption of no-till in WA



No-Till Adoption in the U.S. 1984 - 2004

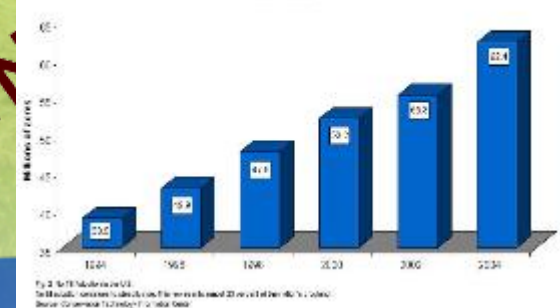
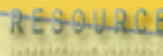
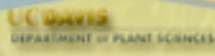
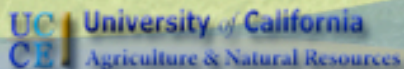
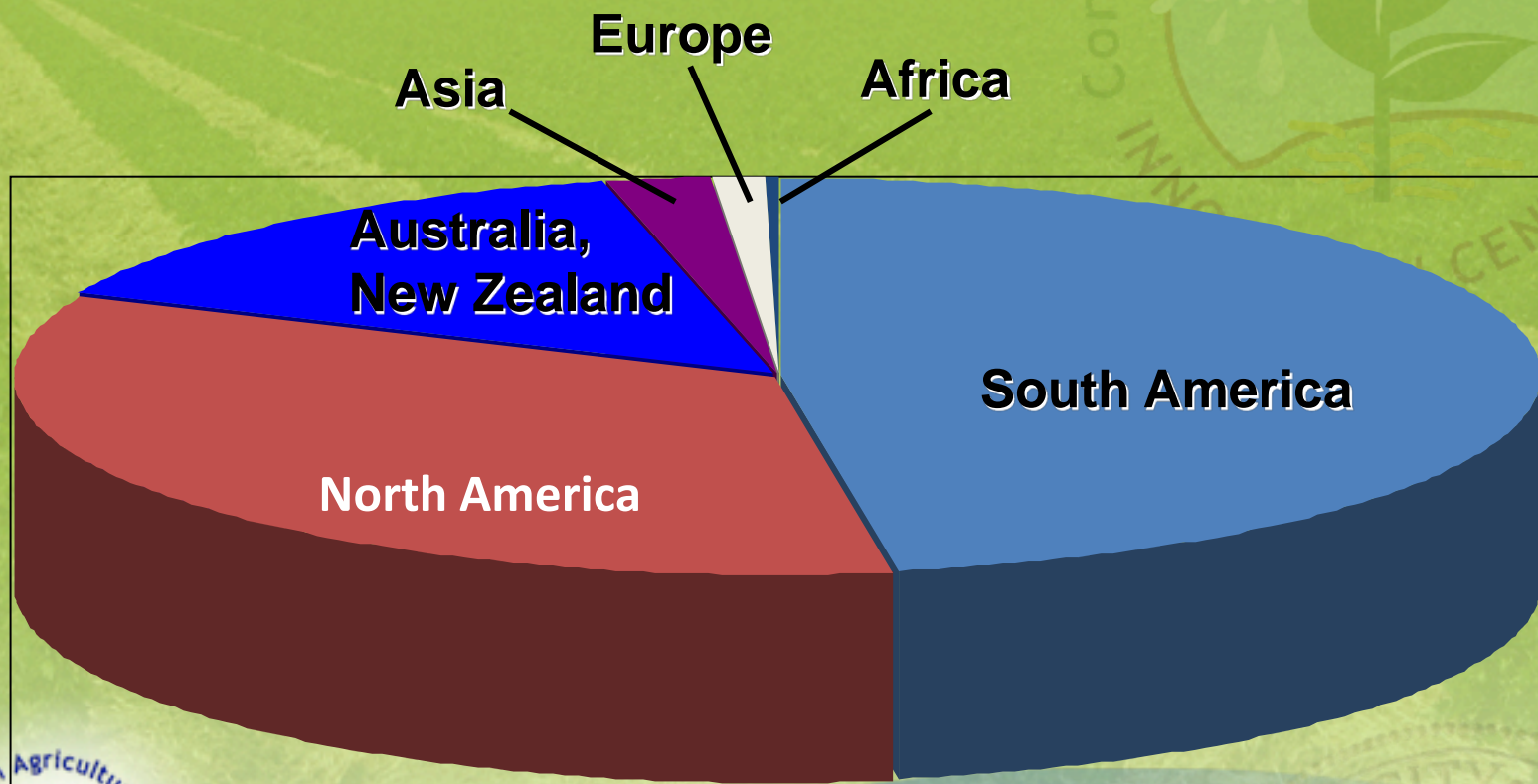


Fig. 2. No-Till Adoption in the U.S. The 50 million acres in 2004 is equivalent to the area of 20 million acres of corn in 2004. Source: Conservation Technology Information Center.

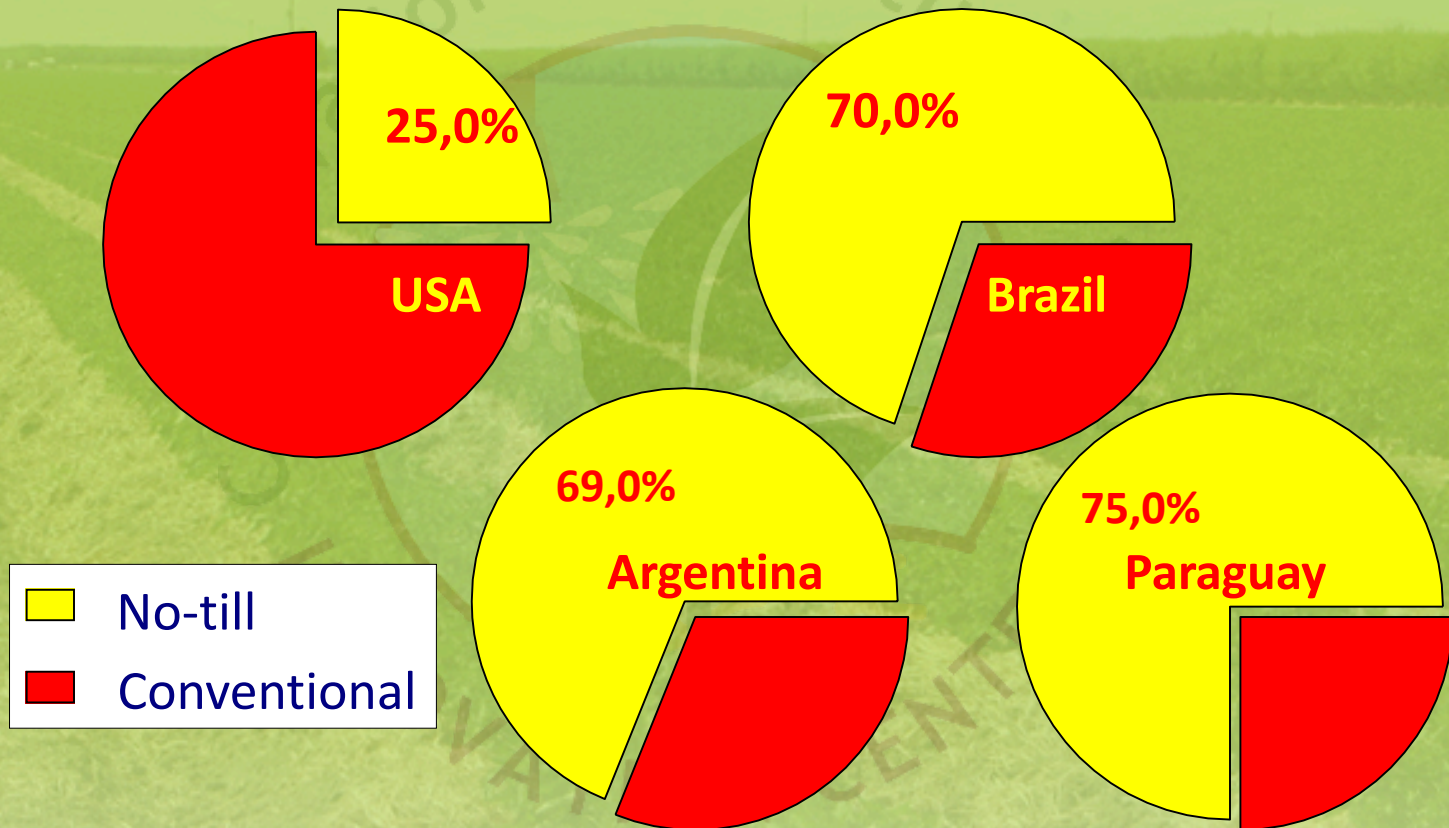
# CA Adoption in percent by region worldwide



Derpsch and Friedrich, 2012

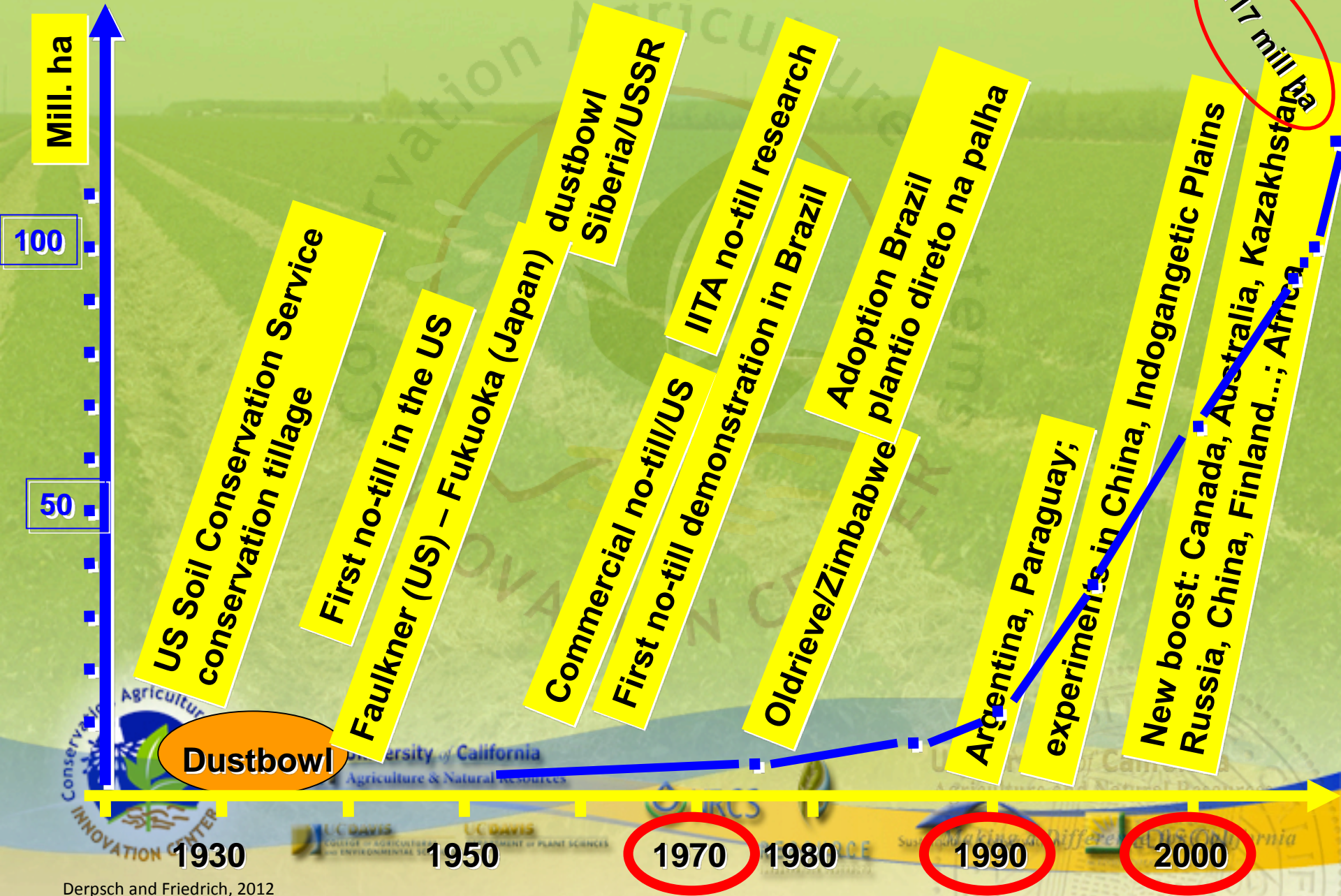


## CA Adoption relative to total cropland



It is estimated that in less than a decade > 85% of the cultivated area will be under No-till.

# History and Adoption of CA



**'DRIVERS' FOR CHANGE**

**TECHNOLOGY and SYSTEMS ADVANCES**

- 1930s **Dryland Farming**  
"Pump Era" - Advent of limited irrigation
- 1957 **Shredder Bedder**  
--Al Ruozi, Interstate Mfg. (Bakersfield, CA)
- 1963 **California Aqueduct**  
Central Valley Improvement Project (Expansion of irrigation)
- 1970s **Wide tractive "spanner" implement (Controlled traffic research)**  
--Lyle Carter, USDA (Shafter, CA)
- 1980s **No-till dryland small grain production (Yolo, Tulare and San Luis Obispo)**  
"Zone tillage," --Lyle Carter, USDA (Shafter, CA)
- 1990s **No-till and ridge-till corn, beans, and wheat --Ralph Cosena, Sr. (Stockton, CA)**
- 1993 **Hahn Bed Disk**
- 1993 **Wilcox Performer**
- 1994 **New World Tillage Incorpramaster**
- 1994 **No-till tomato research --Jeff Mitchell (Five Points, CA)**
- 1998 **CT Workgroup formed**
- 1999 **No-till cotton/tomato long-term research (Five Points, CA)**
- 2000 **New World Tillage Optimizer**
- 2003 **No-till and strip-till cotton farm studies --Bob Prys (Riverdale, CA)**
- 2004 **Wilcox Eliminator**
- 2005 **Strip-till tomatoes --Steve Fortner and Fred Leavitt (Firebaugh, CA)**
- 2005 **Strip-till and no-till daily silage --Tom Barcellos (Tipton, CA)**
- 2008 **Coupling CT with overhead irrigation --John Diener (Five Points, CA)**

Declines in prices for agricultural products

- Widespread use of glyphosate-resistant seed
- NRCS cost-share program
- Widespread use of GPS

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CEI  
University  
Agriculture & Natural Resources



**Changes in Tillage Management in California's Central Valley**



soil

disease control

harvest efficiency

return on investment

emissions

labor

profitability

regulations

insect control

soil life

**RETHINK THE SYSTEM**

residues

weed control

equipment

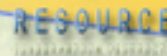
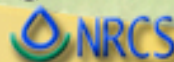
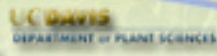
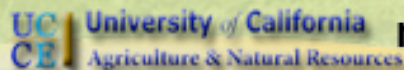
environmental  
impacts

fertilization

technology

information

water  
management



**RETHINK THE SYSTEM**

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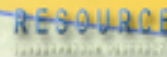
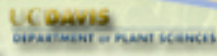
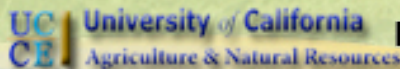
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Sustainable Conservation



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**RETHINK THE SYSTEM**

residues

weed control

equipment

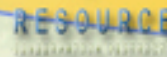
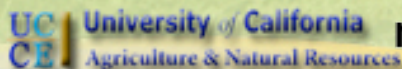
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Sustainable Conservation



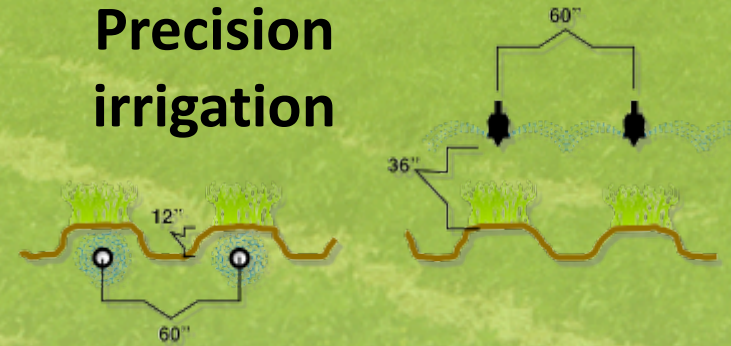
# Merging practices and technologies to achieve advanced conservation agriculture systems

*“No-till is a tool for what we’re trying to achieve.”*

## Microbial diversity



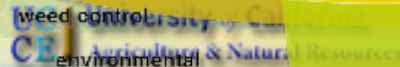
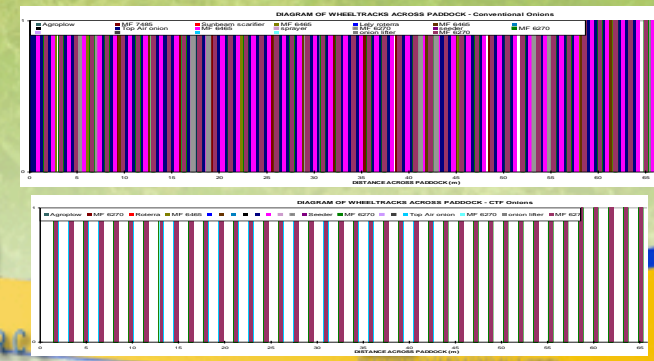
## Precision irrigation



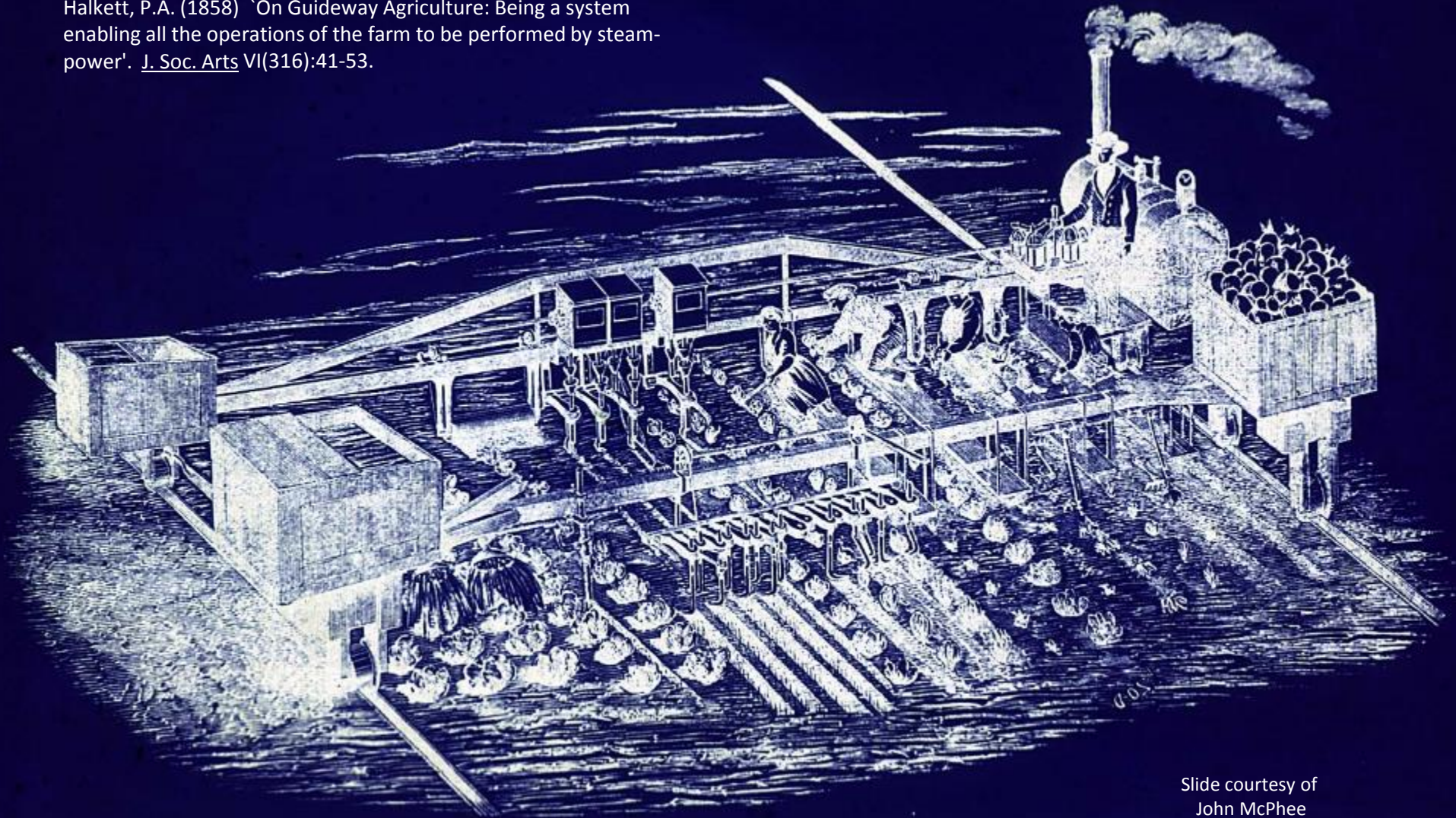
## Generating and preserving surface residues



## Controlled traffic farming

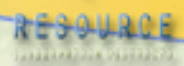


Halkett, P.A. (1858) 'On Guideway Agriculture: Being a system enabling all the operations of the farm to be performed by steam-power'. *J. Soc. Arts* VI(316):41-53.



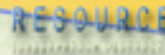
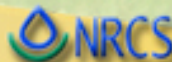
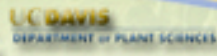
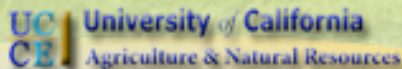
THE KENSINGTON STEAM CULTIVATOR.

Slide courtesy of  
John McPhee  
Tasmania, Australia



# Our goals have been to

- Develop information
- Bring people together
- Partner with innovative farmers
- Emphasize the whole system
- Create a strategy for better educational impact and wider adoption of conservation agriculture and efficient irrigation systems



Sustainable Conservation



# CONSERVATION AGRICULTURE

Row Crop System Development • 1993 - 2017

Cover Crop Residues

Species selection  
1991 - ongoing

Water Use  
1991 - ongoing

Water Balance /  
Runoff 1997 - ongoing

Pollution Reduction  
2001 - ongoing

Single Crop  
CT Development

Tomatoes 1996 -  
ongoing

Melons 1998 - 99

Cotton  
2000 - ongoing

Corn and Wheat  
2000 - ongoing

Integrated Irrigated  
Systems Development

Tomato - Cotton 1999 -  
ongoing

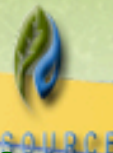
Wheat - Tomato 1999 -  
ongoing

Corn - Tomato 2000 -  
ongoing

Dairy Forage 2000 -  
ongoing

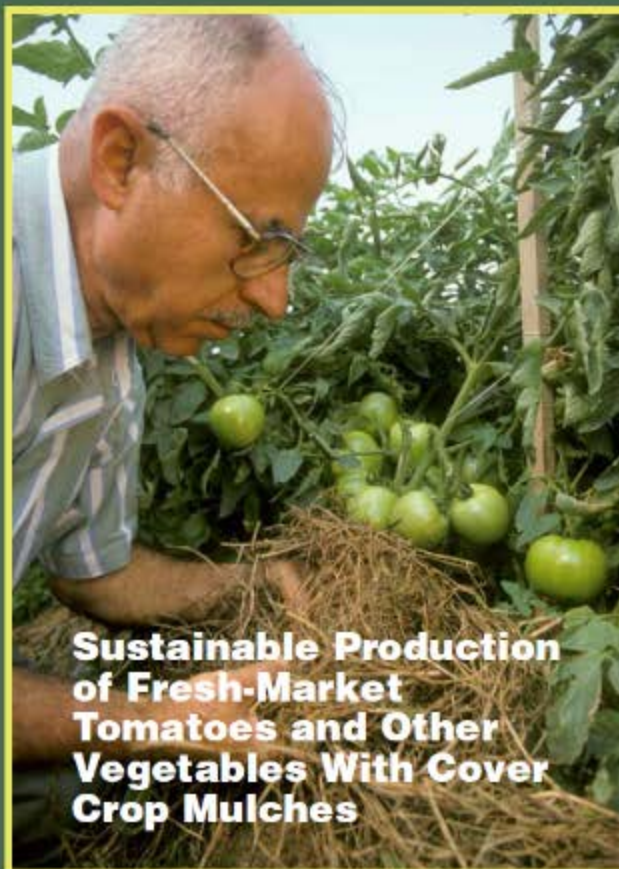


CONSERVATION  
AGRICULTURE  
Cropping Systems



winable Conservation





**Sustainable Production  
of Fresh-Market  
Tomatoes and Other  
Vegetables With Cover  
Crop Mulches**



United States  
Department  
of Agriculture

Agricultural  
Research  
Service

Farmers'  
Bulletin  
No. 2280

October  
2007

“Show me that it won’t work.”

Aref Abdul-Baki  
USDA ARS  
Beltsville, MD



The 'early' history - 1994



Rototiller Strip-tiller  
Hal Robertson  
Tracy, CA  
2001



**Development of no-till tomato  
transplant capability in California  
(1995 – 2004)**

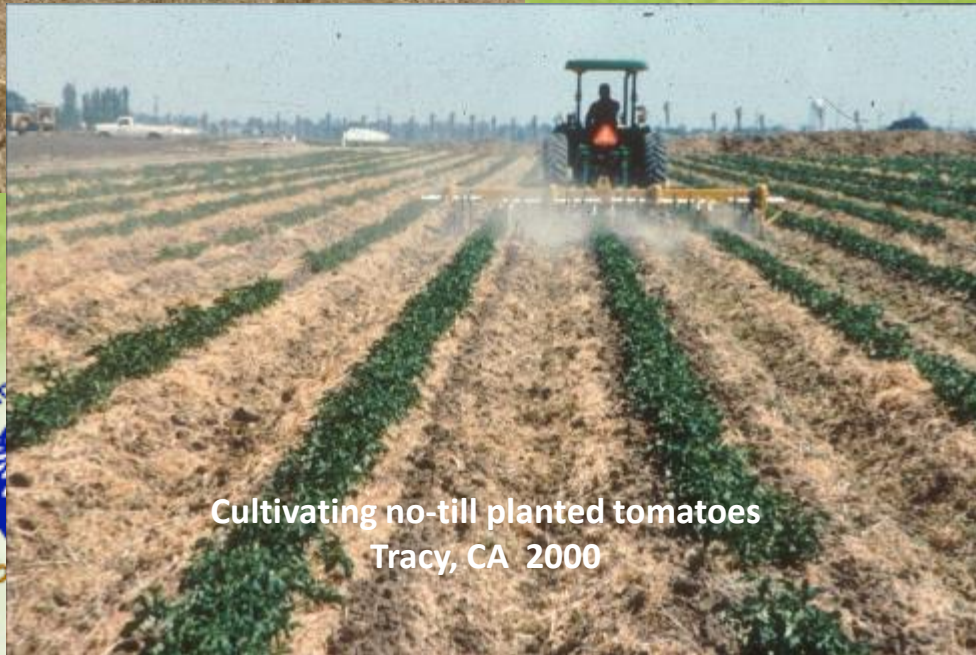
**Acknowledgements: Ron Morse,  
Aref Abdul-Baki and Steve Groff**



No-till tomato transplanting  
Five Points, CA 1997



Strip-till tomato transplanting  
Winters, CA 2001



Cultivating no-till planted tomatoes  
Tracy, CA 2000

**American Vegetable Grower**  
October 2001

**Conservation-Till Tools**  
A New Perspective  
On Vegetable Field Prep  
page 18

Plus:  
Crop Protection 2001 page 30  
Evaluating Irrigation Pump Performance page 34

COMPLIMENTARY ISSUE

AMERICAN VEGETABLE GROWER PUBLISHED BY THE NATIONAL VEGETABLE PROCESSORS ASSOCIATION

Conservation  
INNO




## The research base

**From 1999, ongoing work with CT tomato and cotton systems in Five Points, CA**

NRI CT Project Field Fall 2007  
UC West Side Research and Extension Center  
Five Points, CA



Rainfed winter cover  
crop being seeded  
into cotton and  
tomato residue Five  
Points, CA 2007

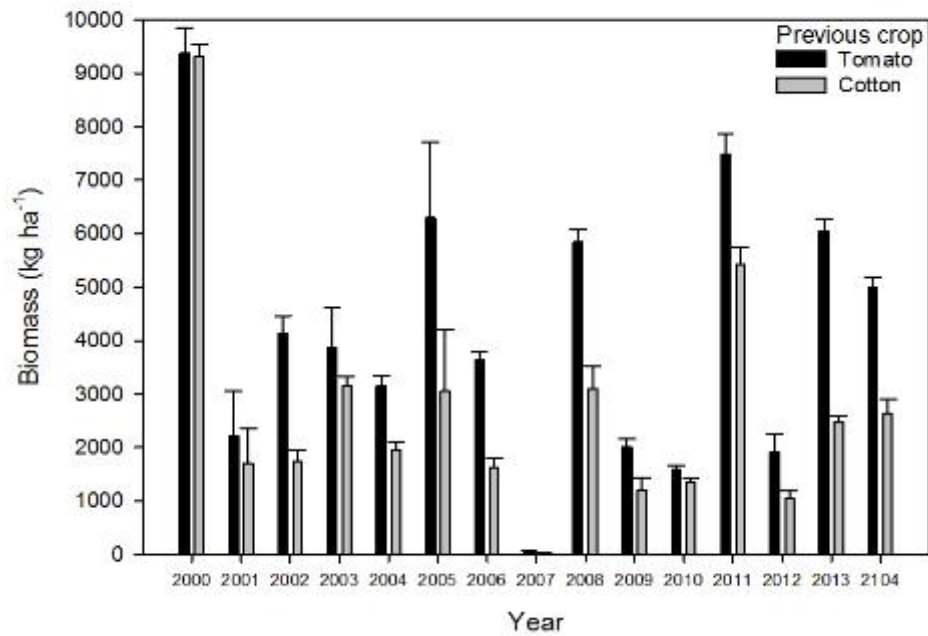


**Winter, rainfed triticale, rye and pea cover crop no-till  
seeded into cotton and tomato residues  
Five Points, CA 2008**

No-till tomato transplanting  
into cotton and cover crop  
residue  
Five Points, CA  
2007



**Cover crop biomass in long-term study  
in  
Five Points, CA  
2000 – 2014**



**20 tons  
of  
organic  
matter**

**7.5 tons of  
carbon**



No-Till

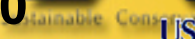
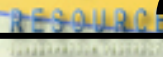
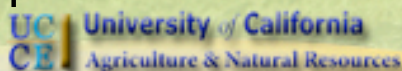
A photograph of a cotton field. The foreground and middle ground are filled with rows of lush green cotton plants. A narrow, straight path of dry, harvested cotton stalks runs down the center of the field, leading towards the horizon. The sky is bright and clear, and the overall scene is well-lit, suggesting a sunny day. The text "No-till cotton 2011 yields" and "3.2 bales/ac" is overlaid on the left side of the image.

**No-till cotton 2011 yields**

**3.2 bales/ac**

**Cultural costs for standard tillage (ST) versus conservation tillage (CT) for processing tomato, Westside Field Station, 2003 (operations expensed at 2007 input prices)**

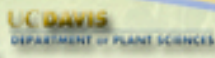
<b>Cultural costs</b>	<b>ST</b>	<b>CT</b>	<b>Difference (ST-CT)</b>
Fertilizer	79	79	0
Seed	176	176	0
Herbicide	76	70	6
Insecticide	0	0	0
Water	163	163	0
Labor (machine)	36	19	17
Labor (irrigation)	110	110	0
Labor (hand weed)	84	84	0
Fuel	58	21	37
Lube and repair	34	16	18
Interest	36	31	5
<b>Total cultural</b>	<b>853</b>	<b>770</b>	<b>83</b>



**Tillage and cover crop system erosion estimates, soil condition index sub-factors, soil tillage intensity rating and estimates of diesel fuel use.**

<b>Cropping System*</b>	<b>Erosion Estimates<sup>‡</sup> RUSLE2 (Mg ha<sup>-1</sup>)</b>	<b>Soil Condition index</b>	<b>STIR Average Annual</b>	<b>Diesel fuel use</b>	<b>Fuel cost for entire simulation (\$)</b>
<b>STNO</b>	<b>0.2</b>	<b>-0.71</b>	<b>261</b>	<b>32</b>	<b>128.6</b>
<b>STCC</b>	<b>0.07</b>	<b>-0.96</b>	<b>390</b>	<b>40</b>	<b>160.6</b>
<b>CTNO</b>	<b>0.04</b>	<b>0.43</b>	<b>30.6</b>	<b>9.3</b>	<b>36.8</b>
<b>CTCC</b>	<b>0.03</b>	<b>0.52</b>	<b>37.1</b>	<b>11</b>	<b>43.27</b>

\* STNO = Standard tillage no cover crop, STCC = Standard tillage with cover crop, CTNO = Conservation tillage no cover crop CTCC = Conservation tillage with cover crop.



Soil carbon mass for tillage and cover crop treatments\* at two soil depths  
At the start of the study in the fall of 1999 and in the fall of 2007.

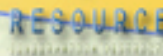
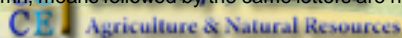
1999			2007		
Depth (cm)	Treatment	Mean <sup>s</sup> (t ha <sup>-1</sup> )	Depth (cm)	Treatment	Mean <sup>s</sup> (t ha <sup>-1</sup> )
0 – 15	<b>NTCC</b>	<b>9.33</b> (0.18, A)	0 - 15	<b>NTCC</b>	<b>16.20</b> (0.53, A)
	<b>STCC</b>	<b>9.25</b> (0.40, A)		<b>STCC</b>	<b>12.69</b> (0.29, AB)
	<b>NTNO</b>	<b>9.27</b> (0.41, A)		<b>NTNO</b>	<b>13.13</b> (0.46, AB)
	<b>STNO</b>	<b>8.87</b> (0.31, A)		<b>STNO</b>	<b>10.84</b> (0.19, B)
15 - 30	<b>NTCC</b>	<b>10.39</b> (0.30, A)	15 - 30	<b>NTCC</b>	<b>12.91</b> (0.62, AB)
	<b>STCC</b>	<b>10.66</b> (0.99, A)		<b>STCC</b>	<b>13.67</b> (0.65, A)
	<b>NTNO</b>	<b>11.40</b> (1.11, A)		<b>NTNO</b>	<b>10.96</b> (0.51, B)
	<b>STNO</b>	<b>9.69</b> (0.52, A)		<b>STNO</b>	<b>11.81</b> (0.31, AB)
Total	<b>NTCC</b>	<b>19.71</b> (0.45, A)	Total	<b>NTCC</b>	<b>29.11</b> (0.94, A)
	<b>STCC</b>	<b>19.91</b> (1.20, A)		<b>STCC</b>	<b>26.36</b> (0.78, AB)
	<b>NTNO</b>	<b>20.67</b> (1.03, A)		<b>NTNO</b>	<b>24.09</b> (0.81, BC)
	<b>STNO</b>	<b>18.57</b> (0.75, A)		<b>STNO</b>	<b>22.65</b> (0.26, C)

**ST**= conventional tillage; **NT**= no-tillage; **NO**= no cover crop; **CC**= winter cover crop

Mitchell et al., 2015  
Agron. J. 107(2):588-596

Values in parentheses are standard error of the means (n= 8).

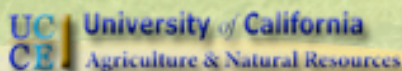
Within a column, means followed by the same letters are not significantly different using a one-way ANOVA analysis with Tukey HSD means comparison.



# USDA NRCS Soil Quality Test Kit



System	Aggregate Stability (%)	Slaking * (Slaking Class)	Water Infiltration (time)	
			(First inch of water)	(Second inch of water)
<b>STNO</b>	28.3 ± 14.2	3.18 ± 0.56	2:02 + 0:44	10:14 ± 2:23
<b>STCC</b>	47.0 ± 19.1	3.65 ± 0.38	0.35 + 0:15	4:54 ± 2:08
<b>CTNO</b>	40.4 ± 15.7	3.76 ± 0.53	1.29 + 1:05	13:41 ± 12:13
<b>CTCC</b>	69.9 ± 9.5	5.28 ± 0.52	0.06 + 0.03	0.53 ± 0.43





## Cover cropping and no-tillage improve soil health in an arid irrigated cropping system in California's San Joaquin Valley, USA



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Randal J. Southard<sup>d</sup>, Richard L. Haney<sup>e</sup>, Radomir Schmidt<sup>d</sup>, Daniel S. Munk<sup>f</sup>,  
William R. Horwath<sup>d</sup>

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<sup>c</sup> Department of Plant Sciences, University of California, Davis, 95616, United States

<sup>d</sup> Department of Land, Air and Water Resources, University of California, Davis, One Shields Avenue, Davis, CA 95616, United States

<sup>e</sup> USDA Agricultural Research Service, 808 E. Blackland Road, Temple, TX 76502, United States

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Conservation agriculture

### ABSTRACT

The concept of soil health has attracted considerable attention during the past two decades, but few studies have focused on the effects on soil health of long-term soil management in arid irrigated environments. We investigated the effects of cover cropping and no-till management on soil physical and chemical properties during a 15-year experiment in California's San Joaquin Valley (SJV) USA. Our objective was to determine if soil health could be improved by these practices in an annual crop rotation. The impact of long-term no-tillage (NT) and cover cropping (CC) practices, alone and in combination, was measured and compared with standard tillage (ST) with and without cover crops (NO) in irrigated row crops after 15 years of management. Soil aggregation, rates of water infiltration, content of carbon, nitrogen, water extractable organic carbon (WEOC) and organic nitrogen (WEON), residue cover, and biological activity were all increased by NT and CC practices relative to STNO. However, effects varied by depth with NT increasing soil bulk density by 12% in the 0–15 cm depth and 10% in the 15–30 cm depth. Higher levels of WEOC were found in the CC surface (0–5 cm) depth in both spring and fall samplings in 2014. Surface layer (0–15 cm) WEON was higher in the CC systems for both samplings. Tillage did not affect WEON in the spring, but WEON was increased in the NT surface soil layer in the fall. Sampling depth, CC, and tillage affected 1-day soil respiration and a soil health index assessment, however the effects were seasonal, with higher levels found in the fall sampling than in the spring. Both respiration and the soil health index were increased by CC with higher levels found in the 0–5 cm depth than in the 5–15 and 15–30 cm depths. Results indicated that adoption of NT and CC in arid, irrigated cropping systems could benefit soil health by improving chemical, physical, and biological indicators of soil functions while maintaining similar crop yields as the ST system.

**NO-TILL  
FARMER**

November 2014  
Volume 43, No. 11  
[www.no-tillfarmer.com](http://www.no-tillfarmer.com)

# Conservation Tillage Guide



## What Makes Your No-Till Soils Tick?

- The No-Till Solution For Preventing Algae Blooms
- How Grazing Cover Crops Gives No-Tillers A Boost
- Gauge Wheels Head Down A New High-Tech Path

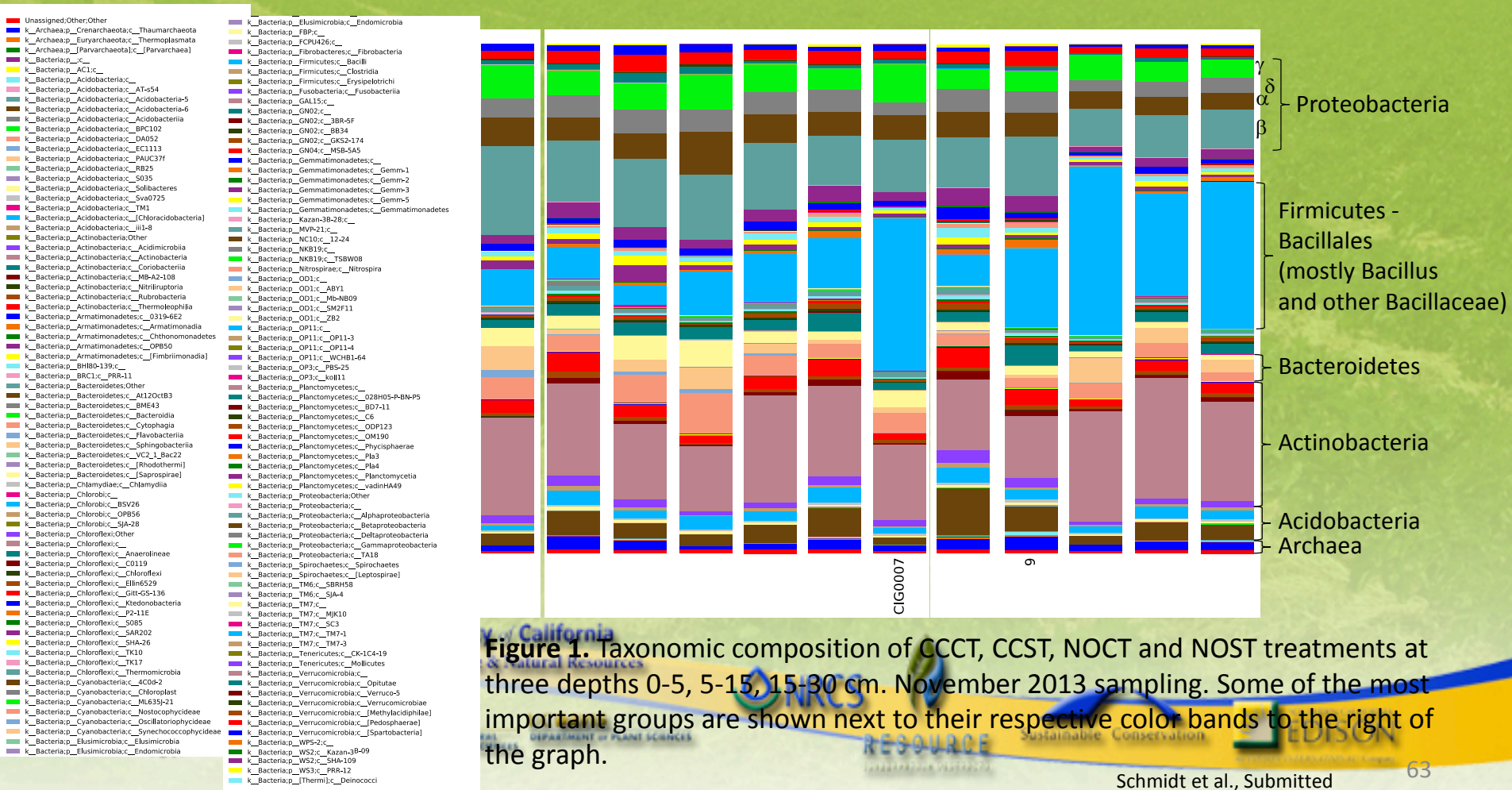


UC  
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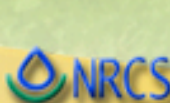
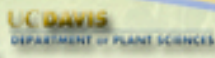
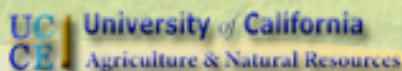
# Community Taxonomic Composition

- NOST at all depths and NOCT 0-5 cm show much higher proportion of Firmicutes (mainly Bacillus and other Bacillaceae) (28.1±5.5%) than all other soils (8.3±3.5%).
- Higher Firmicute numbers are offset primarily by lower Proteobacteria in the high Firmicute soils in comparison to other soils (19.9±3.5% vs 27.4±3.9% respectively).
- Some information on Archaea is available, though the primers used may not provide a highly accurate representation of the Archaeal community.



# Conclusions (preliminary)

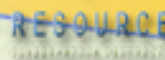
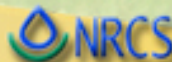
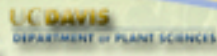
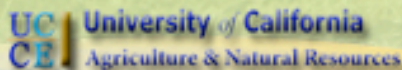
- Some of the cover crop treatment soils show highest species richness, while some of the no cover crop soils show least richness.
- NOST treatments and NOCT at 0-5 cm show similar trends in community composition and also cluster together in beta diversity analysis.
- While we have not yet been able to assign soil functions to differences in firmicute and proteobacteria percentages, the trend for higher percentage of proteobacteria in conservation tilled plots has been observed in at least one other study (no-till rice paddy fields; Aslam, Z, Yasir, M, Yoon, HS, Jeon, CO and Chung, YR (2013). "Diversity of the bacterial community in the rice rhizosphere managed under conventional and no-tillage practices." Journal of Microbiology 51(6): 747-756)
- The sequencing results are consistent with other data from Five Points and show that:
  - cover crops exert a strong influence on microbial community composition as well as soil properties.
  - the NOST treatment is distinct from the other three treatments.
- There is more diversity in the cover crop soils. .
- This might have relevance in terms of resilience.



Schmidt et al., Submitted

# Summary

- We have seen changes in soil properties.
- Principles and theory suggest that they are beneficial.
- Making the changes is not at all a simple thing.
- Next work is aimed at better understanding of the functional meaning of these changes.



Sustainable Conservation



A man wearing a red polo shirt, a light-colored baseball cap, and sunglasses stands in a lush green cornfield. In the background, a large center pivot irrigation system is visible under a clear blue sky. The man is gesturing with his hands as if speaking.

**“Take the ‘E’ out of ‘ET’ and the ‘T’ out of ‘can’t.’”**

**Dwayne Beck  
South Dakota State University  
(South Dakota Hall of Fame 2008)**

November 2013

# Irrigation Extra

www.irrigationextra.com

## Free H<sub>2</sub>O in no-till residue

By DON MCCABE

**Key Points**

- No-till residue traps moisture in the soil.
- No-till residue traps moisture in the soil.
- No-till residue traps moisture in the soil.

It's a form of natural water...  
 Evidence from irrigation...  
 Farmers who irrigate with...  
 Nebraska irrigators...  
 For You



24 | www.FarmProgress.com • October 2013

Dakota Herald

## Crops

### No-till increases dryland moisture

By LORRETTA SORESEN

**Key Points**

- No-till helps improve soil moisture.
- Farmers should consider no-till to save moisture and improve soil quality.
- No-till helps improve soil quality.

**M**ORE of the land surrounding Larry (and 2,000 acres of crops) in northeastern South Dakota, that's because the land is a flat, open, unbroken expanse of grass.

In addition to the challenges of no-till, there's also the challenge of crop residue. Crop residue left in the field can be a double-edged sword. It can help retain moisture and reduce erosion, but it can also be a problem if it's not managed properly.

...the water generally gets...  
 ...the water generally gets...  
 ...the water generally gets...



**SOIL ARMOR:** Dryland crops grow through and around, which is protecting against soil erosion and reducing evaporation.

## Modern Irrigation, Less Tillage Makes Every Drop Of Water Count

With shrinking water supplies, no-till, strip-till and technology tools can conserve the precious resource and even boost crop yields.

By Dick Emrich, Technology Editor

**O**ak the elements involved in producing a healthy crop, water may be the most often used, which are costly resources, production is too cheap.

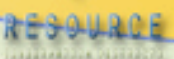
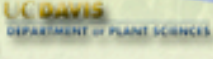
...the water generally gets...  
 ...the water generally gets...  
 ...the water generally gets...

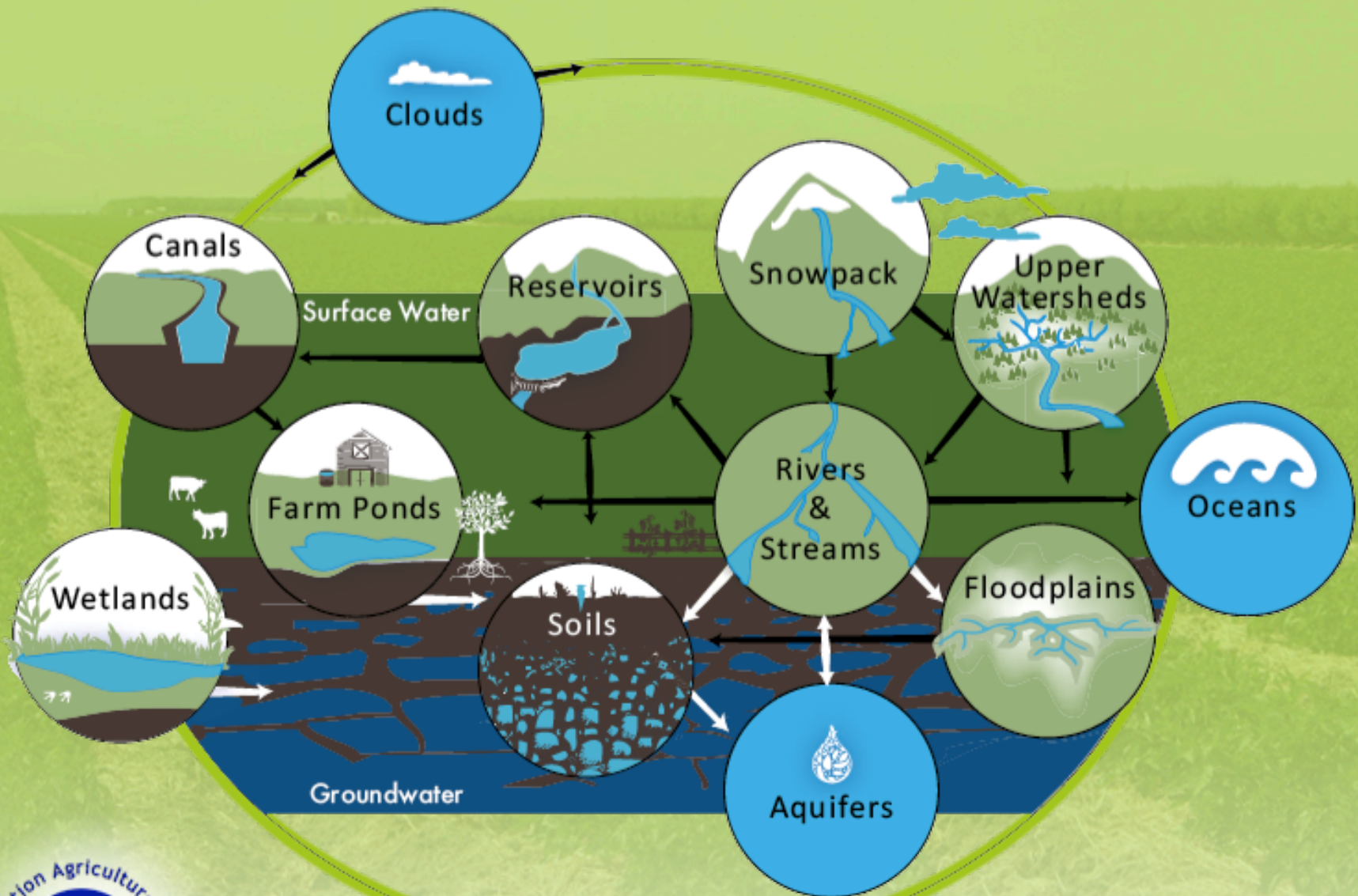
**No-Till Advantages**

Water conservation is...  
 ...the water generally gets...  
 ...the water generally gets...



UC Agriculture & Natural Resources





UC | University of California  
CE | Agriculture & Natural Resources

UC DAVIS  
COLLEGE OF AGRICULTURAL  
AND ENVIRONMENTAL SCIENCES

UC DAVIS  
DEPARTMENT OF PLANT SCIENCES

From Storage to Retention: Expanding California's Options for Meeting its Water Needs  
California Roundtable on Water and Food Supply

November 2012



EDISON  
CALIFORNIA STATE UNIVERSITY

## **% surface residue in tillage and cover crop systems**

	<b>12/10/2009</b>	<b>5/29/2010</b>	<b>8/10/2014</b>	<b>3/19/2016</b>	<b>3/20/2017</b>
Standard till no cover crop	5	2	3	3	6
Standard till cover crop	6	2	27	68	24
No-till no cover crop	90	83	71	77	90
No-till cover crop	91	93	97	97	96



First recorded example of no-till,  
high residue planting with two  
irrigations avoided because of residues

Five Points, CA

July 3, 2003

“Take the ‘E’ out of ‘ET.’”

Dwayne Beck  
South Dakota State University

*We estimated 0.89 and 0.97 inches (2.3 and 2.5 cm) more water retained in the surface foot of soil under no-till than in tilled soil following intercrop tillage between wheat silage and corn.*


*In press  
California Agriculture  
April 2012*



**Soil evaporation study under residue mulch and bare conditions  
Five Points, CA  
September 2009**

*Assuming a seasonal crop evapotranspiration demand of 30 inches,  
coupling no-tillage with high residue preserving practices could  
reduce summer season soil evaporative losses by  
about 4 inches (10.2 cm) or 13%.*

*In press  
California Agriculture  
April 2012*

A wide-angle photograph of a vast agricultural field. The foreground and middle ground are filled with rows of young, green cover crops planted in dark, rich soil. The rows stretch far into the distance, creating a strong sense of perspective. The sky is filled with large, grey, overcast clouds, suggesting an impending storm or a cloudy day. In the far distance, a few utility poles and a small building are visible on the horizon. The overall scene is one of a large-scale agricultural operation.

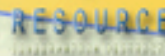
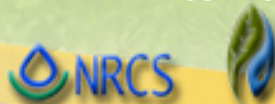
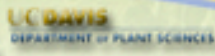
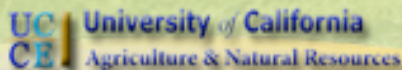
**A big concern related to the use of cover crops in California's Central Valley is of course, their water use.**



Evaluating the extent of soil water depletion with  
winter cover crops  
(Can more water go to transpiration  
rather than through soil water evaporation? - 'Catch and  
release' carbon to gain cropping system benefits - a la Dwayne Beck)

# Difference in volumetric soil water content in top 90 cm from January – March 23, 2013 under fallow and cover crop

- Using Decagon ECHO EC5 sensor                      2.6 inches
- Using neutron probe    1.6 inches



Work in progress  
in tomato fields and almond orchards

A wide-angle photograph of a lush green cover crop field, likely sorghum, stretching to the horizon. The plants are arranged in neat rows, with a dirt path or wheel track visible in the foreground. The sky is overcast and grey. In the distance, some utility poles and structures are visible on the horizon line.

**Typical cover crop growth stage (or do it earlier)  
at time of herbicide application**



Some of the early pioneering work by farmers  
Firebaugh, CA  
2003



Ground-driven strip-tiller  
Firebaugh, CA  
2003

**First ever scaling up of**

**Commercialization of strip-till and cover crop practices  
at Sun Pacific and Sano Farms, Firebaugh, CA  
since 2004**





**“Scaling up” conservation tillage techniques  
at commercial processing tomato farm  
Firebaugh, CA  
2008**



**Strip-till planted processing tomatoes  
Firebaugh, CA 2006**

**First ever subsurface drip coupled with permanent  
beds and strip-till cover cropped fresh  
market tomato production  
Firebaugh, CA  
2003**





Fresh market tomatoes into barley cover crop mulch  
Firebaugh, CA 2003



<https://www.whitehouse.gov/blog/2015/10/27/acting-climate-through-sustainable-agriculture-white-house-champions-change>



- Soil care -  
Farmers observing changes  
in soil quality  
Firebaugh, CA 2006



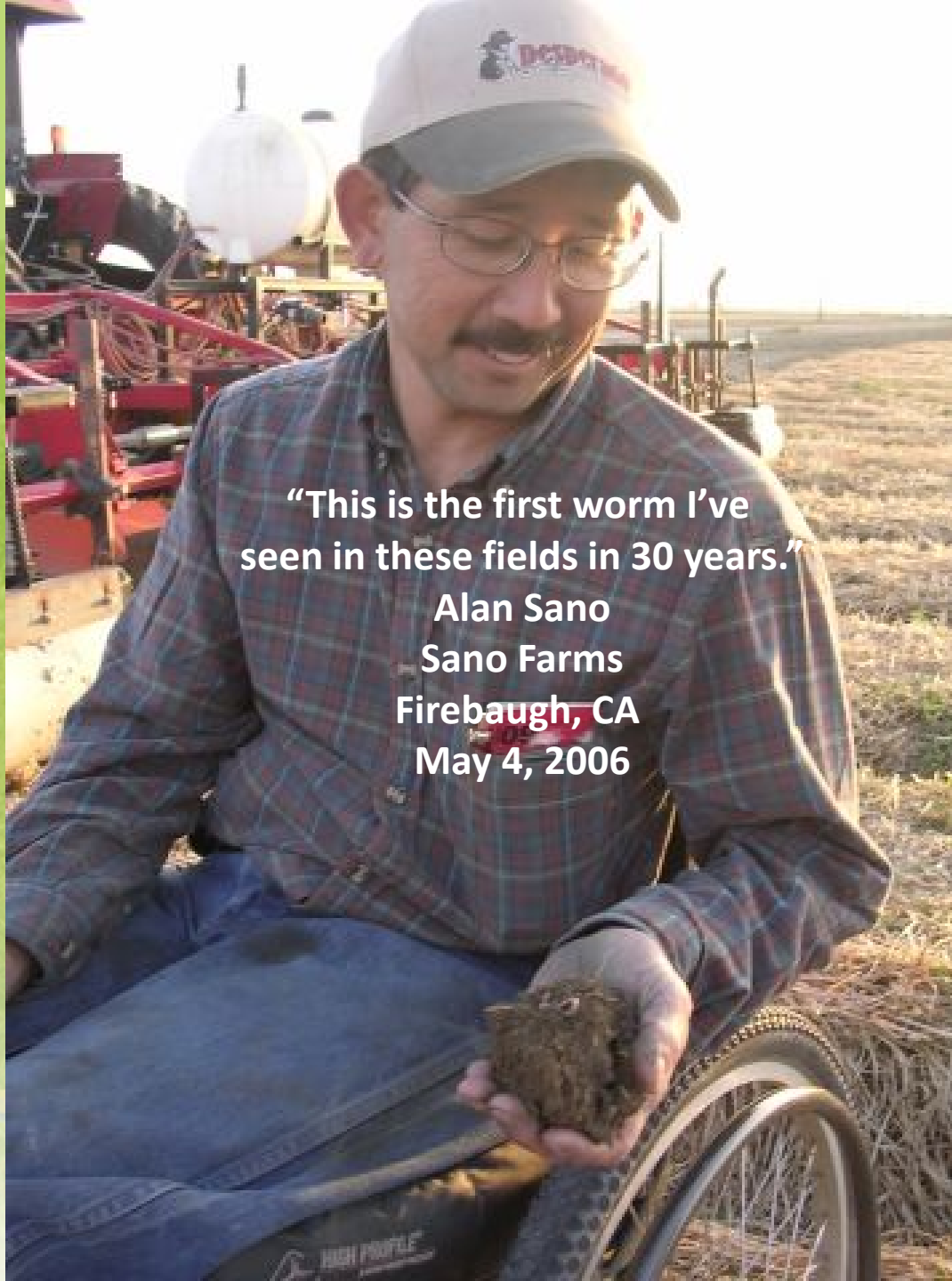
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UC DAVIS DEPARTMENT OF PLANT SCIENCES



Sustainable Conservation





**“This is the first worm I’ve  
seen in these fields in 30 years.”**

**Alan Sano  
Sano Farms  
Firebaugh, CA  
May 4, 2006**





**Eight-row 60" strip-tilled cover crop tomato  
transplanting  
The Morning Star Company  
Hollister, CA  
2010**







UC  
CE



Conservation



EDISON  
Center for Conservation Agriculture



**2005**  
**Bob Prys**  
Lemoore, CA



**2006**  
**Tom Barcellos**  
Tipton



**2007**  
**Jim Couto**  
Kerman



**2007**  
**Tony Turkovich**  
Winters



**2008**  
**Dino Giacomazzi**  
Hanford



**2009**  
**Jesse Sanchez**  
Firebaugh



**2009**  
**Alan Sano**  
Firebaugh



**2010**  
**John Diener**  
Five Points



**2011**  
**Fred Leavitt**  
Firebaugh



**2011**  
**Michael Crowell**  
Turlock



**2012**  
**Gary Martin**  
Firebaugh



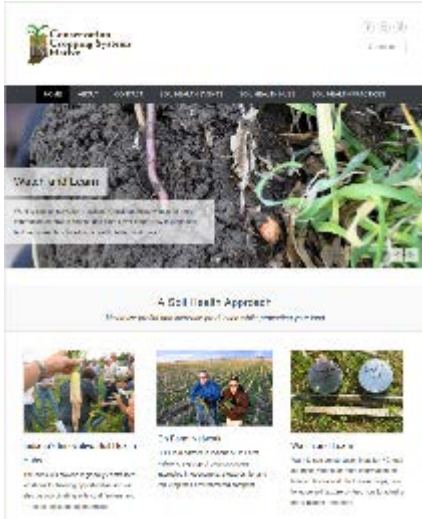
**2013**  
**Danny Ramos**  
Los Banos



**2013**  
**Ralph Ceseña, Sr.**  
Stockton

## Conservation Tillage CT Farmer Innovator Awardees





Indiana Conservation Cropping Systems Initiative

Examples of very successful efforts in other regions that are already working



Pacific Northwest Direct Seed Association



Georgia Conservation Tillage Alliance



Various farmer-led cooperatives in South America



Soil Health Partnership IA, IL, IN

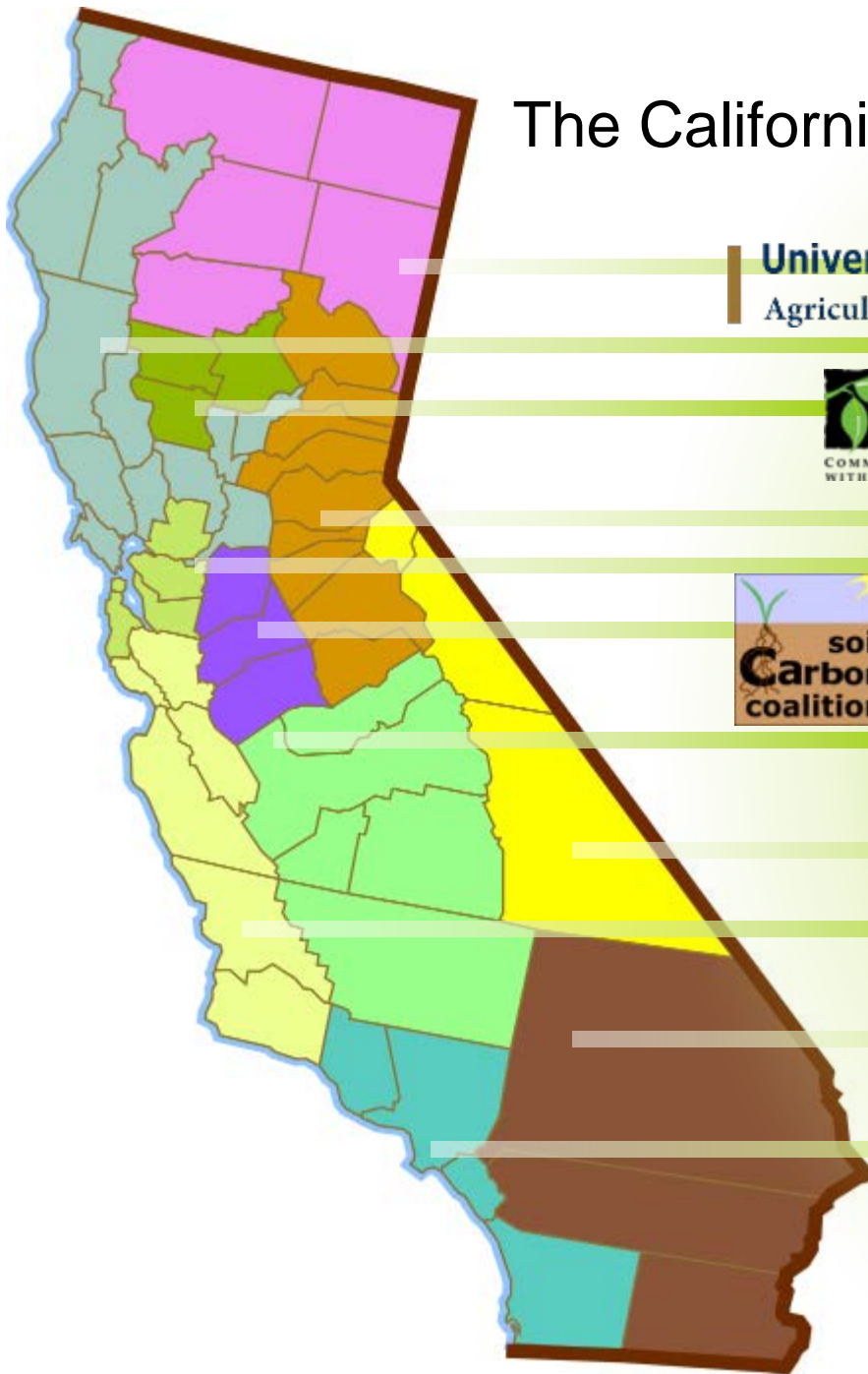
University of California  
Agriculture & Natural Resources



# California Farm Demonstration Network



# The California Farm Demonstration Network



University of California  
Agriculture & Natural Resources





**SHOWCASING OF  
EXISTING  
EXPERIENCE**

- focused on experienced farmers
- public sharing

**EDUCATION, COMPILATION OF  
KNOWLEDGE AND EXPERIENCE,  
AND SHARING OF KNOWLEDGE**

- development of content and information sharing activities

**CLIMATE-SMART  
AGRICULTURE DECISION  
TOOL GUIDANCE AND  
SUPPORT**

**FARM DEMONSTRATION  
EVALUATIONS**

- implementation of conservation agriculture practices and systems by new wave of farmers
- showcasing of practical learning
- connecting people in productive local efforts

**FARM DEMONSTRATION  
PERFORMANCE MONITORING**

- development, testing, of performance-monitoring metrics

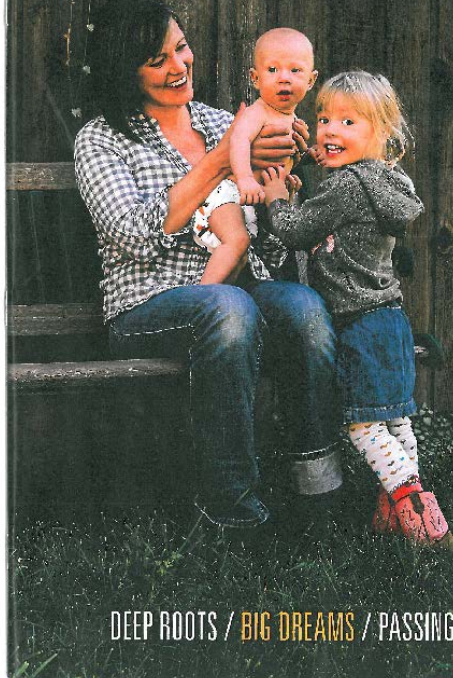
**ONLINE DATA AND  
INFORMATION SHARING**

SPECIAL ISSUE: THE MEASURE OF SUCCESS

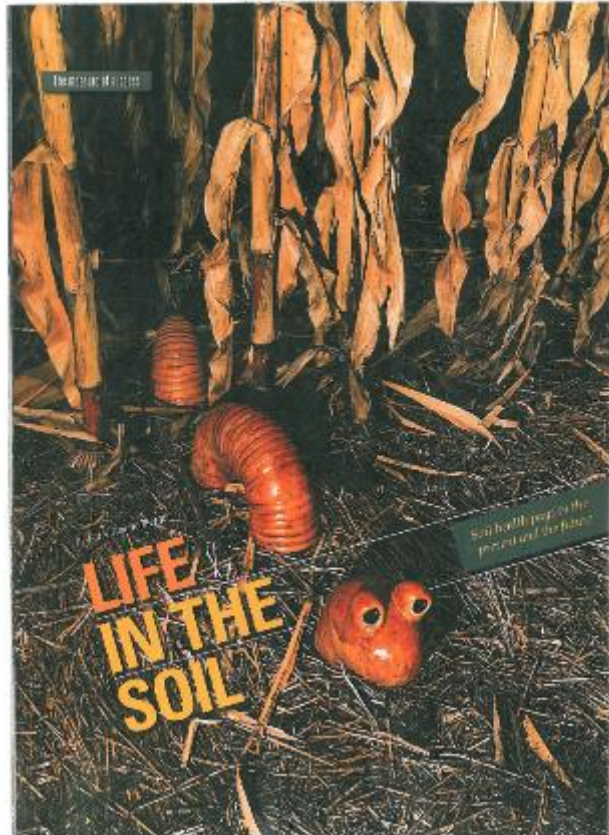
# THE FURROW

FEBRUARY 2014

## BACK TO THE FARM



DEEP ROOTS / BIG DREAMS / PASSING IT ON



THE MEASURE OF SUCCESS

### LIFE IN THE SOIL

Soil health pays for the protection of the future

**H**ealthy soils are the ultimate measure of success for Rick Bieber. With the goal of increasing the Trail City, SD, farmer practices that enhance soil quality, he swears by the old adage, "If you take care of your soil, your soil will take care of you."

"The soil is the greatest source of wealth in the world, but most farmers squander its potential," says Bieber, who farms with his son, Ben. "The soil isn't just a tool, it's a full partner in a farming operation and deserves to be treated with respect. Learn to protect the soil and to manage it like it's really alive—because it is—and you will see an additional response."

**Diversity in crops.** Bieber's recipe for a healthy soil includes legume cover-crops, intensive crop rotation, and cover crops. "We started rotating in 2007 and soon learned we needed to diversify and intensify our crop rotation to utilize the moisture we were saving and to boost microbial activity in the soil. From wheat/fallow and soybean/fallow, we changed to rotations that also include chickpea, alfalfa, flax, sunflower, and alfalfa. More recently we've added cover crops that are planted after wheat and intercropped into growing corn."

"Now, our yields are higher with lower inputs so productivity has increased. And, the impact of drought, heat, and other stress is less. Our 10-year proven corn yields are 430% of the county average, and wheat yields are 200% of the county's," adds Bieber.

**Credit the soil.** Bieber is quick to deflect credit for this performance. "It's really due to the soil—all the dew it provides, what the soil lets us do with its diversity," he says.

What Bieber practices is a steady supply of carbon—is the form of crop residue and living plant roots—that feeds soil microbes, maintains soil temperatures to protect the microbes, shields the soil surface from erosion, and builds soil organic matter levels. Bieber measures performance of his system in various ways. "We used to apply 90 pounds per acre of nitrogen and produce 90 bushels of corn, but now the same amount of nitrogen produces 300 bushels. That's due mostly to our soil organic matter levels, which are 4.8% in our long-term soil."

In contrast, typical conventional tillage fields in Bieber's area have soil organic matter levels around 2%. Soil with higher organic matter not only mineralizes more nitrogen, it also holds more water, and that's the

key to crop resilience and success.

"We manage our management skills by the amount of grain we produce per acre of corn, and we've seen this increase efficiency because our soil health has improved. In 2008 we produced just over 4 bushels of corn per inch of rainfall. By 2013, the first year rain in our rotation zone in over eight years, we had increased to 54 bushels per acre. By 2012, that efficiency had increased to 623 bushels per inch of rainfall."

**Best combination.** Bieber worked with agricultural Cheryl Stepp from South Dakota State University on an intensive cover crop study from 2009 through 2011. "There were 96 trials, and they showed that the best combination of cover crops and fertilizer was planted in 126 bushels of corn per inch of rainfall. That was in 2012, with a severe drought, corn on our farm, next year produced 940 bushels per acre of rainfall, while some no-till ground—in the year of no-till—produced only 4 bushels per inch. That was amazingly similar to what we saw in 1996," says Bieber.

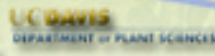
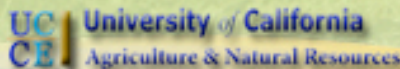
**Hungry soil.** The water use efficiency data has convinced Bieber, but his soils are hungry for the next crop, too. "Living plants sequester carbon from the atmosphere and deposit it in the soil. Though this is not a system, we've found to be something growing every cropland that the world will look to," he says.

Cover crops allow Bieber to put the production into practice. "We have an extra year, so we can plant cover crops right behind the combine during wheat harvest. And, the cover crops we introduced at the V6 stage of our corn may allow soil after the corn matures in the fall," he says.

"We're protecting soil not just for the next generation, but for those 100 and 1,000 years from now," he adds. ■



## “Soil care’ is what we’re doing.”



Rick Bieber  
Trail City, SD  
January 28, 2014

Sustainable Conservation



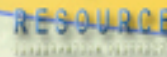
# 2014 Winter Conference of No-till on the Plains

Salina, KS

January 27 – 28, 2014

'Take the hardest crop you have and show that it will work.'

Rick Bieber  
Trail City, SD



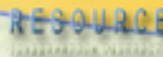
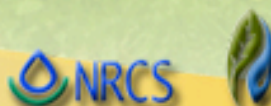
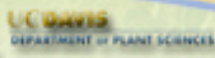
"The Tillage Lab"

USDA



Agricultural  
Research Service

"Until *conservation* is conventional..."



# FORTY CHANCES



Finding Hope in a Hungry World  
Photographs by Howard G. Buffett

NEW YORK TIMES BESTSELLER

Howard G. Buffett

WITH HOWARD W. BUFFETT



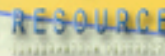
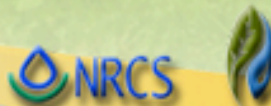
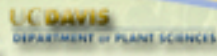
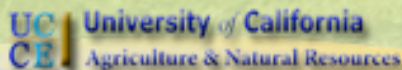
Finding Hope  
in a Hungry World

FOREWORD BY WARREN E. BUFFETT

“Take the ‘E’ out of ‘ET’ and the  
‘T’ out of ‘can’t.”

Dwayne Beck

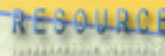
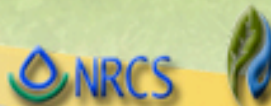
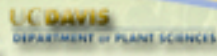
2014



‘Overcome the mindset that it  
can’t be done.’

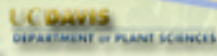
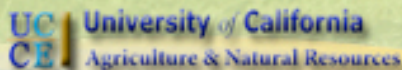
Dwayne Beck

2014



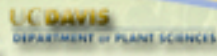
# This has all come from considerable collaboration with many people

- Alan Sano
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- Paul Muller
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- Matt Rossow
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- Randy Southard
- Howard Ferris
- Alan Wilcox
- Juan Trujillo
- Dan Munk
- Jeannette Warnert



# Greetings and thanks to my NRCS colleagues!

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- Josh Elke
- Carol Mandel
- Genett Carstensen
- Joe Williams
- Alison Hatch
- Ray Archuleta
- Johnnie Siliznoff





RESOURCE  
CONSERVATION DISTRICTS



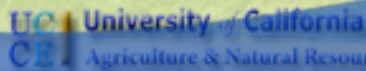
SOIL  
AND WATER  
CONSERVATION  
SOCIETY



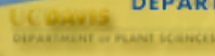
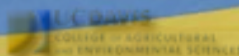
Sustainable Conservation



*Thank you.* **UC  
CE**



*Making a Difference for California*



Sustainable



# Jeff Mitchell

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