After fifteen years of cover cropping and no-tillage, how have soil properties changed?

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2015 Northern SJV Processing Tomato Meeting
In Conjunction with the California Tomato Growers Assocation
68th Annual Meeting of Members and Exhibit
Doubletree Hotel, Modesto, CA
January 29, 2015 10:40 AM

Outline of Discussion

- Cover crops in California's Central Valley annual cropping systems – falling behind
- Long-term cover crop biomass evaluation
- Trade-offs between cover crop productivity and soil water depletion
- Scaled-up innovation with cover crops in California

How might we begin to imagine more water-use-efficient tillage, residue and irrigation management systems becoming of value and adapted and becoming more widely adopted in California?

Mother Nature…

- harvests the maximum amount of sunlight
- leaks very few nutrients including CO_2
- 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

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

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**

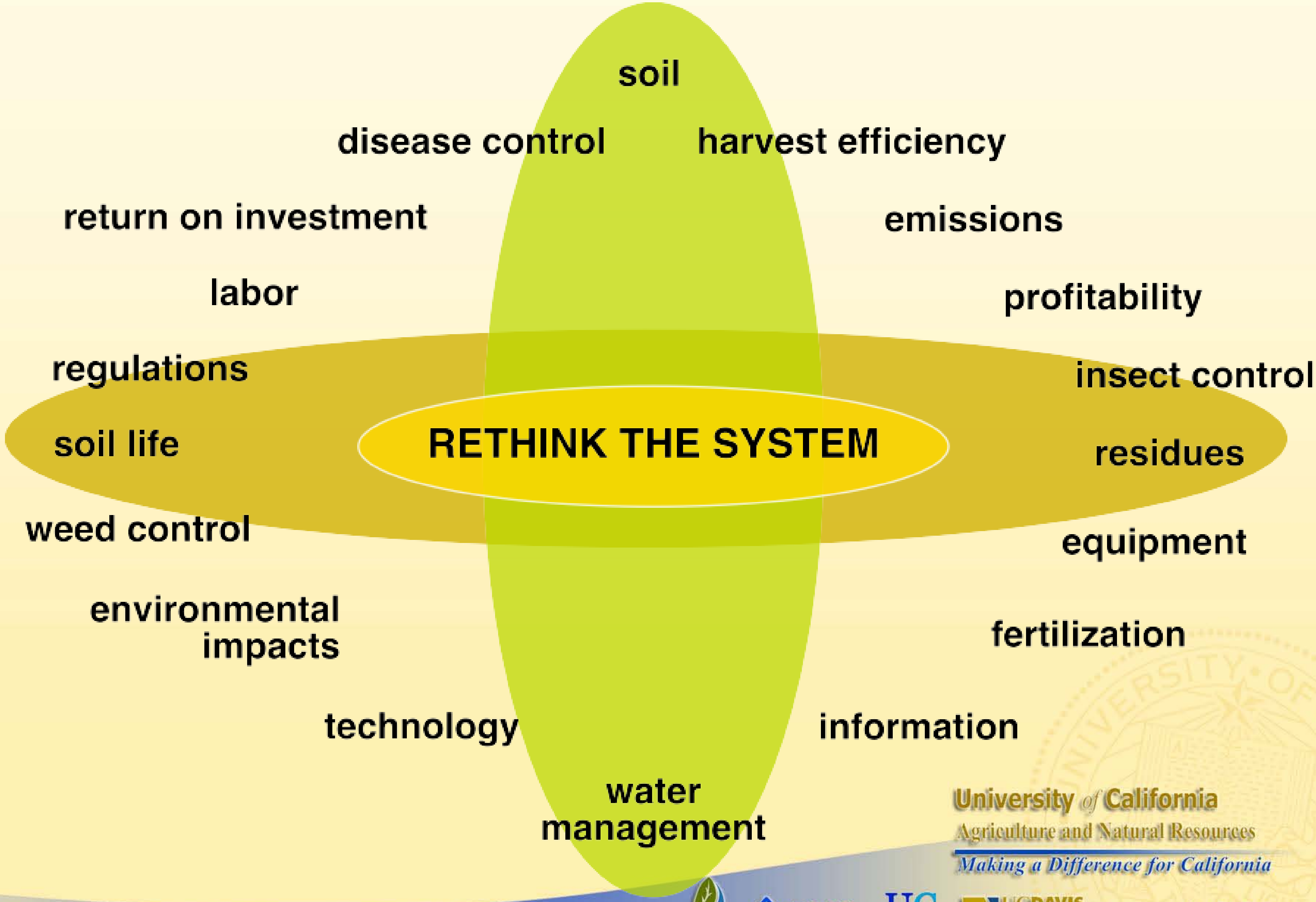
Unlock the Secrets in the Soil

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

Soil improving practices

1. Feed the soil (OM) (not take away everything, not mine the soil)
2. Reduced soil disturbance (physical, chemical, and biological)
3. Increase diversity (biodiversity)
4. Keep the soil covered
5. Minimize diversity-reducing inputs
6. Promote optimal soil structure
7. Reduce extremes in temperature
8. Build soil carbon
9. Use diverse cover crops
10. Rotate crops
11. Manage salinity
12. Manage nitrogen
13. Precision irrigation
14. Decrease soil-borne pests
15. Reduce compaction
16. Monitor soil conditions (lab analyses)

This list was developed in a meeting with farmers, NRCS conservationists, private sector consultants, and university researchers held at the UC West Side Research and Extension Center in Five Points, CA, April 23, 2013.



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

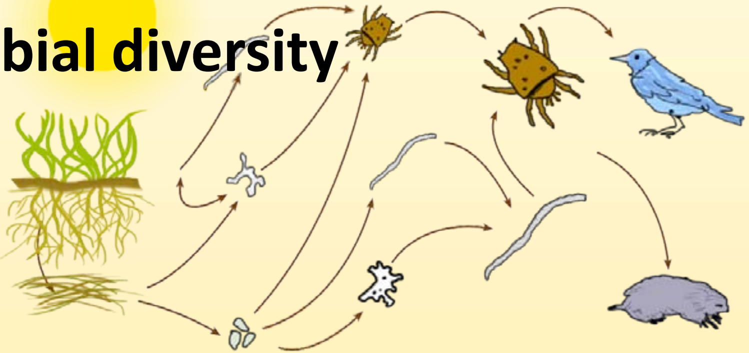
water management

O. Menard, 2014

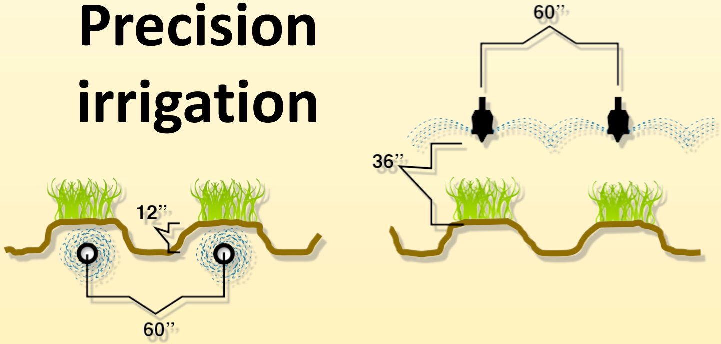
Merging practices and technologies to achieve advanced conservation agriculture systems

"No-till is a tool for what we're trying to achieve."

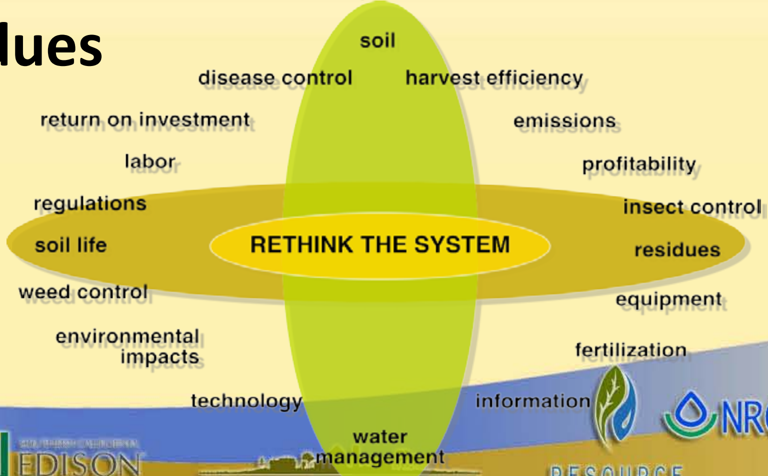
Microbial diversity



Precision irrigation



Generating and preserving surface residues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Controlled traffic farming

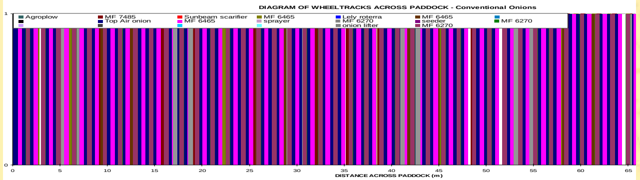


DIAGRAM OF WHEELTRACKS ACROSS PADDOCK - Conventional Onions

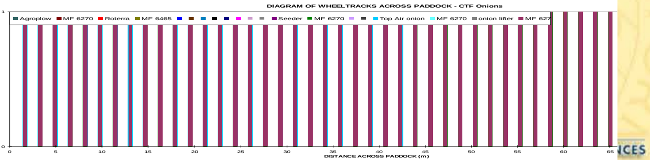
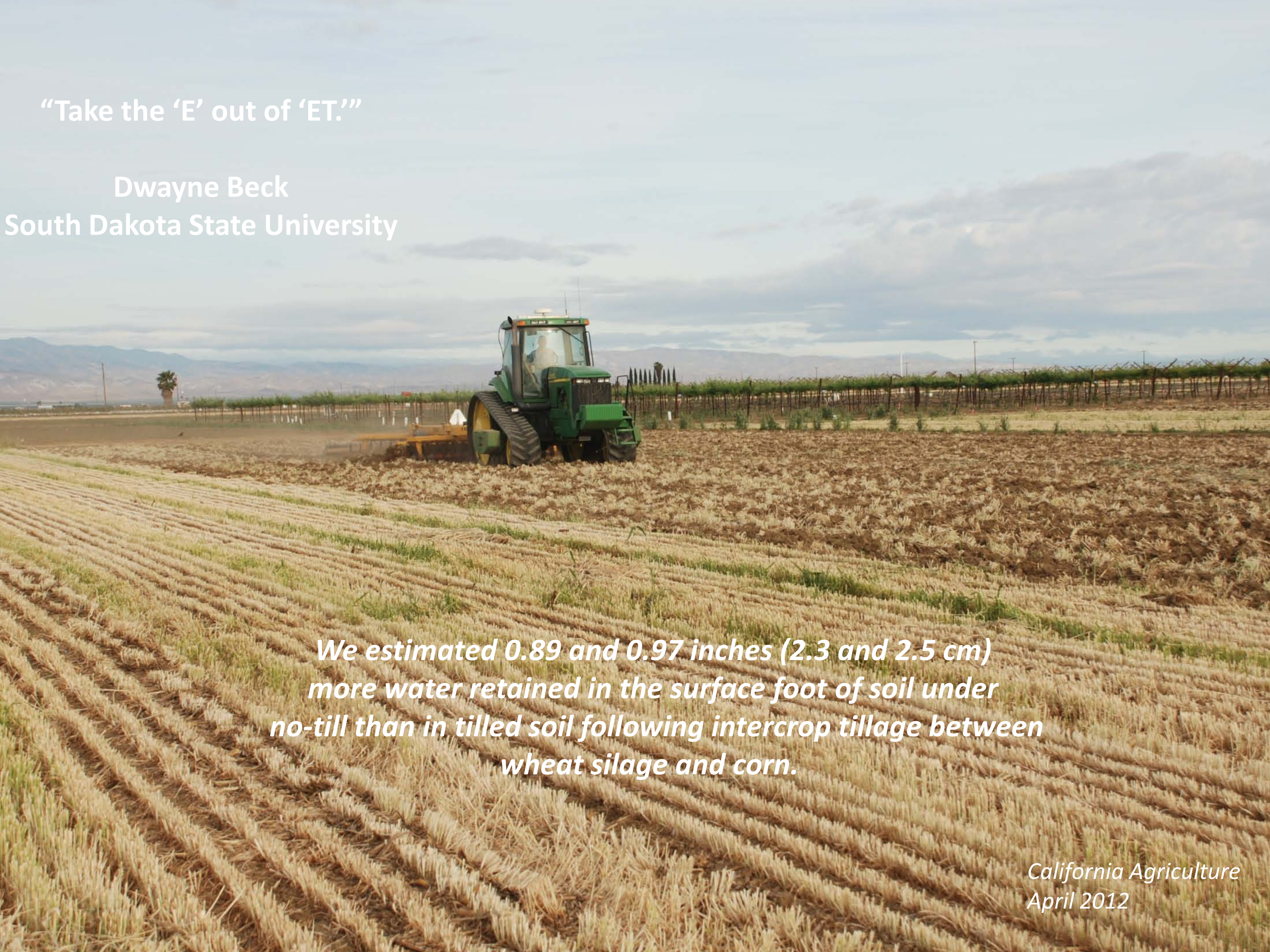


DIAGRAM OF WHEELTRACKS ACROSS PADDOCK - CTF Onions

"Take the 'E' out of 'ET.'"

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



"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.

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 (76 cm), coupling no-tillage with high residue preserving practices could reduce summer season soil evaporative losses by about 4 inches (10.2 cm) or 13%.

California Agriculture
April 2012

Patos de Minas, Brazil
2007

Silage wheat chopping ahead of tomato transplanting
Turkey
2009

Tomato transplanting following silage wheat chopping
Turkey
2009

No-till tomato transplanting
Turkey
2009

Conservation / Standard Tillage Comparison Study

(1999 – ongoing)

Standard Tillage

- With cover crop
- Without cover crop

Conservation Tillage

- With cover crop
- Without cover crop

Conservation Agriculture Systems
INNOVATION CENTER

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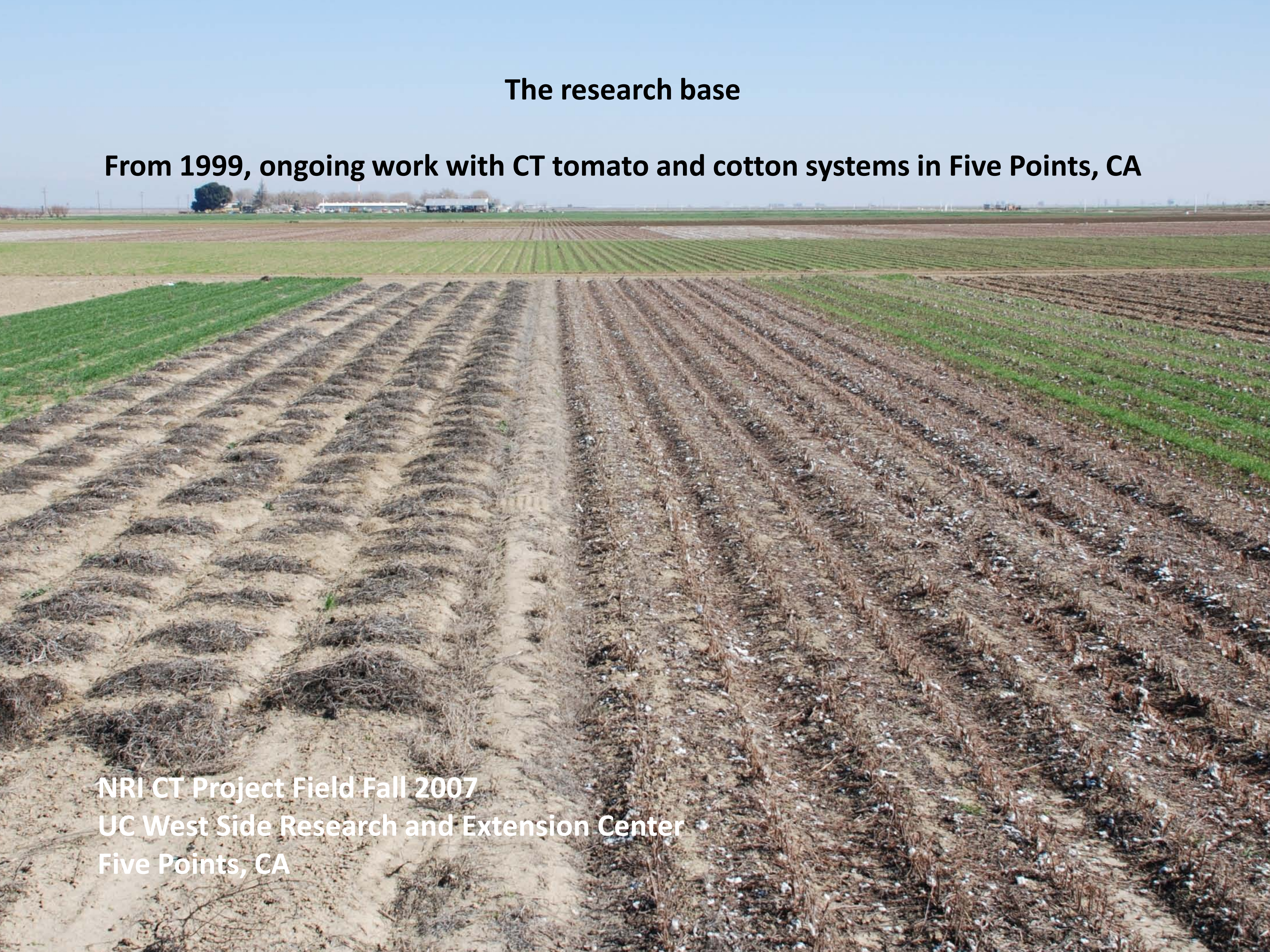
The research base

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

Descriptions of winter cover crop mixtures, planting and termination dates, and seeding rates used annually in the long-term study in Five Points, CA 2000 to 2014.

	Planting Date	Termination Date	Total Growing Days	3-way Mixture*	Brassica Mixture†	Annual Clover Mix‡	Legume/Radish Mix§
1999-2000	Oct. 10, 1999	Apr. 6, 2000	148	*			
2000-2001	Nov. 2, 2000	Mar. 14, 2001	133	*			
2001-2002	Nov. 10, 2001	Mar. 15, 2002	126	*			
2002-2003	Oct. 18, 2002	Mar. 25, 2003	159	*			
2003-2004	Nov. 2, 2003	Mar. 17, 2004	136	*			
2004-2005	Oct. 16, 2004	Mar. 18, 2005	154	*			
2005-2006	Oct. 20, 2005	Mar. 21, 2006	152	*			
2006-2007	Nov. 22, 2006	Mar. 21, 2007	120	*			
2007-2008	Nov. 2, 2007	Mar. 22, 2008	140	*			
2008-2009	Dec. 11, 2008	Mar. 17, 2009	96	*			
2009-2010	Nov. 20, 2009	Mar. 20, 2010	121	*			
2010-2011	Nov. 24, 2010	Mar. 19, 2011	119				*
2011-2012	Nov. 10, 2011	Apr. 4, 2012	143				*
2012-2013	Oct. 30, 2012	Mar. 8, 2013	130		*	*	
2013-2014	Nov. 18, 2013	Mar. 24, 2014	127		*	*	

3-way Mixture* Juan triticale (*Triticosecale* Wittm.) (30% by weight), Merced ryegrain (*Secale cereale* L.) (30% by weight), and common vetch (*Vicia sativa*) (40% by weight)

Brassica Mixture† Oriental mustard (*Brassica juncea*), Braco mustard (*Brassica alba*), and Daikon mustard (*Raphanus sativus*)

Annual Clover Mix‡ Crimsom clover (*Trifolium incarnatum* (30%), Hykon rose clover (*Trifolium hirtum* (5%), Sardi Persian clover (*Trifolium resupinutum* (10%), Parriago Medic (*Medicago truncatula*) (10%), Cavalier Medic (*Medicago polymorpha*) (10%), Dalkerth Subclover (*Trifolium subterraneum*) (10%), Seaton Park Clover (*Trifolium subterraneum*) (10%), Wooenellap Subclover (*Trifolium subterraneum*) (10%), Trikkala Subclover (*Trifolium subterraneum*) (7.5%), Seaton Park Subclover (*Trifolium subterraneum*) (7.5%) (at a rate of 11.2 kg ha^{-1})

Legume/Radish Mix§ Biomaster pea (*Pisum sativum* L.) (67%), Faba bean (*Vicia faba* L.) (7%), Blue lupin (*Lupinus difusus*), Tillage radish (*Raphanus sativus*) (17%), Phacelia (*Phacelia tanacetifolia*) (3%)

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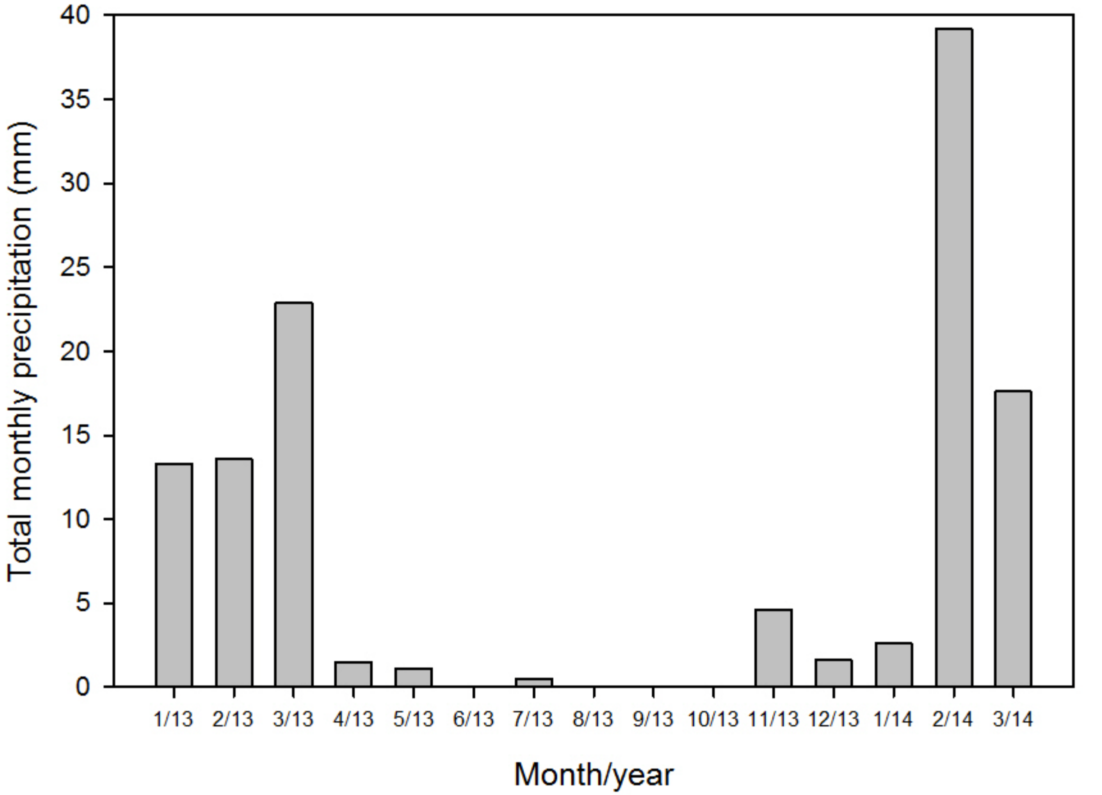
185 lbs


195 lbs

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

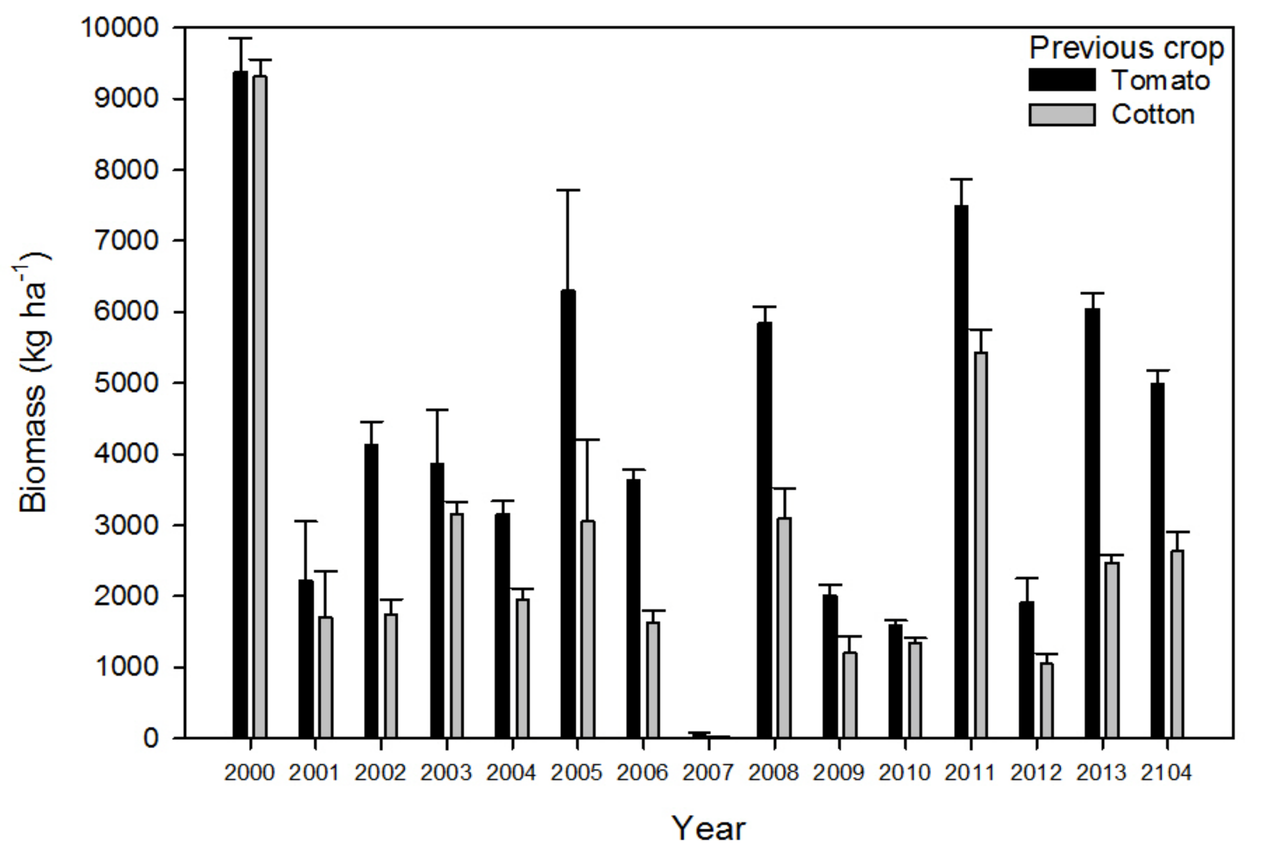
Winter, rainfed triticale, rye and pea cover crop no-till seeded into cotton and tomato residues
Five Points, CA 2008

No-till transplanting processing tomatoes
Five Points, CA
2010


Total monthly precipitation (mm)
40
35
30
25
20
15
10
5
0
1/13
2/13
3/13
4/13
5/13
6/13
7/13
8/13
9/13
10/13
11/13
12/13
1/14
2/14
3/14
Month/year

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

20 tons of organic matter



7.5 tons of carbon

7 tons of carbon

USDA NRCS Soil Quality Test Kit

Number of samples per determination

Soil quality determination	# of samples per plot	# of samples per field
Water infiltration	2	64
Slaking	4	256
Aggregate stability	4	256
pH	4	256
EC	4	256

-

Soil pH and EC

System	pH	EC (dS/m)
STNO	**7.46** ± 0.3	**1.04** ± 0.32
STCC	**7.44** ± 0.25	**0.98** ± 0.25
CTNO	**7.38** ± 0.18	**1.0** ± 0.4
CTCC	**7.45** ± 0.33	**0.81** ± 0.29

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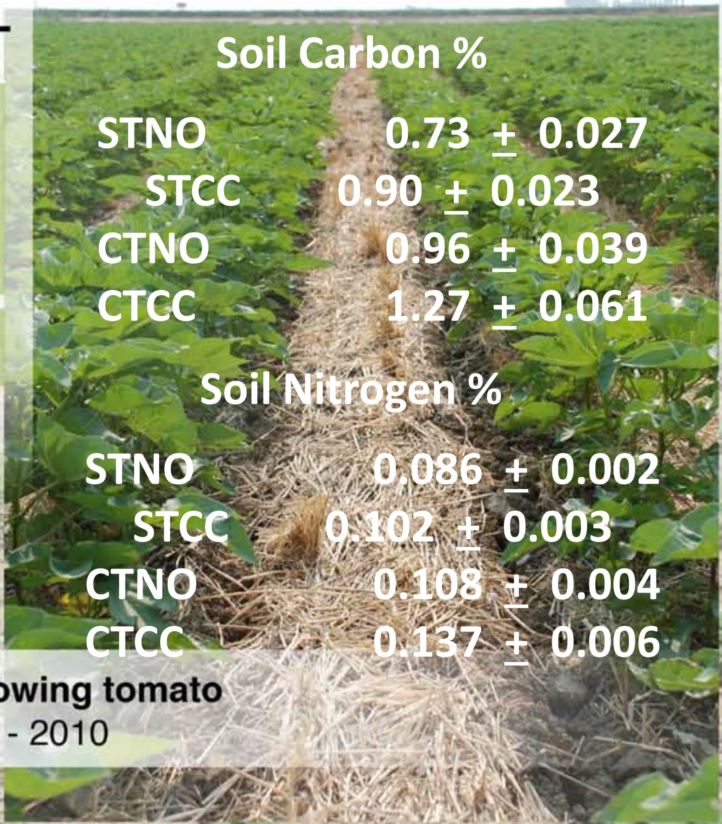
*Stability Class	Criteria for assignment to stability class (for 'Standard Characterization')
0	Soil too unstable to sample (falls through sieve)
1	50% of structural integrity lost within 5 seconds of insertion in water
2	50% of structural integrity lost 5 – 30 seconds after insertion
3	50% of structural integrity lost 30 – 300 seconds after insertion or < 10% of soil remains on the sieve after 5 dipping cycles
4	10 – 25% of soil remaining on sieve after 5 dipping cycles
5	25 – 75% of soil remaining on sieve after 5 dipping cycles
6	75 – 100% of soil remaining on sieve after 5 dipping cycles

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

Soil Carbon weights (t/ha)

Depth (cm)	Standard Till No Cvr Crop	Standard Till Winter Cvr Crop	Conservation Tillage No Cvr Crop	Conservation Tillage Winter Cvr Crop
0-15	10.74 (0.26)	13.68 (0.43)	14.51 (0.61)	15.95 (3.43)
15-30	11.59 (0.43)	13.69 (0.73)	11.69 (0.45)	12.89 (0.54)
Total	22.33 C	27.37 B	26.20 B	28.84 A

Values in parentheses are standard error of the means (n=8; north and south field mean averages were not significantly different therefore treatments combined for analysis). Letters represent significant differences among treatments using a one-way ANOVA analysis with Tukey HSD means comparison.



Soil Carbon %

STNO	**0.73 ± 0.027**
STCC	**0.90 ± 0.023**
CTNO	**0.96 ± 0.039**
CTCC	**1.27 ± 0.061**

Soil Nitrogen %

STNO	**0.086 ± 0.002**
STCC	**0.102 ± 0.003**
CTNO	**0.108 ± 0.004**
CTCC	**0.137 ± 0.006**

No-till cotton production following tomato

Five Points, CA • 2000 - 2010

Conservation Tillage Workgroup

ANR University of California · UCCE · UC Davis Plant Sciences · UC Davis College of Agricultural & Environmental Sciences · NRCS · Sustainable Conservation · Resource Conservation Districts · American Farmland Trust

Five Points Conservation Tillage Plots

Next Generation Sequencing Data

Background and Objectives

- Illumina sequencing allows the analysis of whole soil bacterial communities by identifying bacteria to their respective species (sometimes only genus) level based on their 16S rRNA gene sequences.
- The primary aim of this study was to establish a baseline comparison of the depth-dependent and treatment-dependent microbial population composition differences of the four treatments (CCCT, CCST, NOCT and NOST) at the Five Points conservation tillage test plots.
- For this baseline analysis, we were interested in community composition differences that are associated with the different treatments regardless of their position within the test field. The field block scheme was not used to differentite sample source plots (for technical reasons using the block scheme would have also been both more difficult and considerably more costly to implement).

Five Points Conservation Tillage Plots Sequencing Data

Methods

- Soil source
  - plots 1-16
  - sampling date 11/22/13.
- Sampling intensity
  - 0-5, 5-15, 15-30 cm.
  - 6 samples per depth per plot.
  - the 6 samples from each plot/depth were homogenized before further analysis.
- Next generation sequencing
  - DNA extracted in triplicate
  - 12 subsamples per treatment and depth (4 plots, triplicate extractions) amplified individualy, but with identical barcodes.
  - 144 total barcoded PCR products purified, pooled and submitted to UCD genome center for sequencing.
  - Data analyzed using the QIIME data analysis pipeline.

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 Fimicute 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 Archaeaal community.

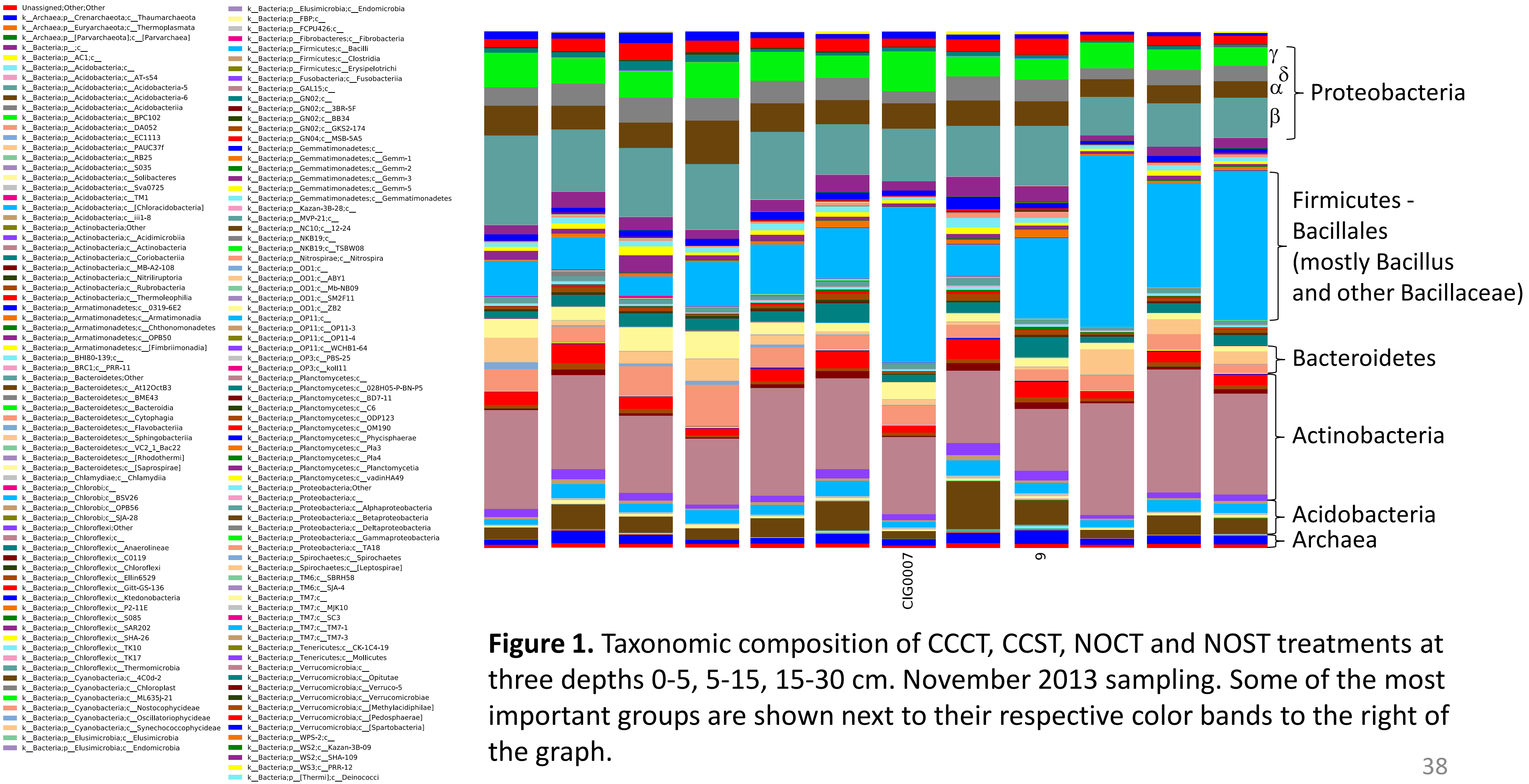
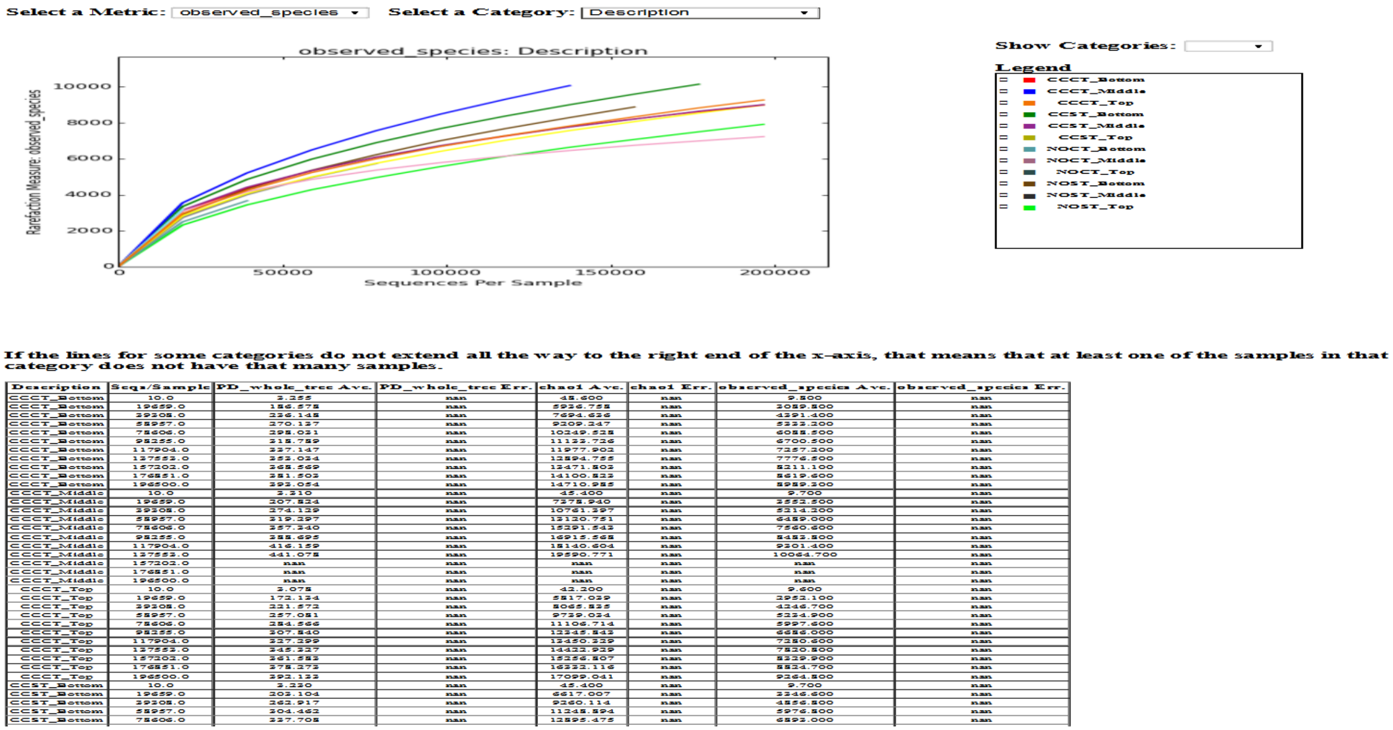


Figure 1. Taxonomic composition of CCCT, CCST, NOCT and NOST treatments at three depths 0-5, 5-15, 15-30 cm. November 2013 sampling. Some of the most important groups are shown next to their respective color bands to the right of the graph.

Alpha Diversity

- Alpha diversity is the variation in species composition within each sample.
- CCCT 5-15 cm, CCST 15-30 cm show highest species diversity (Figure 2).
- NOST 0-5 cm, NOCT 5-15 cm show lowest species diversity (Figure 2).



If the lines for some categories do not extend all the way to the right end of the x-axis, that means that at least one of the samples in that category does not have that many samples.

Description	Seqs/Sample	PD_whole_tree Ave.	PD_whole_tree Err.	chao1 Ave.	chao1 Err.	observed_species Ave.	observed_species Err.
CCCT_Bottom	10.0	3.255	nan	48.600	nan	9.800	nan
CCCT_Bottom	19659.0	186.578	nan	5926.758	nan	3059.800	nan
CCCT_Bottom	39308.0	236.148	nan	7694.626	nan	4391.400	nan
CCCT_Bottom	58957.0	270.137	nan	9209.247	nan	5333.200	nan
CCCT_Bottom	78606.0	298.031	nan	10249.528	nan	6088.500	nan
CCCT_Bottom	98255.0	318.789	nan	11133.726	nan	6700.500	nan
CCCT_Bottom	117904.0	337.147	nan	11977.902	nan	7257.200	nan
CCCT_Bottom	137553.0	352.034	nan	12894.755	nan	7776.500	nan
CCCT_Bottom	157202.0	368.569	nan	13471.803	nan	8211.100	nan
CCCT_Bottom	176851.0	381.503	nan	14100.823	nan	8619.600	nan
CCCT_Bottom	196500.0	393.054	nan	14710.985	nan	8959.200	nan
CCCT_Middle	10.0	3.310	nan	45.400	nan	9.700	nan
CCCT_Middle	19659.0	207.824	nan	7378.940	nan	3552.500	nan
CCCT_Middle	39308.0	274.129	nan	10761.397	nan	5214.200	nan
CCCT_Middle	58957.0	319.297	nan	13120.751	nan	6489.000	nan
CCCT_Middle	78606.0	357.340	nan	15291.543	nan	7560.600	nan
CCCT_Middle	98255.0	388.695	nan	16915.568	nan	8482.800	nan
CCCT_Middle	117904.0	416.159	nan	18140.604	nan	9301.400	nan
CCCT_Middle	137553.0	441.078	nan	19590.771	nan	10064.700	nan
CCCT_Middle	157202.0	nan	nan	nan	nan	nan	nan
CCCT_Middle	176851.0	nan	nan	nan	nan	nan	nan
CCCT_Middle	196500.0	nan	nan	nan	nan	nan	nan
CCCT_Top	10.0	3.078	nan	42.200	nan	9.600	nan
CCCT_Top	19659.0	172.134	nan	5817.029	nan	2952.100	nan
CCCT_Top	39308.0	221.572	nan	8065.825	nan	4246.700	nan
CCCT_Top	58957.0	257.081	nan	9729.024	nan	5224.900	nan
CCCT_Top	78606.0	284.566	nan	11106.714	nan	5997.600	nan
CCCT_Top	98255.0	307.840	nan	12345.843	nan	6686.000	nan
CCCT_Top	117904.0	327.299	nan	13450.329	nan	7280.600	nan
CCCT_Top	137553.0	345.227	nan	14422.929	nan	7820.800	nan
CCCT_Top	157202.0	361.583	nan	15256.807	nan	8329.900	nan
CCCT_Top	176851.0	378.273	nan	16332.116	nan	8824.700	nan
CCCT_Top	196500.0	392.133	nan	17099.041	nan	9264.800	nan
CCST_Bottom	10.0	3.220	nan	45.400	nan	9.700	nan
CCST_Bottom	19659.0	203.104	nan	6617.007	nan	3346.600	nan
CCST_Bottom	39308.0	262.917	nan	9260.114	nan	4856.800	nan
CCST_Bottom	58957.0	304.462	nan	11248.894	nan	5976.800	nan
CCST_Bottom	78606.0	327.708	nan	12895.475	nan	6592.000	nan

Figure 2. Rarefactio plot for CCCT, CCST, NOCT and NOST treatments at three depths 0-5, 5-15, 15-30 cm. November 2013 sampling.

Beta Diversity

- Beta diversity is the variation in species composition among distinct samples (e.g. treatment, depth).
- Unweighted Pair Group Method with Arithmetic mean (UPGMA) is a hierarchical clustering method using average linkage used to interpret beta diversity distance matrices.
- Clustering of NOST treatments at all depths with NOCT 0-5 cm (Figure 3) is consistent with similarities observed n taxonomic composition analysis.

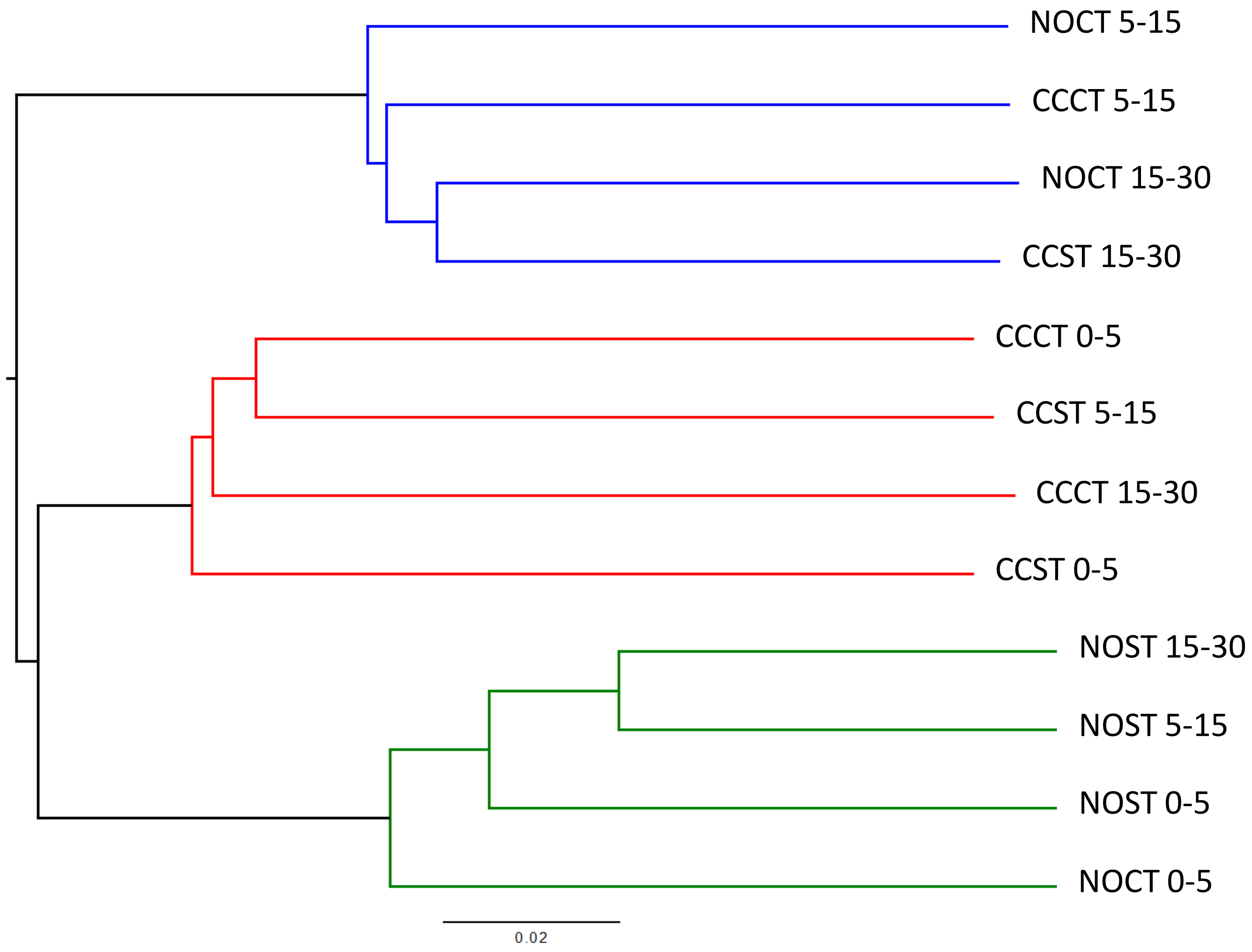
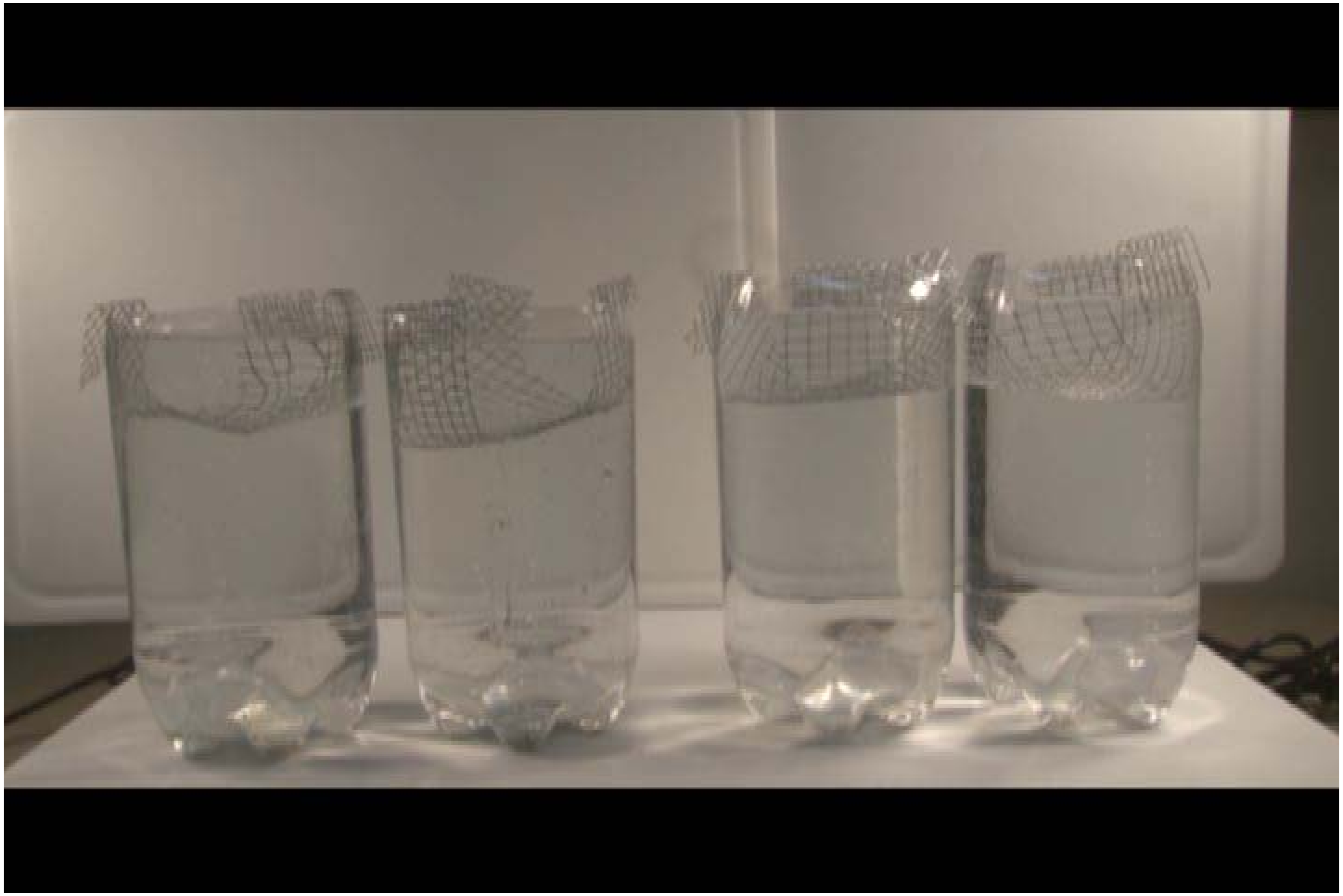


Figure 3. UPGMA consensus tree for beta diversity of CCCT, CCST, NOCT and NOST treatments at three depths 0-5, 5-15, 15-30 cm. November 2013 sampling.

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.



A big concern related to the use of cover crops in the SJV 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)

Cover crop mixtures used in 2013 and 2014 water depletion studies in Five Points, CA

Mixture	Composition	Seeding rate
Legume	Bell bean (*Vicia faba* L.) (45%) Dundale pea (*Pisum sativum* L,) (35%) Common vetch (*Vicia sativa*) (20%)	112 kg ha^{-1}
Legume/triticale	Dundale pea (*Pisum sativum* L.) 40%) Common vetch (Vicia sativa))30%) Triticale (*Triticosecale* Wittm.) (30%)	112 kg ha^{-1}
Brassica	Oriental mustard (*Brassica juncea*) (45%) Martigena Mustard (*Sinapsis alba*) (40%) Daikon Radish (*Raphanus sativus*) (15%)	24 kg ha^{-1}

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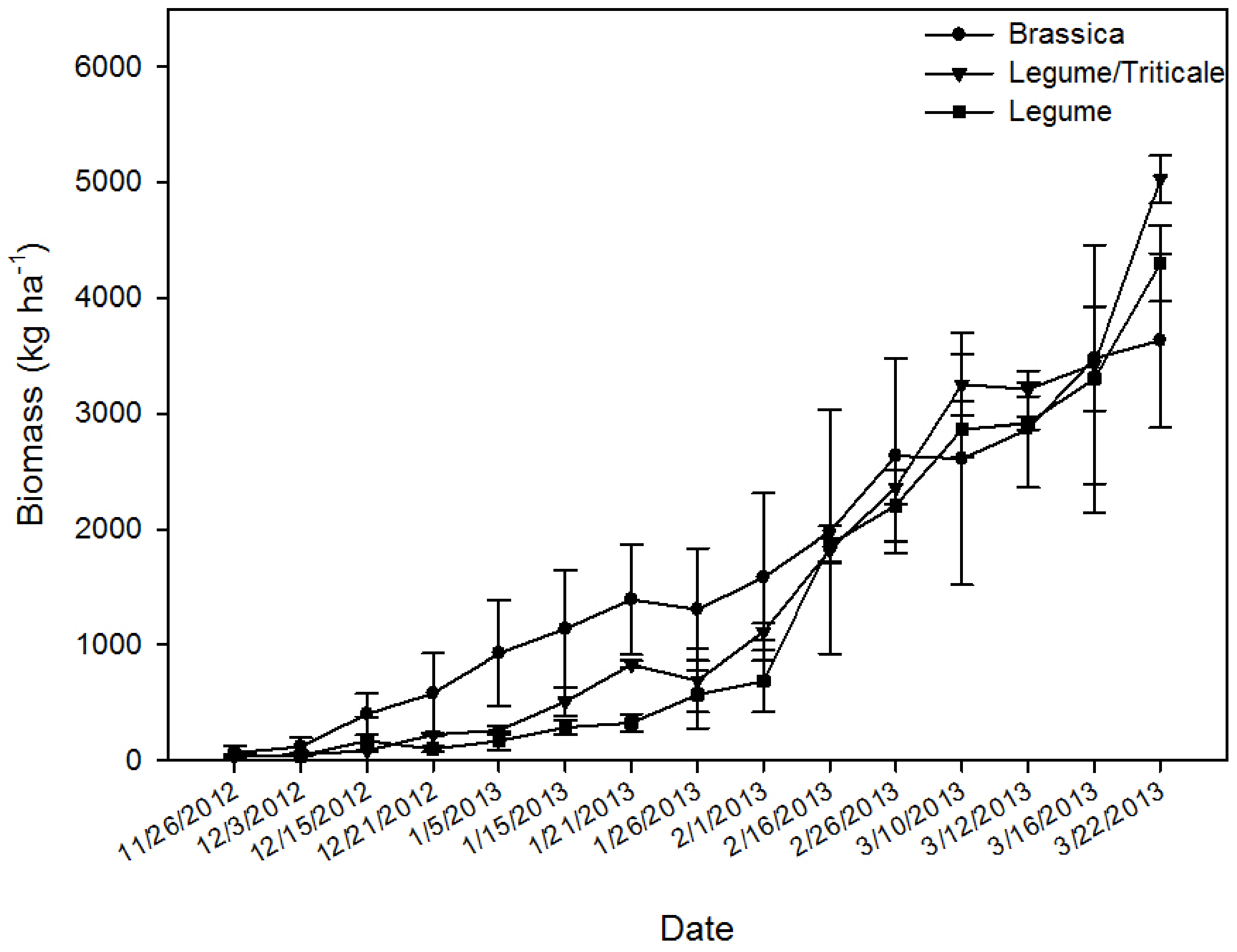
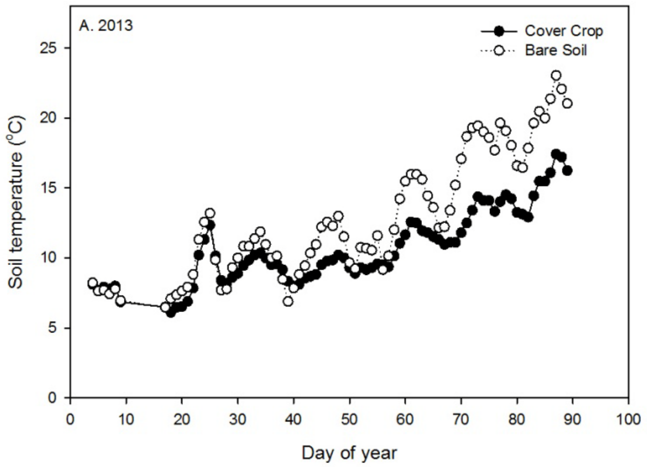
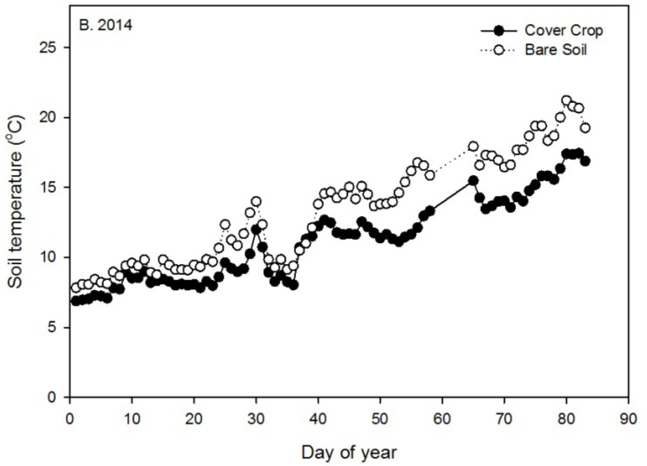
Cover crop aboveground biomass for brassica, legume and legume/triticale mixtures in the water depletion study in the winter of 2012 and 2013 winter in Five Points, CA

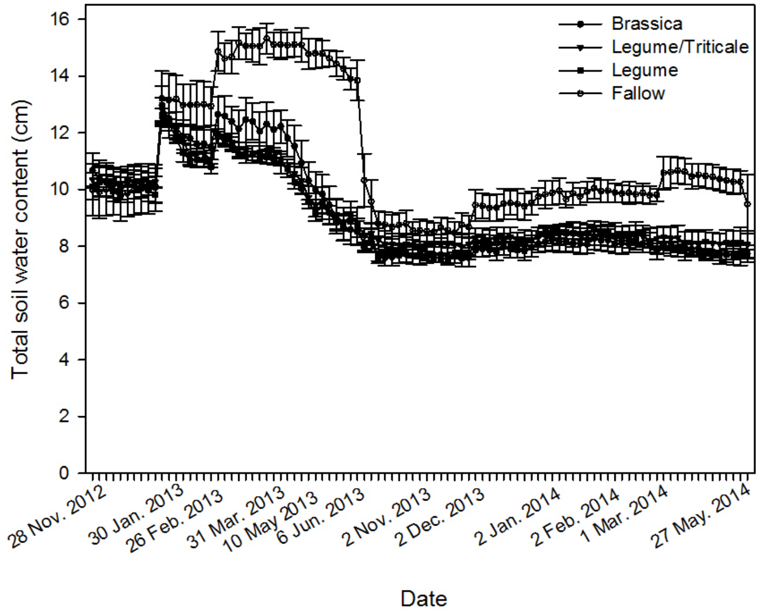


Soil temperature at 10 cm depth under legume/triticale and fallow plots 2013 and 2014

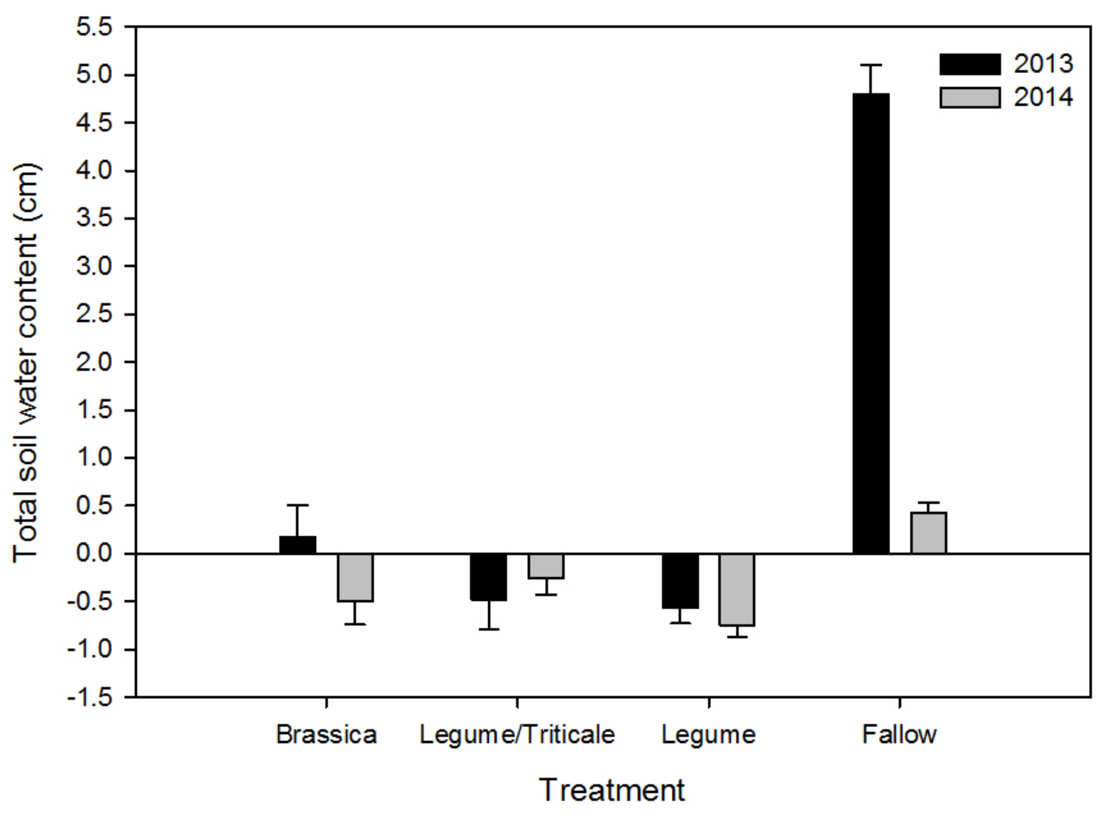




Total soil water in the 0 – 90 cm soil depth in fallow and brassica, legume, and legume/triticale cover crop plots from November 2012 through May 2014 in the water depletion study in the winter of 2012 and 2013 in Five Points, CA.



Changes in total soil water in the 0 – 90 cm soil depth under fallow and brassica, legume, and legume/triticale cover crops in the water depletion study in the winter of 2012 and 2013 in Five Points, CA.



Summary

- 25.6 t ha^{-1} aboveground cover crop biomass produced over the 1999 – 2014 period
- Biomass varied from 39 to 9,346 kg ha^{-1}
- Cover crops depleted 5.3 cm and 0.67 cm more water than winter fallow in 2013 and 2014
- Adoption of cover cropping is increasing
- Solid December precipitation may be key

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Soil health summary profiles of experienced practitioners

	David Brandt Ohio	Gabe Browne North Dakota	Gail Fuller Kansas	Leon Moses North Carolina	Lawrence Sanchez New Mexico
Acres farmed	1100	5400 (crops+pasture)	2000	492	300
Years in soil health system	30	20	8	6	12
Primary crops	Corn, wheat, soybeans	Corn, wheat, sunflowers, alfalfa, oats, triticale, hairy vetch, red clover, peas	Corn, grain sorghum, triticale, winter barley, winter wheat, soybeans	Corn, soybeans, hay	Grass, alfalfa, corn, winter wheat, oats
Primary cover crops	All mixes, some 8- and 14-way blend; most used: peas, radishes, hairy vetch, crimson clover, ryegrass	Cocktail mixes with 20 to 25 different plant species	All mixes, some 8- and 14-way blend; most used: peas, radishes, hairy vetch, crimson clover, ryegrass	Ryegrass, hairy vetch, clover	Fescue, orchardgrass, clovers
Yields	7- to 10- bushel/Ac increase in corn, 8% increase in soybeans	20% higher than county average	Increased	Doubled	Increased
Commercial fertilizer use	$100-per-acre annual savings in nitrogen	No synthetic fertilizer used	Cut by 25% overall, up to 60% in some instances	Commercial nitrogen use cut by 100lbs/Ac	Reduced; but often uses manure in heavy does on newly rented land
Insecticide use	None	None used for past 10yrs.	None used for past 4yrs.	Better control with reduced use	None
Herbicide use	Very little	Cut by 75%	Dropped at least 1 herbicide pass in every field	Reduced; johnsongrass nearly eradicated	Reduced
Other benefits	Virtually no soil erosion; nutrients stay on the farm; less soil compaction; greener, healthier crops; reduced soil compaction; better water filtration; less worry about drought	Organic matter rose from 2% to more than 5%; water holding capacity and infiltration at highest levels; wildlife populations and diversity increased exponentially.	Higher-quality, more nutritious grains; no live called for in nearly 15 years; much better bottom line	Reduced soil compaction; much better water infiltration; better soil structure; 35% return on investment	Superior, more nutritios crops; less irrigation water needed; stronger soil structure; protection from wind and water erosion

(Source: Lynn Betts, 'Put the Soil First,' Dakota Farmer, January 2013, Farm Progress (permission granted))

California soil health summary profiles of experienced practitioners, 2015

	Scott Park **Meridian, CA**	**Alan Sano and Jesse Sanchez** **Firebaugh, CA**	**Fritz Durst** **Winters CA**	**Danny Ramos** **Santa Nella, C**	**Steve Fortner** **Firebaugh, CA**
Acres farmed	**1450**	**2500**	**800**	**5000**	**1200**
Years in soil health system (No-till, strip-till, residue preservation, cover crops)	**27**	**11**	**30**	**4**	**10**
Primary crops	Tomato, corn, rice, wheat, sunflower, dry beans, vine seed, veg seed, millet, herbs, stevia	Tomato/cotton	Various dryland and irrigated no-till crops including wheat, edible dry beans, garbanzos,	Processing tomatoes, corn	Fresh market tomatoes
Primary cover crops or soil health improving practices used	Cover crop mixes- cereals, vetch, peas, bell beans depending on past, future crops	Triticale (6 – 7 years) Minimum tillage	No-tillage, high residue production approaches	Wheat, triticale and diverse multi-species cover crop mixtures, strip-tillage tomato transplanting	Barley, wheat cover crops when water available coupled with strip-tillage tomato transplanting and seasonal controlled traffic
Yields	All organic- comparable to or better than conventional	Increased 35 – 50% With about 4 inches less water each summer	Maintained or increased yields with strip-tillage	Similar to prior conventional management	Equal or comparable to prior conventional yields
Commercial fertilizer use	only compost, microbials, seaweed				
Insecticide use					
Herbicide use	None				
Other benefits	better water retention, no run off, earlier planting, earlier harvest, better drought resistance, less	Soil is a lot more mellow with less compaction	Greatly improved soil tilth, reduced production costs	Overall improved soil health, soil organic matter, achieved profitable	Noticeable improvements in soil tilth with reduced water use

First ever scaling up of

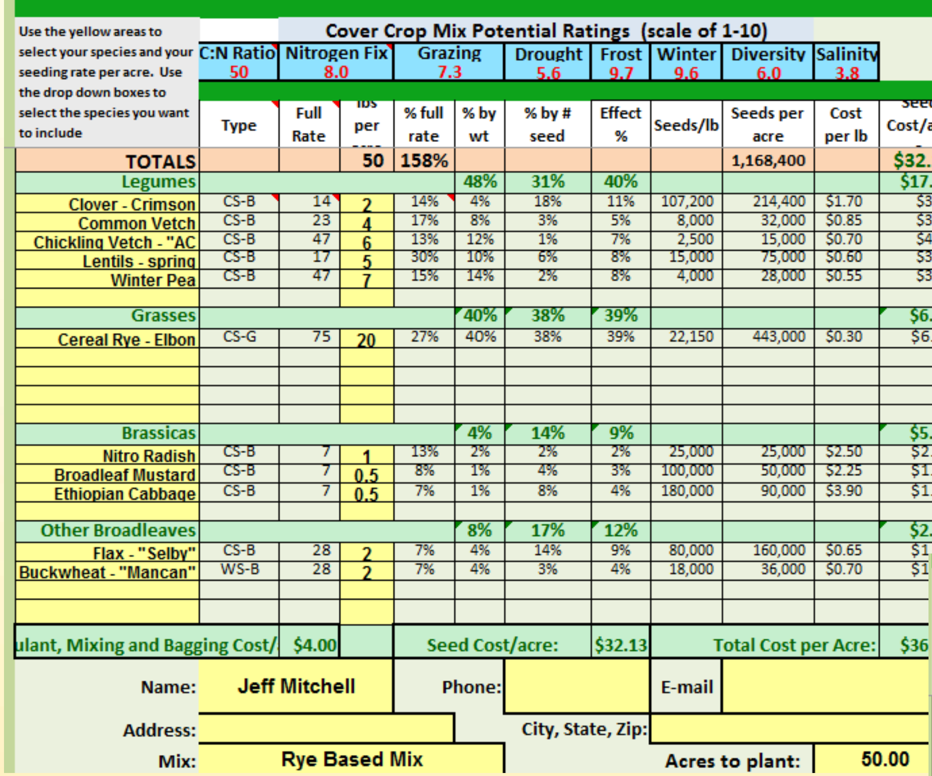
Commercialization of strip-till and cover crop practices at Sun Pacific and Sano Farms, Firebaugh, CA since 2004

First ever subsurface drip coupled with permanent beds and strip-till cover cropped fresh market tomato production

Firebaugh, CA

2003

About the maximum cover crop biomass farmers are comfortable with before converting to a surface mulch



Use the yellow areas to select your species and your seeding rate per acre. Use the drop down boxes to select the species you want to include

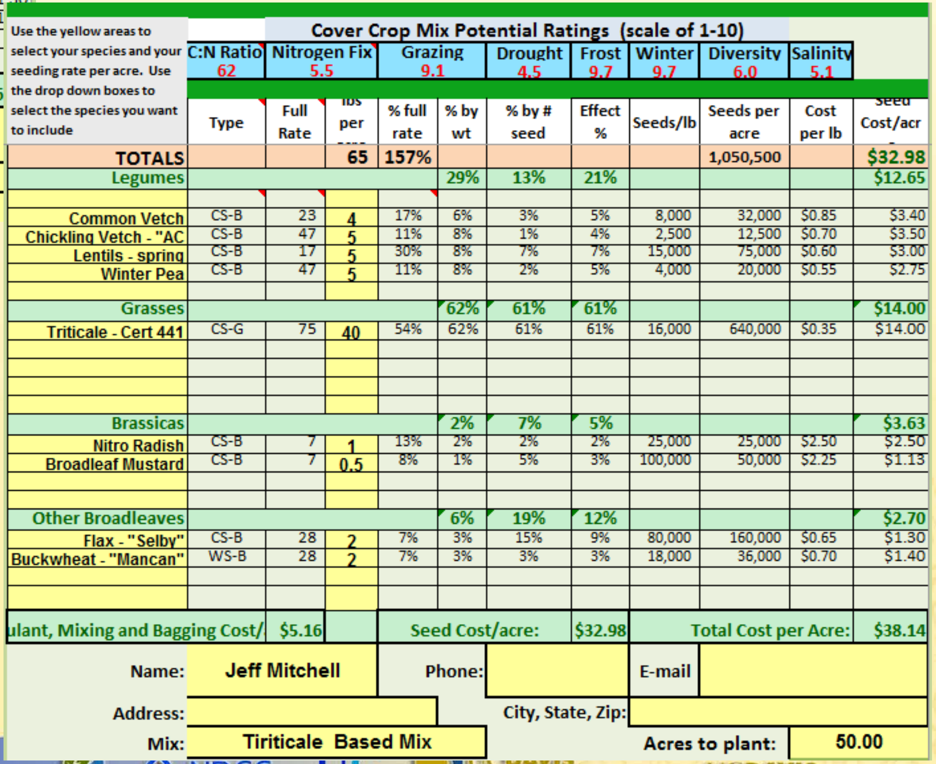
Cover Crop Mix Potential Ratings (scale of 1-10)

C:N Ratio	Nitrogen Fix	Grazing	Drought	Frost	Winter	Diversity	Salinity
50	8.0	7.3	5.6	9.7	9.6	6.0	3.8

	Type	Full Rate	lbs per	% full rate	% by wt	% by # seed	Effect %	Seeds/lb	Seeds per acre	Cost per lb	Seed Cost/acr
TOTALS			50	158%					1,168,400		$32.13
Legumes					48%	31%	40%				$17.85
Clover - Crimson	CS-B	14	2	14%	4%	18%	11%	107,200	214,400	$1.70	$3.40
Common Vetch	CS-B	23	4	17%	8%	3%	5%	8,000	32,000	$0.85	$3.40
Chickling Vetch - "AC	CS-B	47	6	13%	12%	1%	7%	2,500	15,000	$0.70	$4.20
Lentils - spring	CS-B	17	5	30%	10%	6%	8%	15,000	75,000	$0.60	$3.00
Winter Pea	CS-B	47	7	15%	14%	2%	8%	4,000	28,000	$0.55	$3.85
Grasses					40%	38%	39%				$6.00
Cereal Rye - Elbon	CS-G	75	20	27%	40%	38%	39%	22,150	443,000	$0.30	$6.00
Brassicas					4%	14%	9%				$5.58
Nitro Radish	CS-B	7	1	13%	2%	2%	2%	25,000	25,000	$2.50	$2.50
Broadleaf Mustard	CS-B	7	0.5	8%	1%	4%	3%	100,000	50,000	$2.25	$1.13
Ethiopian Cabbage	CS-B	7	0.5	7%	1%	8%	4%	180,000	90,000	$3.90	$1.95
Other Broadleaves					8%	17%	12%				$2.70
Flax - "Selby"	CS-B	28	2	7%	4%	14%	9%	80,000	160,000	$0.65	$1.30
Buckwheat - "Mancan"	WS-B	28	2	7%	4%	3%	4%	18,000	36,000	$0.70	$1

ulant, Mixing and Bagging Cost/	$4.00	Seed Cost/acre:	$32.13	Total Cost per Acre:	$36

Name: **Jeff Mitchell**
Phone:
E-mail
Address:
City, State, Zip:
Mix: **Rye Based Mix**
Acres to plant: **50.00**



Use the yellow areas to select your species and your seeding rate per acre. Use the drop down boxes to select the species you want to include

Cover Crop Mix Potential Ratings (scale of 1-10)

C:N Ratio	Nitrogen Fix	Grazing	Drought	Frost	Winter	Diversity	Salinity
62	5.5	9.1	4.5	9.7	9.7	6.0	5.1

	Type	Full Rate	lbs per	% full rate	% by wt	% by # seed	Effect %	Seeds/lb	Seeds per acre	Cost per lb	Seed Cost/acr
TOTALS			65	157%					1,050,500		$32.98
Legumes					29%	13%	21%				$12.65
Common Vetch	CS-B	23	4	17%	6%	3%	5%	8,000	32,000	$0.85	$3.40
Chickling Vetch - "AC	CS-B	47	5	11%	8%	1%	4%	2,500	12,500	$0.70	$3.50
Lentils - spring	CS-B	17	5	30%	8%	7%	7%	15,000	75,000	$0.60	$3.00
Winter Pea	CS-B	47	5	11%	8%	2%	5%	4,000	20,000	$0.55	$2.75
Grasses					62%	61%	61%				$14.00
Triticale - Cert 441	CS-G	75	40	54%	62%	61%	61%	16,000	640,000	$0.35	$14.00
Brassicas					2%	7%	5%				$3.63
Nitro Radish	CS-B	7	1	13%	2%	2%	2%	25,000	25,000	$2.50	$2.50
Broadleaf Mustard	CS-B	7	0.5	8%	1%	5%	3%	100,000	50,000	$2.25	$1.13
Other Broadleaves					6%	19%	12%				$2.70
Flax - "Selby"	CS-B	28	2	7%	3%	15%	9%	80,000	160,000	$0.65	$1.30
Buckwheat - "Mancan"	WS-B	28	2	7%	3%	3%	3%	18,000	36,000	$0.70	$1.40

ulant, Mixing and Bagging Cost/	$5.16	Seed Cost/acre:	$32.98	Total Cost per Acre:	$38.14

Name: **Jeff Mitchell**
Phone:
E-mail
Address:
City, State, Zip:
Mix: **Tiriticale Based Mix**
Acres to plant: **50.00**

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Cover crop seeding
October 23, 2014
Los Banos, CA

Cover crop seeding ahead of 2015 tomato crop
October 23, 2014
Los Banos, CA

“Diverse,” multi-species cover crop
Los Banos, CA
2015

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