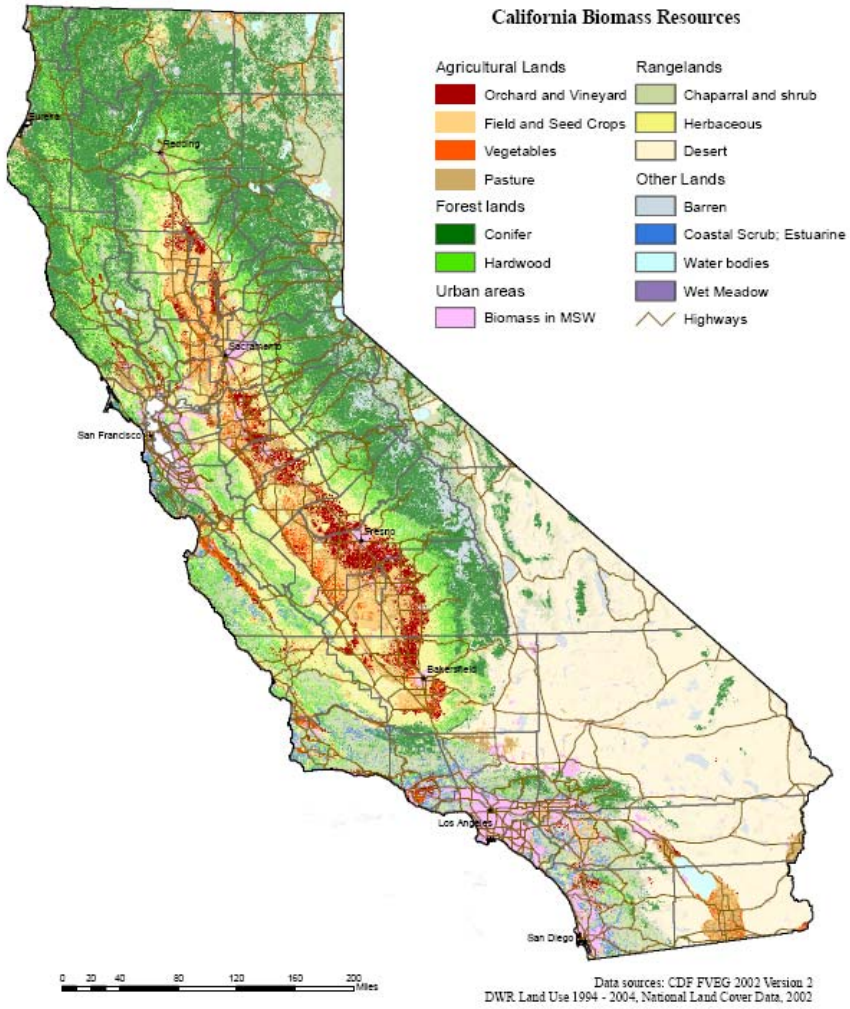
Prospects for Agricultural Feedstocks for Biofuels in California

Steve Kaffka, Mark Jenner
Department of Plant Sciences &
California Biomass Collaborative

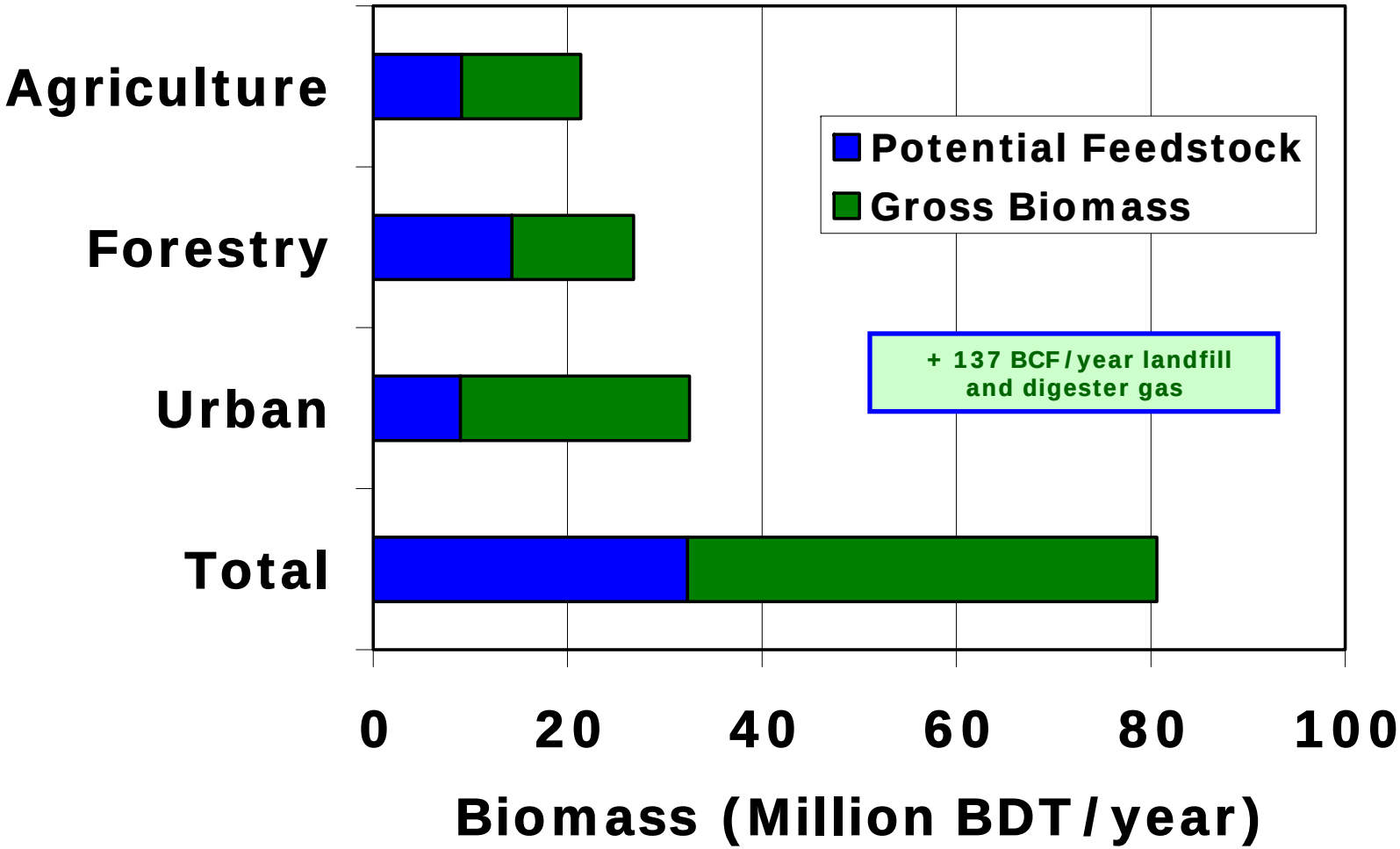
Funded by: PIERS Program,
California Energy Commission

California Biomass Resources



Jenkins et al. (2006) A roadmap for the development of biomass in California

Potential Tons of Biomass



California Production Differs from Other 'Top 5' Value States

	California	Iowa	Texas	Nebraska	Illinois
	$1,000	$1,000	$1,000	$1,000	$1,000
Food-plant	**$16,490,102**	**$23,681**	**$593,523**	**$66,434**	**$116,780**
Food-animal	**$10,[illegible],300**	**$10,007,347**	**$14,167,468**	**$8,624,935**	**$2,422,917**
Feed	**$2,408,398**	**$10,225,065**	**$3,971,174**	**$6,735,085**	**$10,318,090**
Fiber	$[illegible],272	$32,159	$1,217,333	$8,058	$5,218
Ornamentals	**$3,725,194**	**$107,520**	**$987,533**	**$50,937**	**$458,294**
Other	$58,798	$22,324	$64,042	$20,585	$7,807
Total Value	**$33,885,064**	**$20,418,096**	**$21,001,074**	**$15,506,034**	**$13,329,106**

USDA, NASS, 2007 Census of Agriculture

California Biomass Supply and Use

California's soils, water and related natural resources, and associated biomass production potentials are diverse. National models reflect mid-western agriculture well, but not California's unique conditions.

- **One California Biomass Collaborative objective is to fill in the resource 'gaps' in national models for the benefit of bioenergy feedstock development in California.**
- **Another is to estimate the likely locations, types, and costs of agricultural biomass in California to support use of these resources for energy where it is sensible to do so.**

National Crop Production Models Capture a Different California

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- Existing national agricultural models do not model CA well. (REAP, POLYSYS, GTAP, FASOM). These national models are being used to predict future production of biofuels based on conventional feed-valued crops.
- Local models based on California resources and production more accurately reflect the potential for biomass production from CA cropping systems.

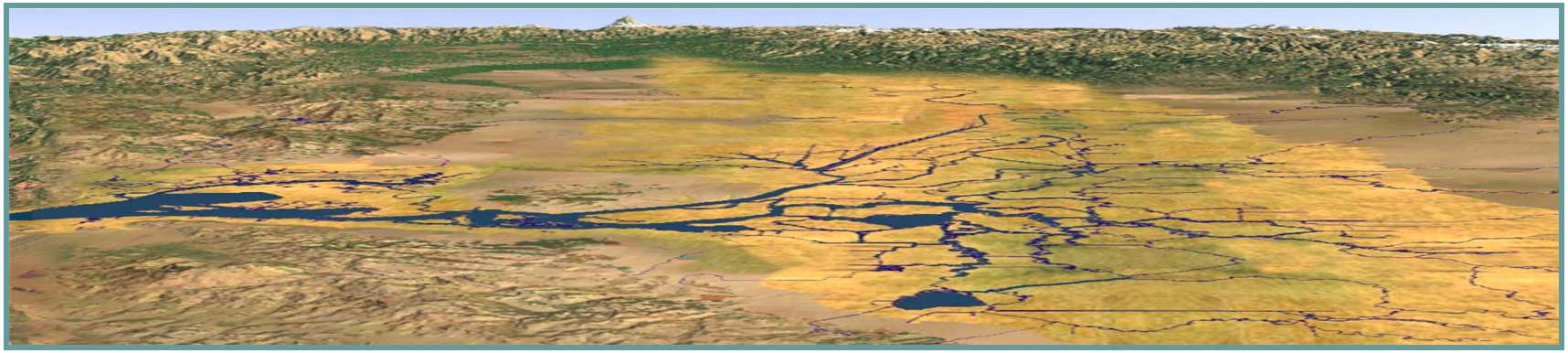
USDA Roadmap Estimates

Advanced Biofuel Production from New Capacity (billion gallons)

Region	% of Total Advanced Volume	Advanced Biofuels		Total Advanced Volume	Total Advanced RFS2 Basis (1)
		Ethanol	Biodiesel		
Southeast (2)	49.8	10.45	0.01	10.46	10.47
Central East (3)	43.3	8.83	0.26	9.09	9.22
Northeast (4)	2.0	0.42	0.01	0.42	0.43
Northwest (5)	4.6	0.79	0.18	0.96	1.05
West (6)	**<0.3**	**0.06**	**0.00**	**0.06**	**0.06**
United States		20.55	0.45	21.00	21.23

(1) RFS2 Basis - higher density fuels receive higher weighting relative to ethanol. Biodiesel is 1.5
(2) Feedstocks: Perennial grasses, soyoil, energy cane, biomass (sweet) sorghum, logging residues
(3) Feedstocks: Perennial grasses, canola, soyoil, biomass (sweet) sorghum, corn stover, logging residues
(4) Feedstocks: Perennial grasses, soyoil, biomass (sweet) sorghum, corn stover, logging residues
(5) Feedstocks: Canola,straw, logging residues
(6) Feedstocks: Biomass (sweet) sorghum, logging residues

Diverse soils and landscapes lead to differing cropping systems in CA



Soil age: ----------→

oldest 100K 30-80K 10K youngest

350K

Silts, loams low OM, crusting

High clay content, drainage limitations, salinity , alkalinity

Basin rim

Natural levees

Hardpans, thick clay layers, (vernal pools)

Soils with structured horizons

A: Bt: C

Oak-savanna/rangelands

rangeland/pasture, some perennials

perennials, annuals

mostly annuals

Soil use →

California Biomass Collaborative Uses a Regional Approach

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- ***Cropping Systems –*** Used state pesticide and crop data to establish farmers' crop preferences, and individual farmer interviews.
- ***Crop Land Area –*** Total acres and spatial location of crop production aligned with county production acreage data.
- ***Economics –*** Developed >90 enterprise budgets which include regional price and technology effects for 27 annual crops.
- ***Results –*** Non-linear, PMP model used to determine scope of change in crop cover based on energy crop adoption.

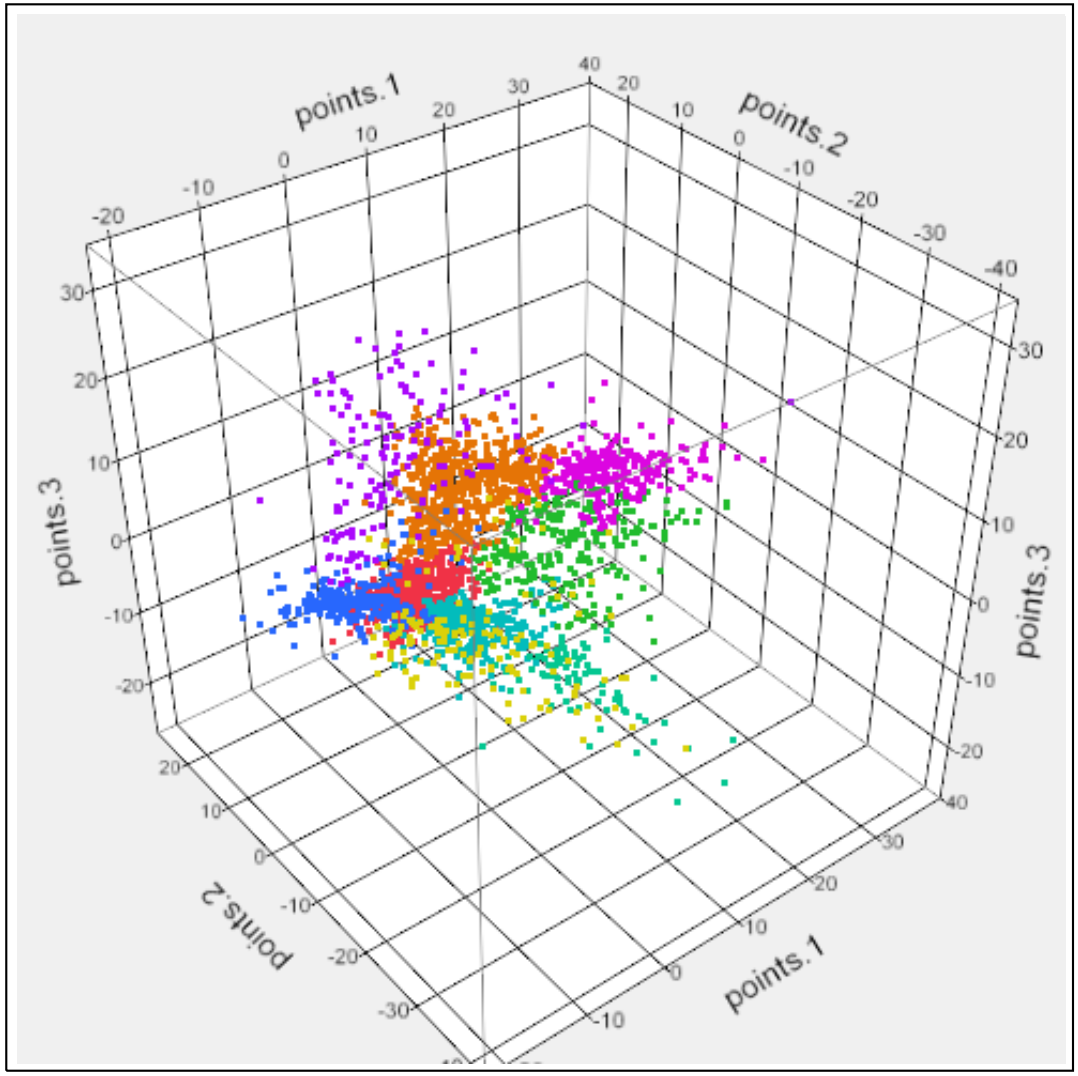
Cropping System Identification

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- 10 years of pesticide use/crop choice data for most of the crop producing areas of California.
- Department of Pesticide Regulation (DPR) data is on 1-section units (640 acres).
- This translates to over 17,000 sections or land unit records across the state.
- A Multidimensional Scaling, Cluster Analysis was conducted to identify naturally occurring cropping patterns within five macro-regions of California.

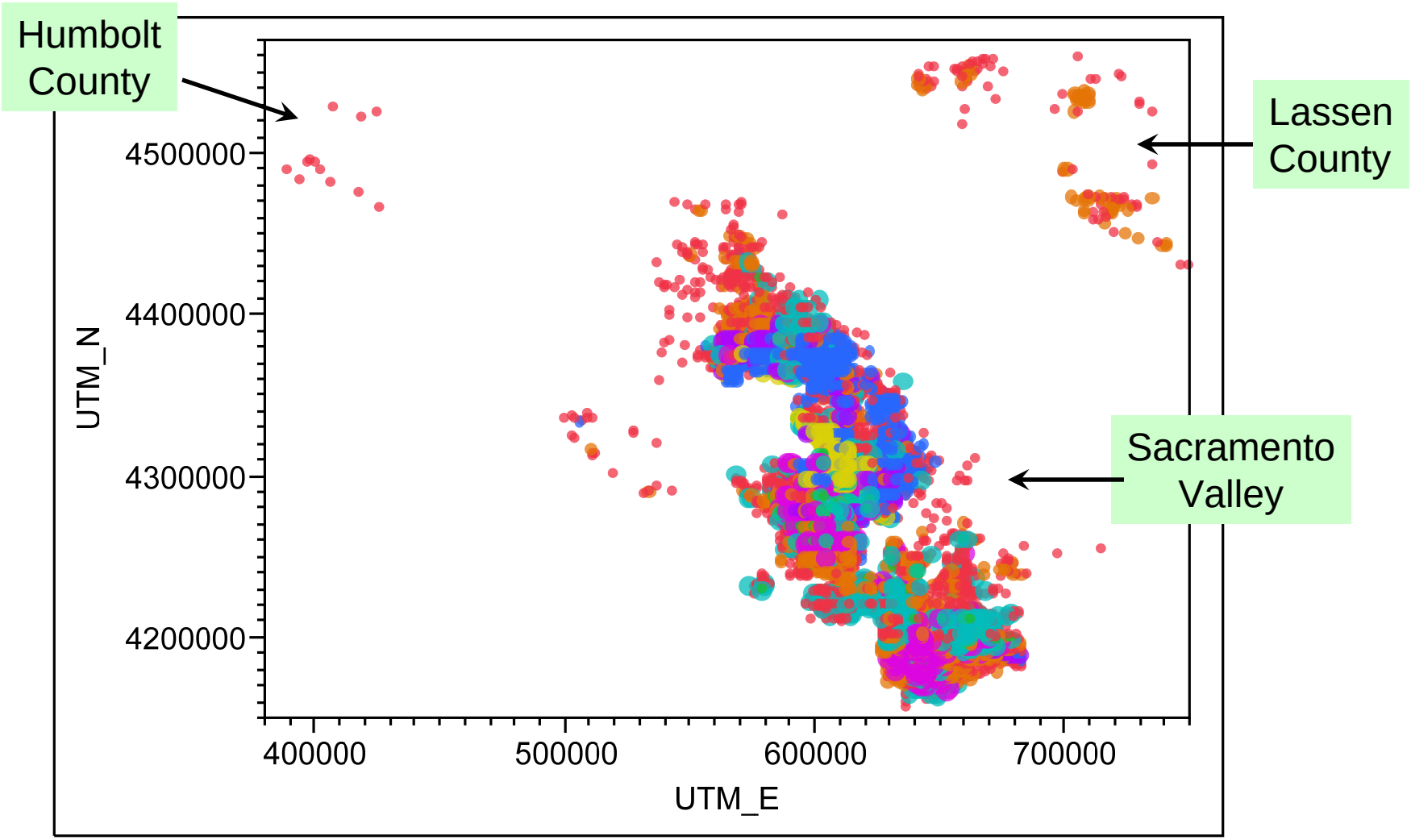
Northern CA (SAC/InterMT)
– 9 Clusters of Cropping Patterns

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Northern California
– 9 Clusters of Cropping Systems

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Modeling approach

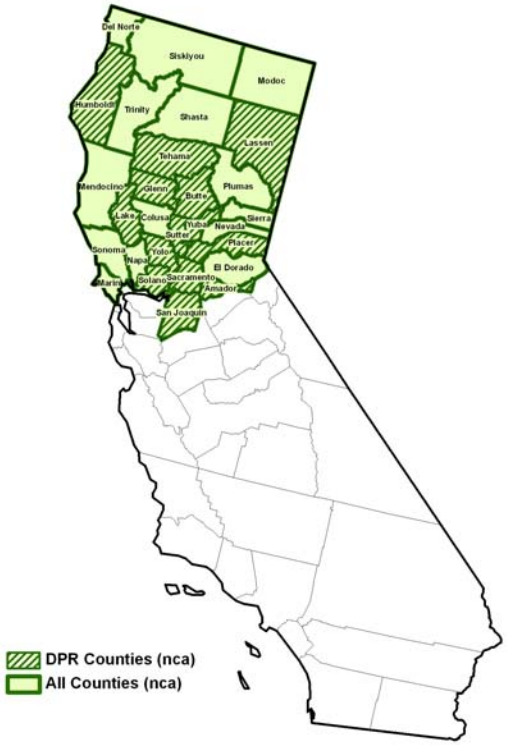
srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- **Goal was to develop a model with sufficient detail to capture the effects of region and landscape position.**

- **And to run the model on as small a unit as the data allows, then sum the results to aggregate regional and state level potential.**

Counties in Aggregated Regions

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Northern California (NCA)

9 Cropping Clusters

Central California (CEN)

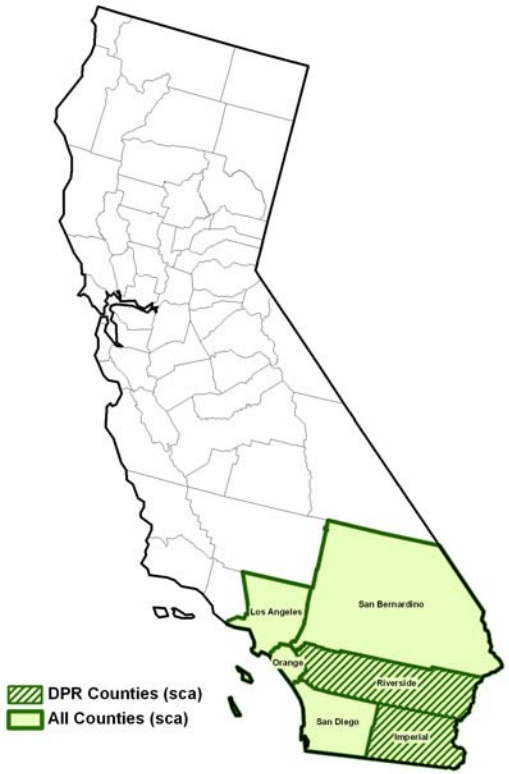
9 Cropping Clusters

South San Joaquin (SSJ)

8 Cropping Clusters

Counties in Aggregated Regions

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Southern California (SCA)

6 Cropping Clusters

Central Coast (COA)

13 Cropping Clusters

Modeling approach

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

1) **Develop a non-linear, economic optimization model (with the positive mathematical programming (PMP) function)**
2) **Develop regionally-sensitive enterprise budgets (27 crops, 5 regions).**
3) **Optimize the 45 cropping systems 'clusters' as representative farms based on CAC acreage using the PMP model and tabulate change in crop cover from acreage shifts.**

CBC Optimization Model

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

Production function

$$\underset{X_{e,g,i,j}}{Max} \sum_{g} \sum_{j} \left[\begin{array}{r} \sum_{i} \left(P_{g,i,j} \times \left(\beta_{g,i,j} - \omega_{g,i,j} X_{g,i,j} \right) - C_{g,i,j} \right) X_{g,i,j} \\ + \sum_{e} \left(P_{e,g,j} Y_{e,g,j} - C_{e,g,j} \right) X_{e,g,j} \end{array} \right] \begin{array}{l} \} \text{ PMP function} \\ \} \text{ Energy crop function} \end{array}$$

Subject to: $\sum_{i} \sum_{e} X_{g,i,e,j} \leq \overline{R_{g,j}}$ *j= {A(acres), w(ac-ft of water)}*

$\boldsymbol{P}_{g,i,e,j}$ = *farm price of crop, i, and energy crop e, in region, g, and resource, j.*

$\boldsymbol{Y}_{g,i,e,j}$ = *yield of crop, i, and energy crop e, in region, g, and resource, j.*

$\overline{\boldsymbol{R}}_{g,j}$ = *total availability of resource, j, (land, water) in region, g*

$\boldsymbol{X}_{g,i,j}$ = *level of inputs applied for crop, i, in region, g, and resource, j.*

$\boldsymbol{\beta}_{g,i,j}$ = *intercept of the quadratic (marginal) curve of crop, i, in region, g, resource, j.*

$\boldsymbol{\omega}_{g,i,j}$ = *slope of quadratic (marginal) curve of crop, i, in region, g, and resource, j.*

Crop Data Coverage

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

Region	model code	Crop Acres (Census of Ag)	Annual Crop Acres	Total Counties	DPR Counties	Crop/Farm Clusters
Northern CA	NCA	3,190,441	1,538,971	29	14	9
Central CA	CEN	2,314,332	1,179,789	9	5	9
South SJV	SSJ	2,094,486	1,193,752	3	3	8
Southern CA (IV)	SCA	818,787	599,237	6	2	6
Coastal CA	COA	1,038,340	395,633	11	6	13
		9,456,386	4,907,383			45

- Model includes annual crop acres, but not perennial fruit/nut tree and vine crops, dryland systems, or irrigated pastures.
- DPR data was calibrated to historical County Agricultural Commissioner crop data.

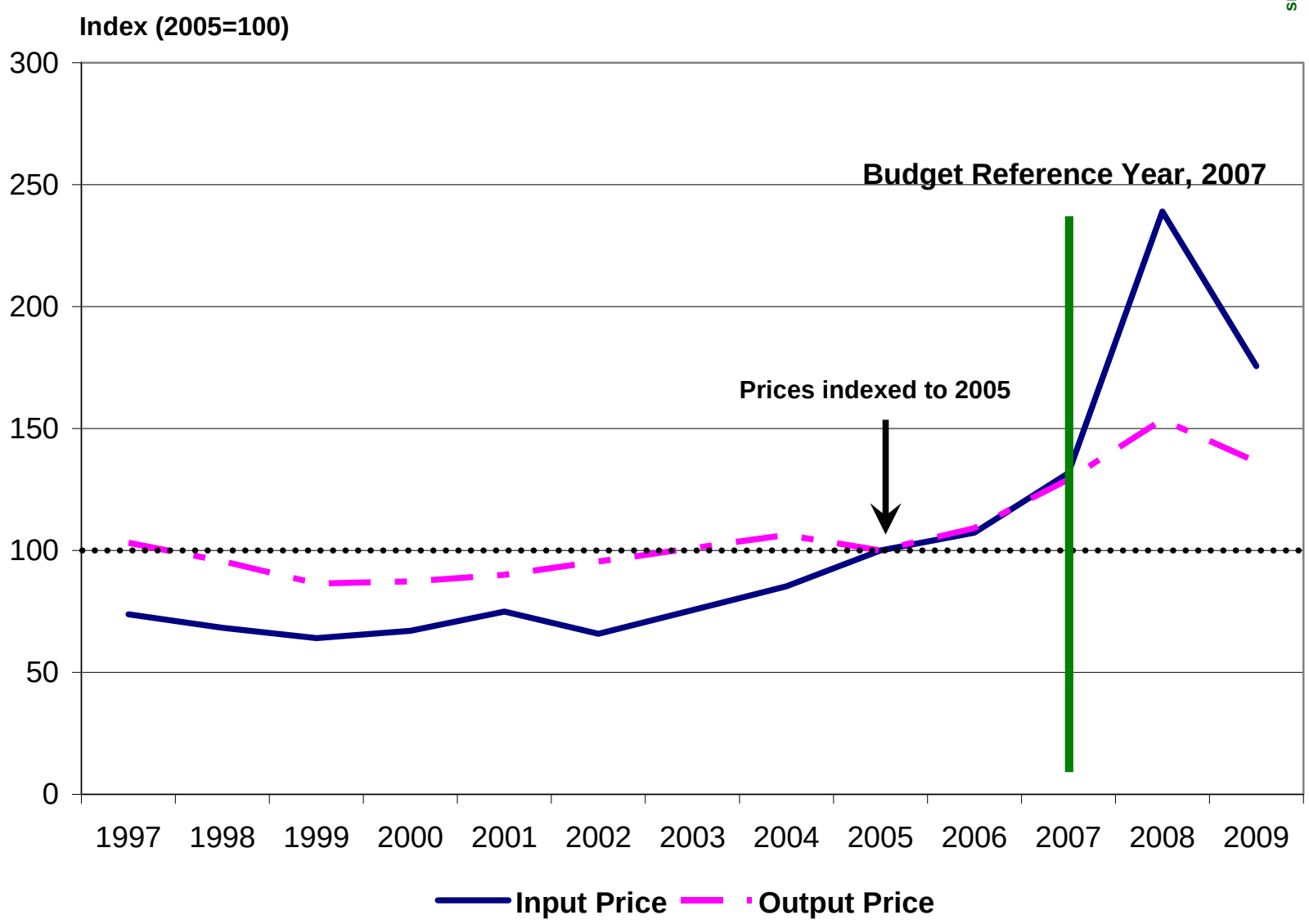
Assumptions and Caveats

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- **'Profit' in this model refers to the incremental increase in profit for the crop analyzed. For example: a '$40/acre profit' level refers to an additional $40 per acre for that crop compared to others already in the system – not total farm profit. This reflects the amount a bioenergy firm would have to pay to acquire a particular feedstock.**
- **All prices and costs are set at 2007 price levels for consistency across all crop budgets.**
- **Water use is consistent with allocations during the period for which DPR data was acquired (1999-2008).**

Price-Level Adjustments

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

Results

For the sake of discussion, a scenario with a large profit advantage for the biofuel crops over others currently grown is used here.

Northern CA (C7)

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

Crop	Score	Dist %	Dist %
Rice	7.215	29.3%	32.0%
Tomato	3.944	16.0%	17.5%
Wheat	3.285	**10.2%**	11.2%
Beans	2.486	10.1%	11.0%
Safflower	2.292	9.3%	10.2%
Melons	2.285	9.3%	10.1%
Corn	1.271	5.2%	5.6%
Alfalfa	0.542	2.2%	2.4%
Onion	0.424	1.7%	
Cotton	0.271	1.1%	
Carrots	0.236	1.0%	
Oats	0.132	0.5%	
Sorghum	0.125	0.5%	
Sugarbeet	0.063	0.3%	
Barley	0.028	0.1%	
Ryegrass	0.021	0.1%	
Broccoli	0.014	0.1%	
Sudangrass	0.014	0.1%	
Bermudagrass	0.000	0.0%	
Forage Grasses	0.000	0.0%	
Garlic	0.000	0.0%	
Lettuce	0.000	0.0%	
Potato	0.000	0.0%	
Rape	0.000	0.0%	
	24.646		100%

Green box shows the representative farm defined by **90%** of crops in Cluster 7

Input Coefficients for NCA Cluster #7

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

	Yield/Ac	Units	Price ($/unit)	Input Cost/Ac	Profit ($/ac)	Acres	Water (ac-ft)
Alfalfa Hay	7.0	tons	$171.45	$725.19	$474.98	2,292	3.6
Dry Edible Beans	1.3	tons	$655.38	$788.24	$30.99	10,522	2.7
Corn	5.5	tons	$140.04	$706.56	$63.66	5,378	3.2
Melons	680.0	boxes	$2.46	$1,387.00	$284.88	9,669	1.5
Rice	83.0	cwt	$15.50	$1,181.23	$105.27	30,536	4.3
Safflower	1.2	tons	$361.45	$366.08	$67.67	9,699	0.5
Tomatoes	35.0	tons	$58.82	$1,864.37	$194.21	16,693	3.5
Wheat	3.0	tons	$156.20	$434.36	$34.24	10,680	0.5
Canola	1.0	tons	$340.80	$340.80	$0.00	---	0.5
Sweet Sorghum	32.0	tons	$26.00	$832.00	$0.00	---	2.0
Sugarbeets	30.0	tons	$37.80	$1,134.00	$0.00	---	3.0
Bermudagrass	3.2	tons	$170.00	$554.75	-$10.75	---	4.0
Total Acres in Cluster						95,470	

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

Canola Price Sensitivity, NCA Cluster #7

Land Use Activities

	Alfalfa	Dry Bean	Corn	Melon	Rice	Safflower	Tomato	Wheat	Canola	Canola
$/ton	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Share
$340	2,293	10,513	5,379	9,670	30,539	9,700	16,695	10,681		
$345	2,293	10,513	5,379	9,670	30,539	9,700	16,695	10,681		
$350	2,297	9,153	5,459	9,637	31,216	9,434	16,766	10,045	**1,463**	1.5%
$355	2,302	7,148	5,577	9,589	32,214	9,042	16,871	9,105	**3,621**	3.8%
$360	2,308	5,143	5,696	9,540	33,213	8,650	16,975	8,166	**5,779**	6.1%
$365	2,314	3,138	5,814	9,491	34,211	8,258	17,080	7,227	**7,937**	8.3%
$370	2,320	1,133	5,933	9,443	35,210	7,866	17,184	6,288	**10,095**	10.6%
$375	2,314		5,652	9,367	34,689	7,474	17,047	5,348	**13,579**	14.2%
$380	2,300		5,149	9,277	33,323	7,082	16,775	4,409	**17,155**	18.0%
$40	8	(10,513)	(230)	(394)	2,784	(2,618)	80	(6,272)	**17,155**	

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

Canola Price Sensitivity, NCA Cluster #7

Water Use Activities

$/ton	Alfalfa Ac-ft	Dry Bean Ac-ft	Corn Ac-ft	Melon Ac-ft	Rice Ac-ft	Safflower Ac-ft	Tomato Ac-ft	Wheat Ac-ft	Canola Ac-ft
$340	8,311	28,034	17,087	14,505	129,791	4,850	58,433	5,341	
$345	8,311	28,034	17,087	14,505	129,791	4,850	58,433	5,341	
$350	8,325	24,409	17,342	14,456	132,668	4,717	58,681	5,022	732
$355	8,346	19,062	17,718	14,383	136,911	4,521	59,047	4,553	1,811
$360	8,368	13,715	18,094	14,310	141,155	4,325	59,413	4,083	2,889
$365	8,389	8,368	18,470	14,237	145,398	4,129	59,779	3,613	3,968
$370	8,410	3,021	18,846	14,164	149,642	3,933	60,145	3,144	5,047
$375	8,387		17,954	14,051	147,430	3,737	59,664	2,674	6,789
$380	8,339		16,357	13,915	141,623	3,541	58,713	2,205	8,577
$40	28	(28,034)	(730)	(590)	11,832	(1,309)	280	(3,136)	8,577

Estimates for water use by crop are used for each crop cluster.

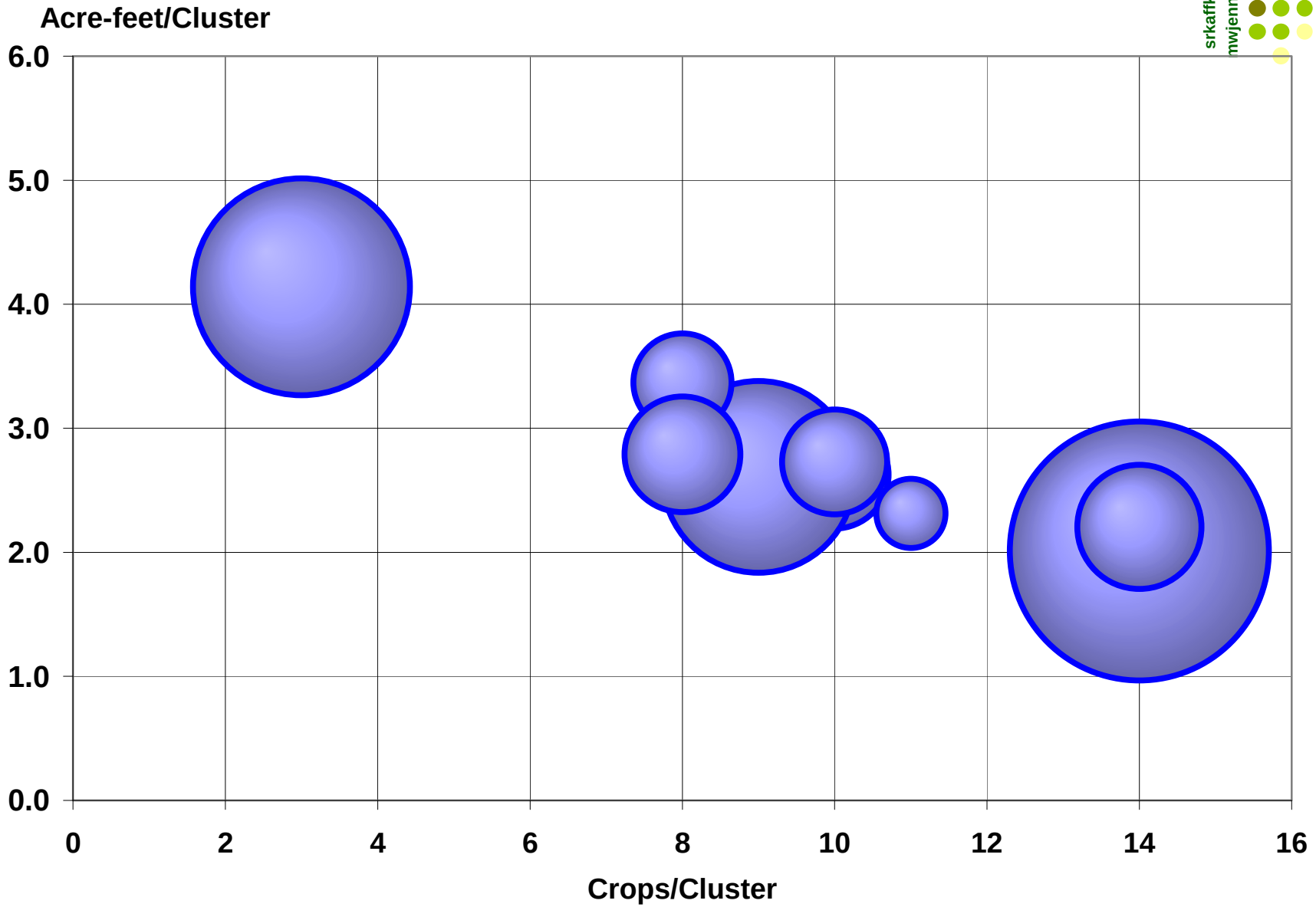
The Local Effects are Compelling

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- **The cropping pattern clusters capture local resource and economic conditions, minimizing the loss of useful information.**
- **The northern California region (NCA) is diverse and with 9 clusters that have a variety of crops, water-use values, and profitability.**
- **The southern San Joaquin (SSJ) regional clusters are more homogeneous, with less variability in crop number, water-use and profitability.**

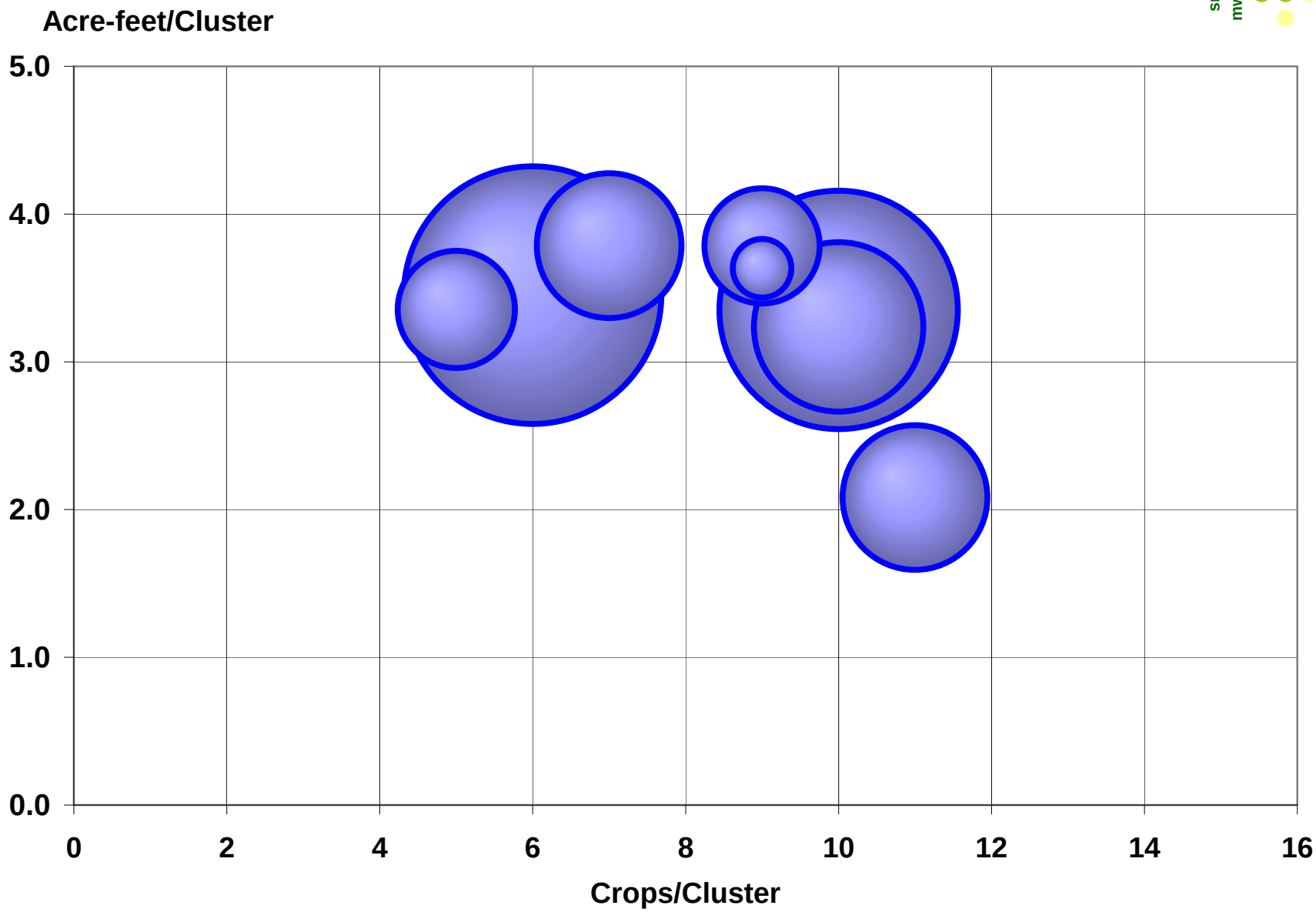
NCA Region Water, Crop, and Acres

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



SSJ Region Water, Crop, and Acres

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Price advantage for biofuel crops

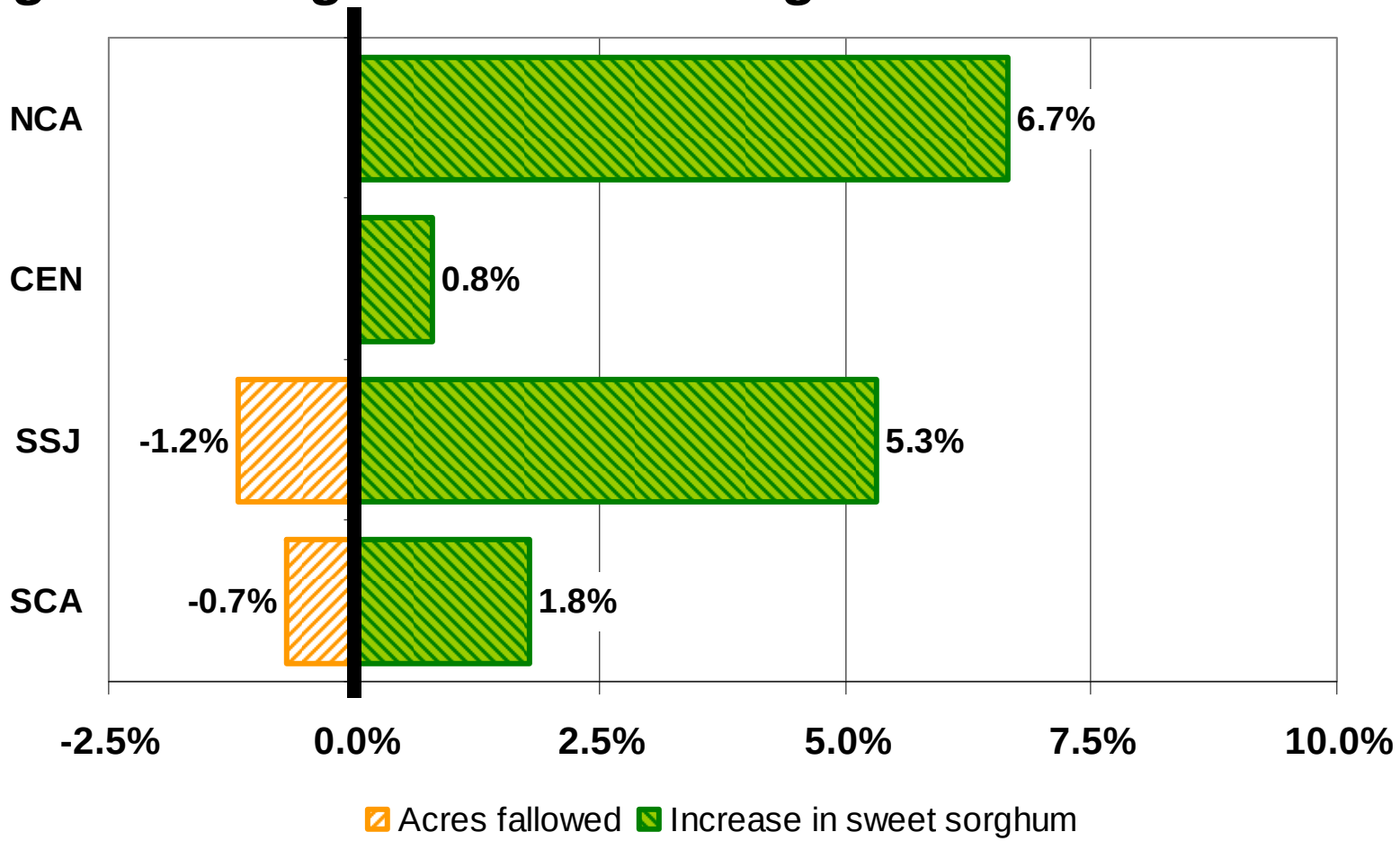
srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- **An increase of $40/acre profit is ‘additional’ profit per acre for the biofuel crop compared to others in the cluster.**
- **In this analysis, $40/acre is a large profit advantage.**
- **This incremental profit level represents the additional amount a processor must pay to assure farmer participation at projected levels.**

$40/acre Sweet Sorghum Profit Induced Changes in Crop and Fallow Acres

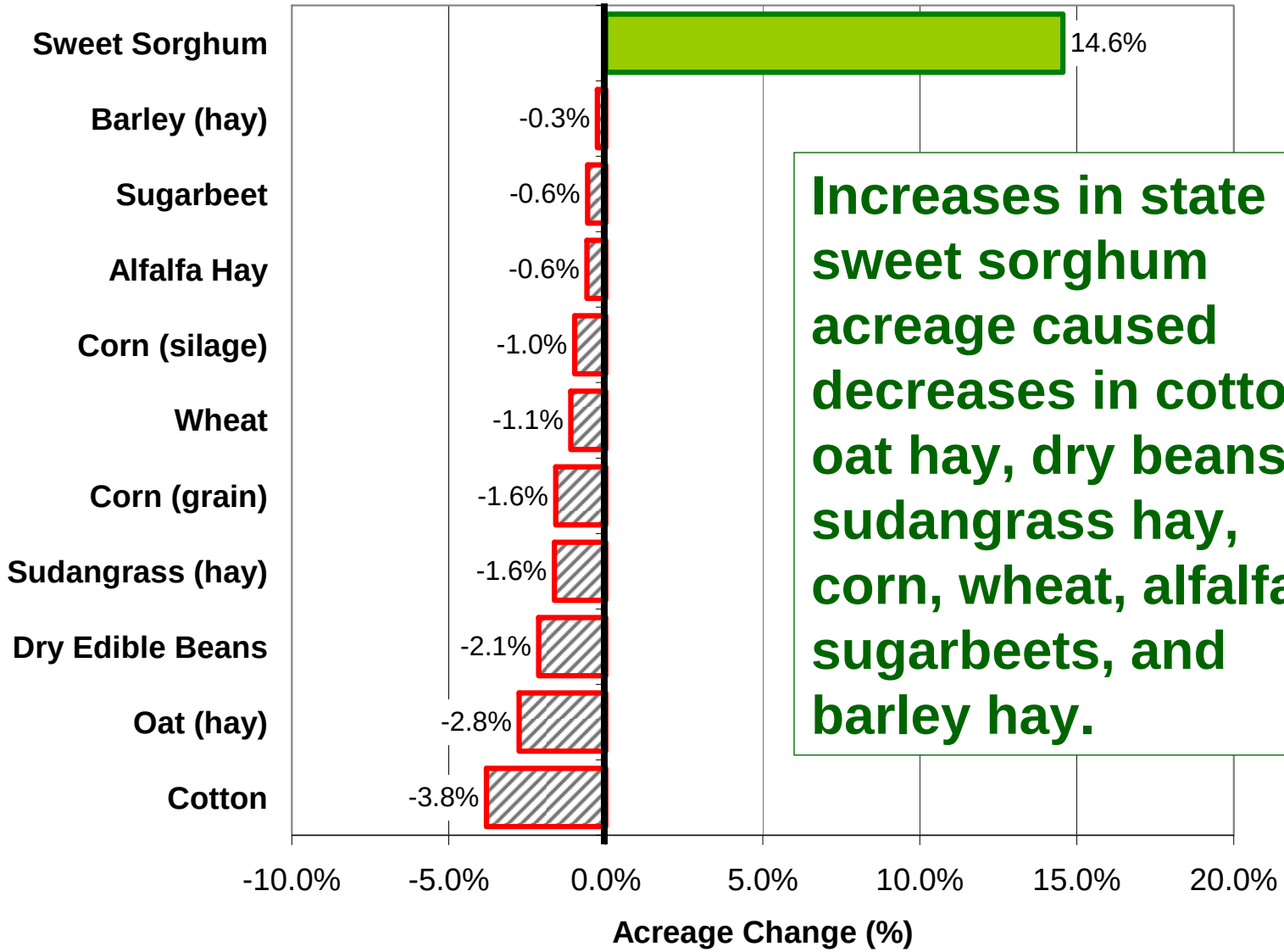
srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

As sweet sorghum acreage increased, some land was fallowed in the SSJ and SCA Regions. No sweet sorghum was grown in COA Region.



Acreage Changes from $40/acre Increase in Sweet Sorghum Profit

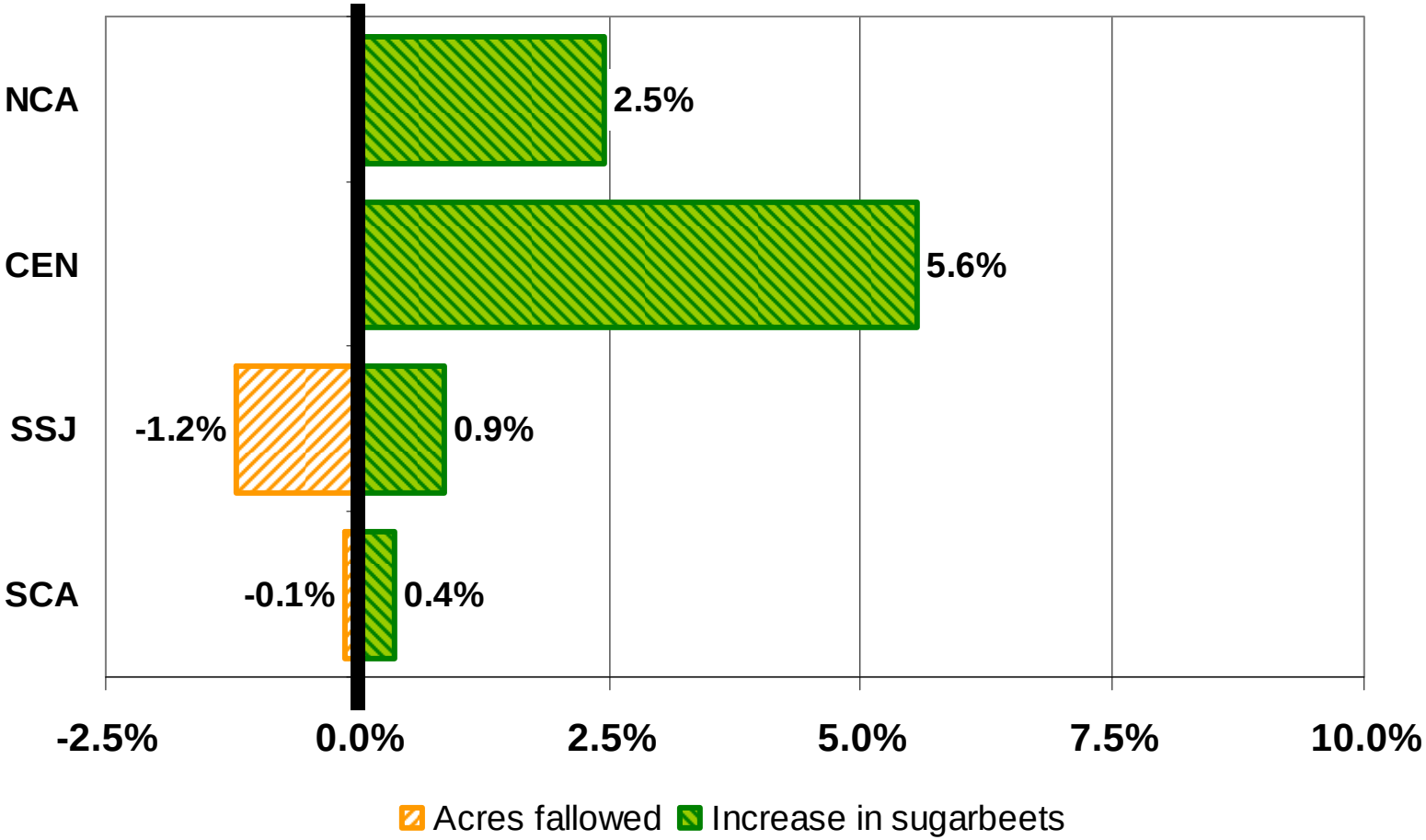
srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Increases in state sweet sorghum acreage caused decreases in cotton, oat hay, dry beans, sudangrass hay, corn, wheat, alfalfa, sugarbeets, and barley hay.

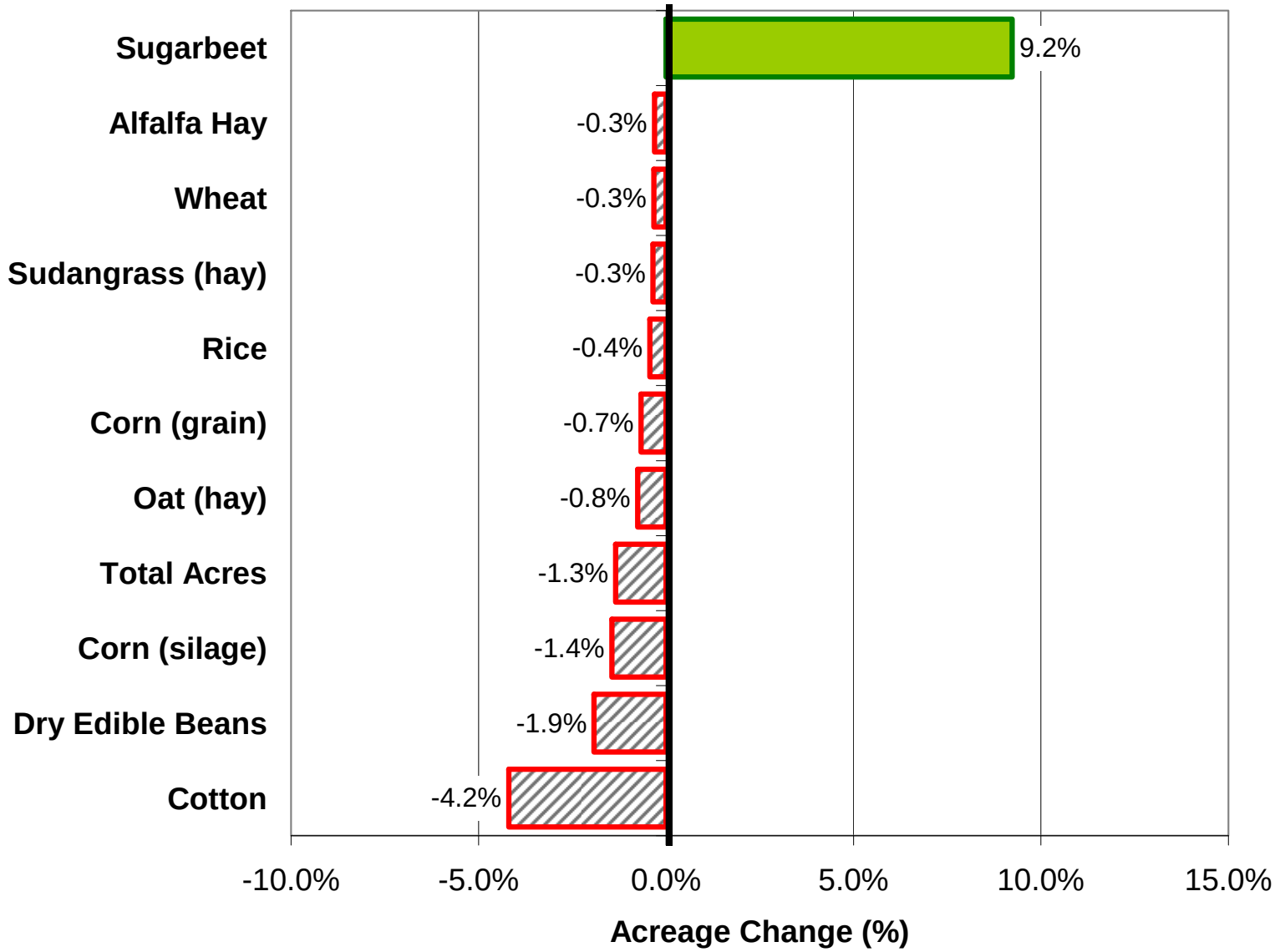
$40/acre Sugarbeet Profit Changes in Crop and Fallow Acres

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Acreage Changes from $40/acre Increase in Sugarbeet Profit

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

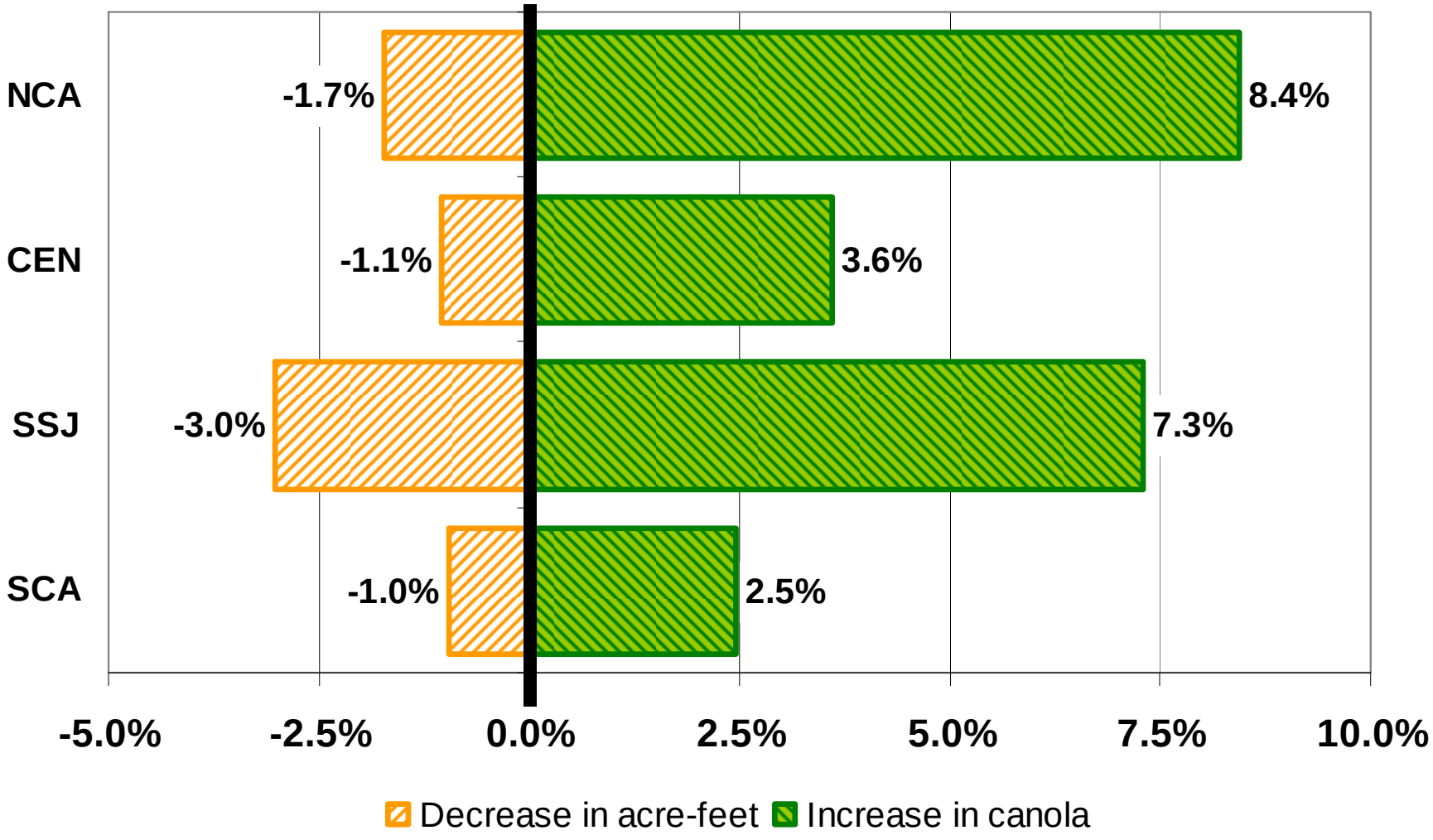


Shasta Lake

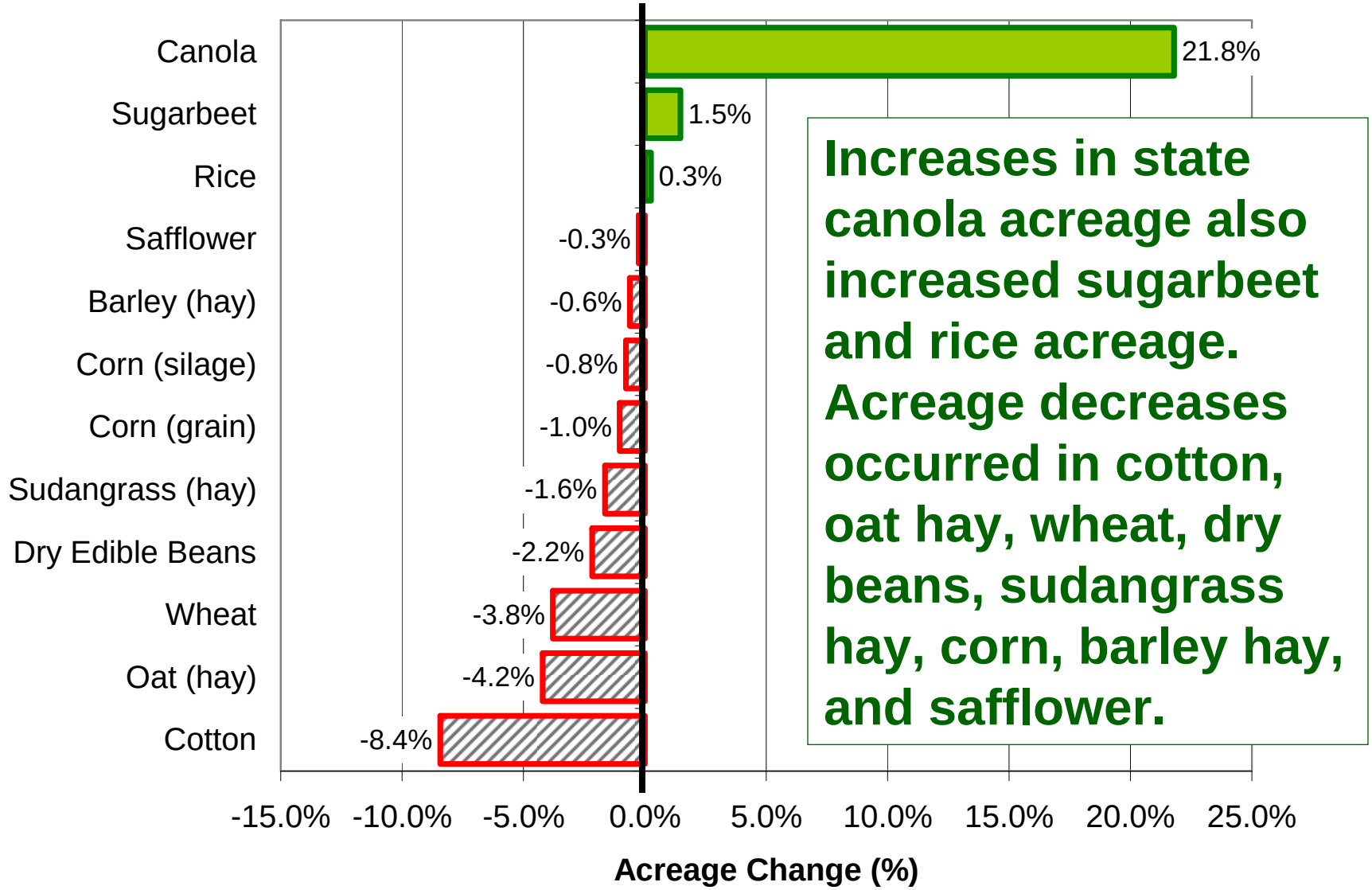
Major Water Projects in California move water from north to south.

$40/acre Canola Profit Changes in Regional Acres and Water Use

As canola acreage increased, regional water use decreased. No canola was grown in Coastal Region.



State Acreage Changes from $40/acre Increase in Canola Profit



Increases in state canola acreage also increased sugarbeet and rice acreage. Acreage decreases occurred in cotton, oat hay, wheat, dry beans, sudangrass hay, corn, barley hay, and safflower.

Regional Assessment Effectively Models Local Resources

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- An economic benchmark of an average increase in profit of $40/acre integrates variation in yield, output price, and input cost.
- Lower-valued crops were displaced subject to timing and water resources.
- Energy crops like canola that require less water lowered regional water demand.
- Some higher-valued crops increased as water resources became available.

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

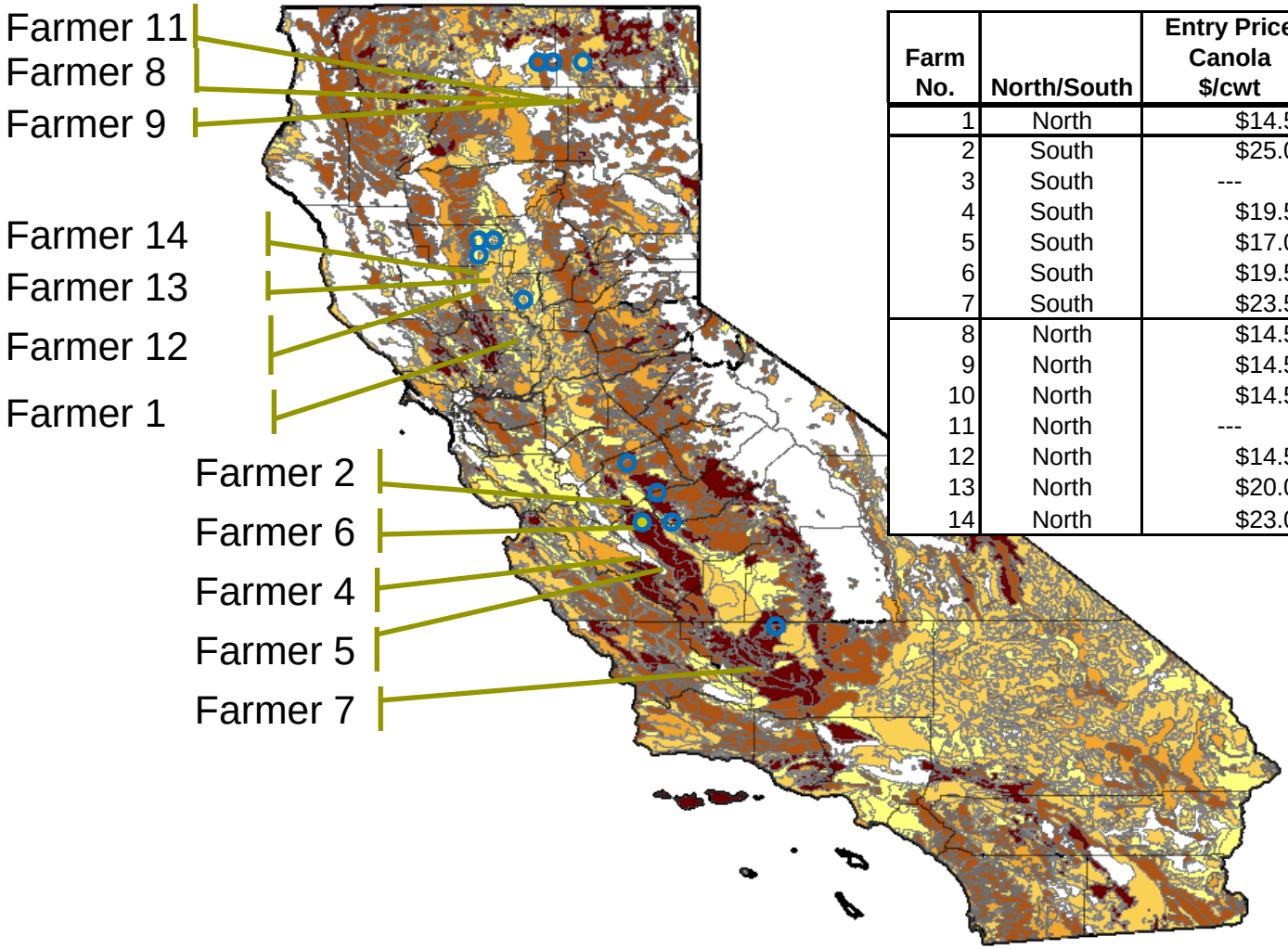
Further Work

- Five crops have been modeled so far (canola, sweet sorghum, sugarbeets, bermuda grass, and corn). More will be added including sugarcane and other perennial grasses.
- Dryland farming systems will be added.
- Additional resource use assessments will be carried out (fertilizers, pesticides) and effects of local variations in water supply/price will be assessed.
- Specific, local analyses to support the development of individual biorefinery projects will be carried out.
- Results will be available at the California Biomass Collaborative website.

http://biomass.ucdavis.edu/index.html

Bio-energy Crop Price Response for Representative Growers

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu



Farm No.	North/South	Entry Price Canola $/cwt	Entry Price Swt Sorghum $/ton
1	North	$14.50	$22.50
2	South	$25.00	$28.50
3	South	---	---
4	South	$19.50	$25.50
5	South	$17.00	$22.00
6	South	$19.50	$25.50
7	South	$23.50	$40.00
8	North	$14.50	$22.50
9	North	$14.50	$22.50
10	North	$14.50	$22.50
11	North	---	---
12	North	$14.50	$22.50
13	North	$20.00	$26.00
14	North	$23.00	---

Contact Information:

srkaffka@ucdavis.edu
mwjenner@ucdavis.edu

- Steve Kaffka, Director
  California Biomass Collaborative
  530-752-8108
  srkaffka@ucdavis.edu

- Mark Jenner, Biomass Systems Economist
  California Biomass Collaborative
  530-752-4112
  mwjenner@ucdavis.edu