Biomass Resources in California: Potential for Economic Use

Policy support (briefly)
Urban biomass resources
Forest biomass resources
Agricultural biomass resources
Marginal lands
Biogas

USDA/DOE Biomass Advisory Committee

Emeryville , California

November 19, 2015

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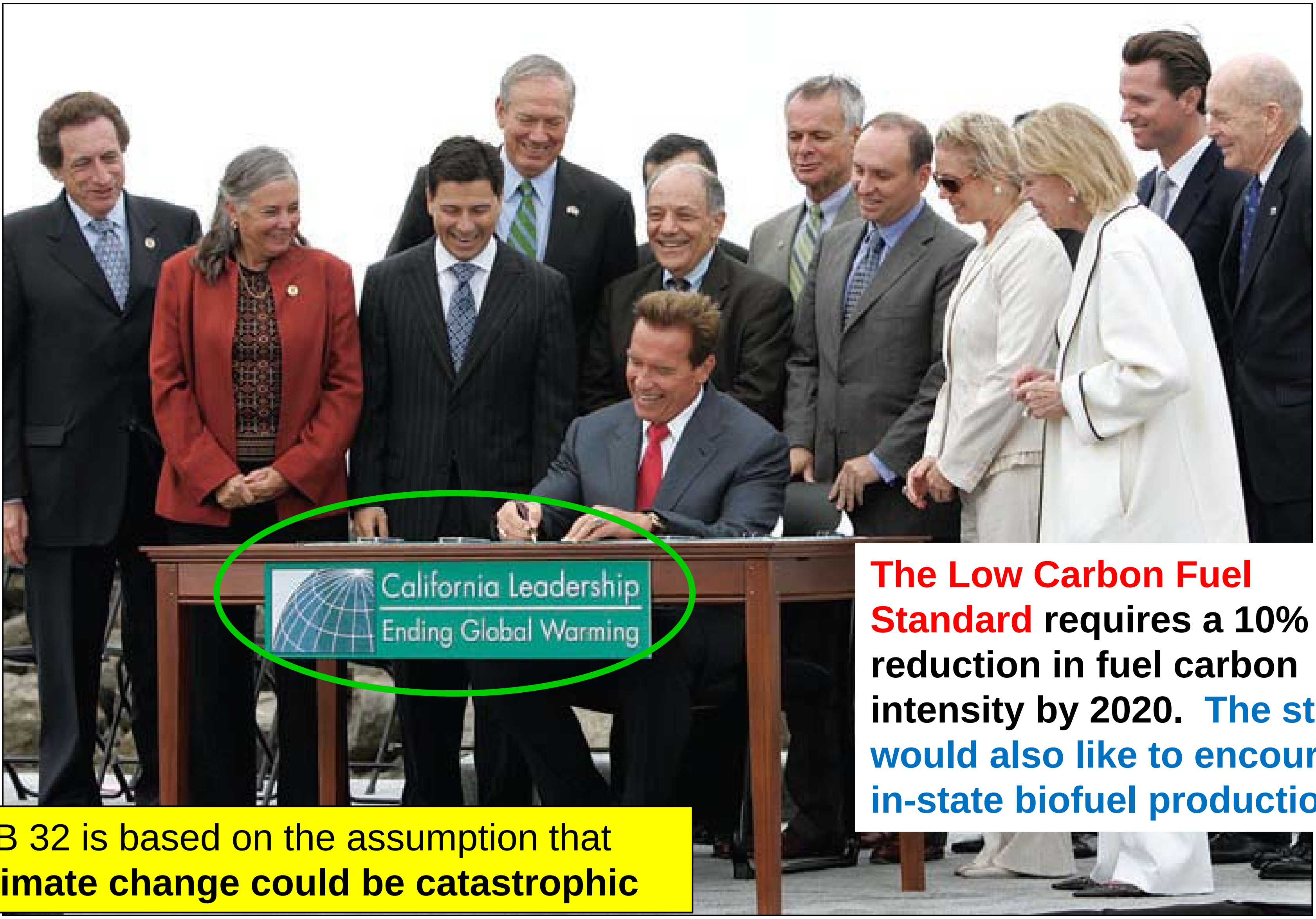
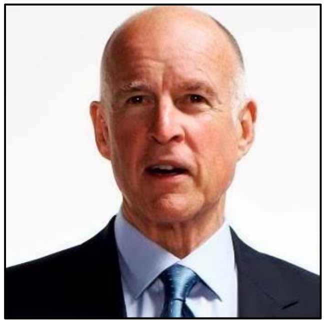
Signing AB 32: The Global Warming Solutions Act



The Low Carbon Fuel Standard requires a 10% reduction in fuel carbon intensity by 2020. The state would also like to encourage in-state biofuel production.

AB 32 is based on the assumption that **climate change could be catastrophic**

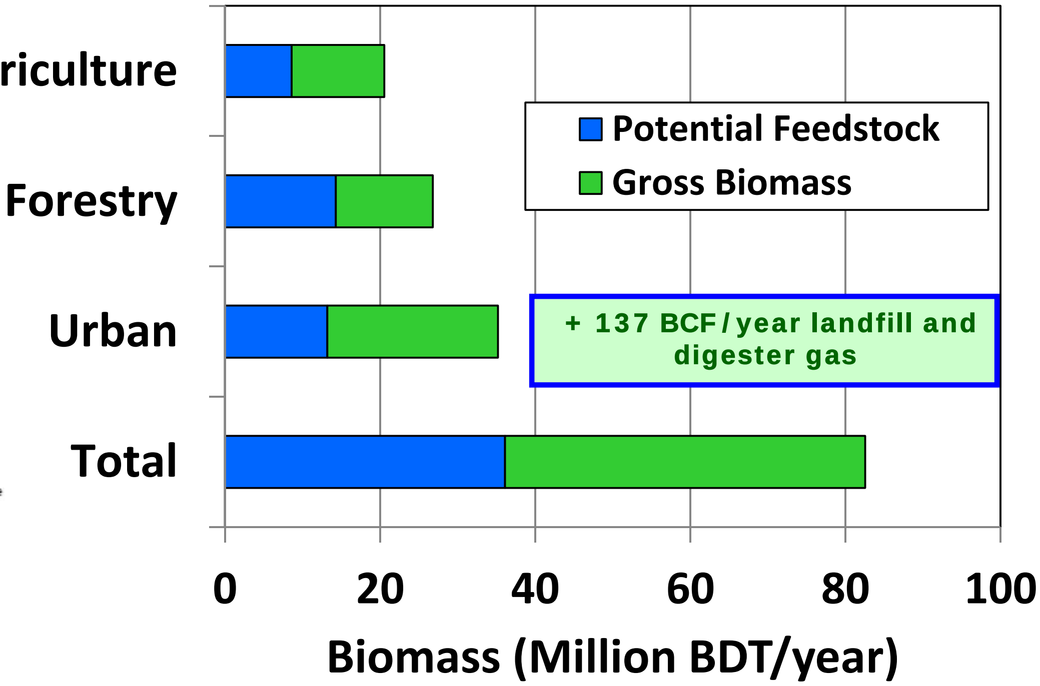
Governor Brown’s Goals

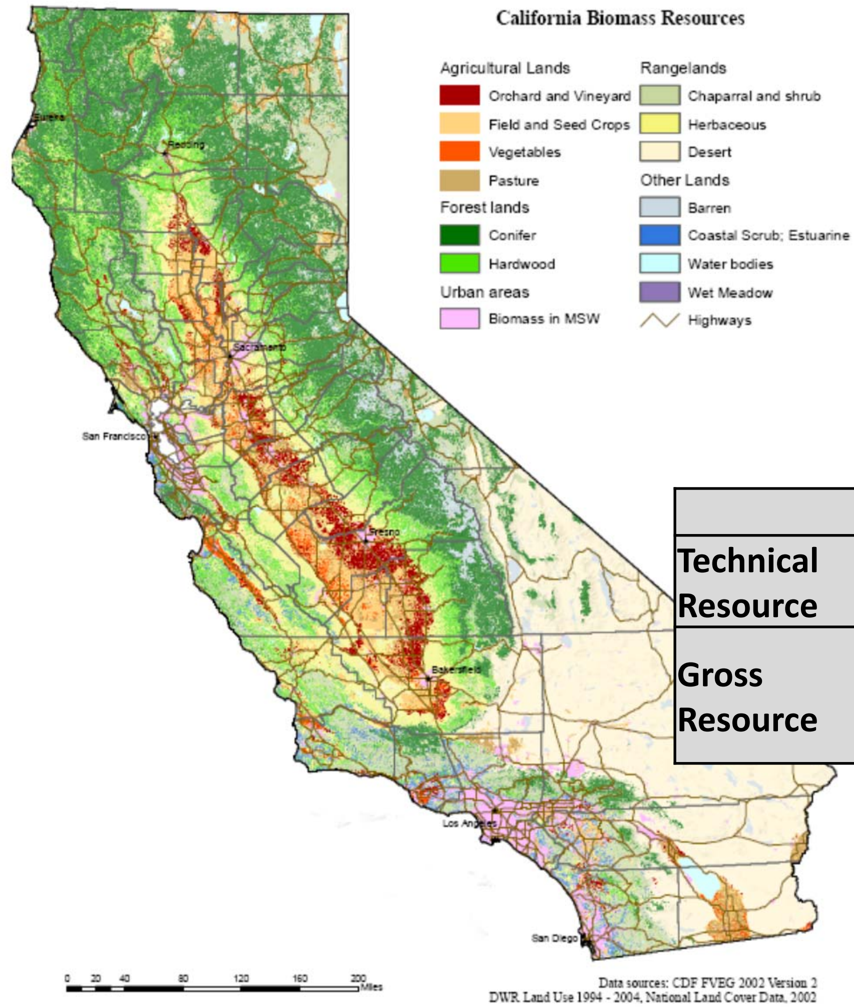


- Executive Order B-30-15: Reduce greenhouse gas emissions 40% below 1990 levels by 2030
  - Double the efficiency savings achieved at existing buildings and make heating fuels cleaner
  - Increase from 33% to 50% renewable electricity
  - Reduce today's petroleum use in cars and trucks by up to 50%
- The Clean Energy and Pollution Reduction Act of 2015 (Senate Bill 350, DeLeón, 2015)

California Energy Commission- 2015 IEPR

California Biomass Resources Are Diverse



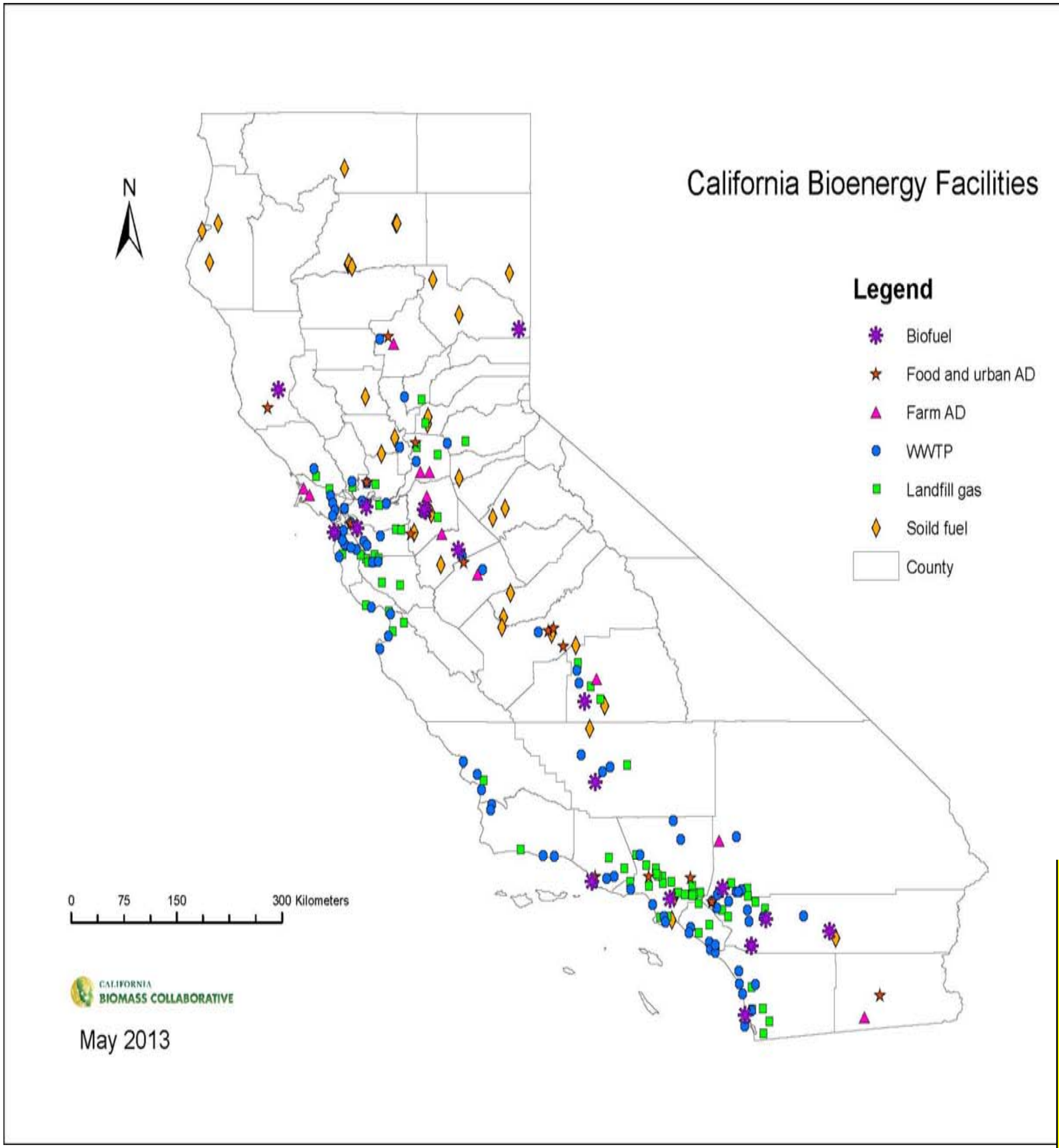


Data sources: CDF FVEG 2002 Version 2
DWR Land Use 1994 - 2004, National Land Cover Data, 2002

	Urban	Agriculture	Forestry	Total
Technical Resource	8.6 (from landfill stream)	12.5	14.3	35.4
Gross Resource	12.9 (landfill) 12. 4 (diverted/recycled) 25.3 Total	25.8	26.8	77.9

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

CALIFORNIA BIOMASS COLLABORATIVE



iofuel facilities are
el manufacturers
esidual Fats, Oils, and
s (FOG) and some
ble oil; there are 4
ethanol facilities
using imported corn grain, attempting a shift to grain sorghum. There are legacy biomass to power facilities and new AD systems to process MSW and dairy manure.

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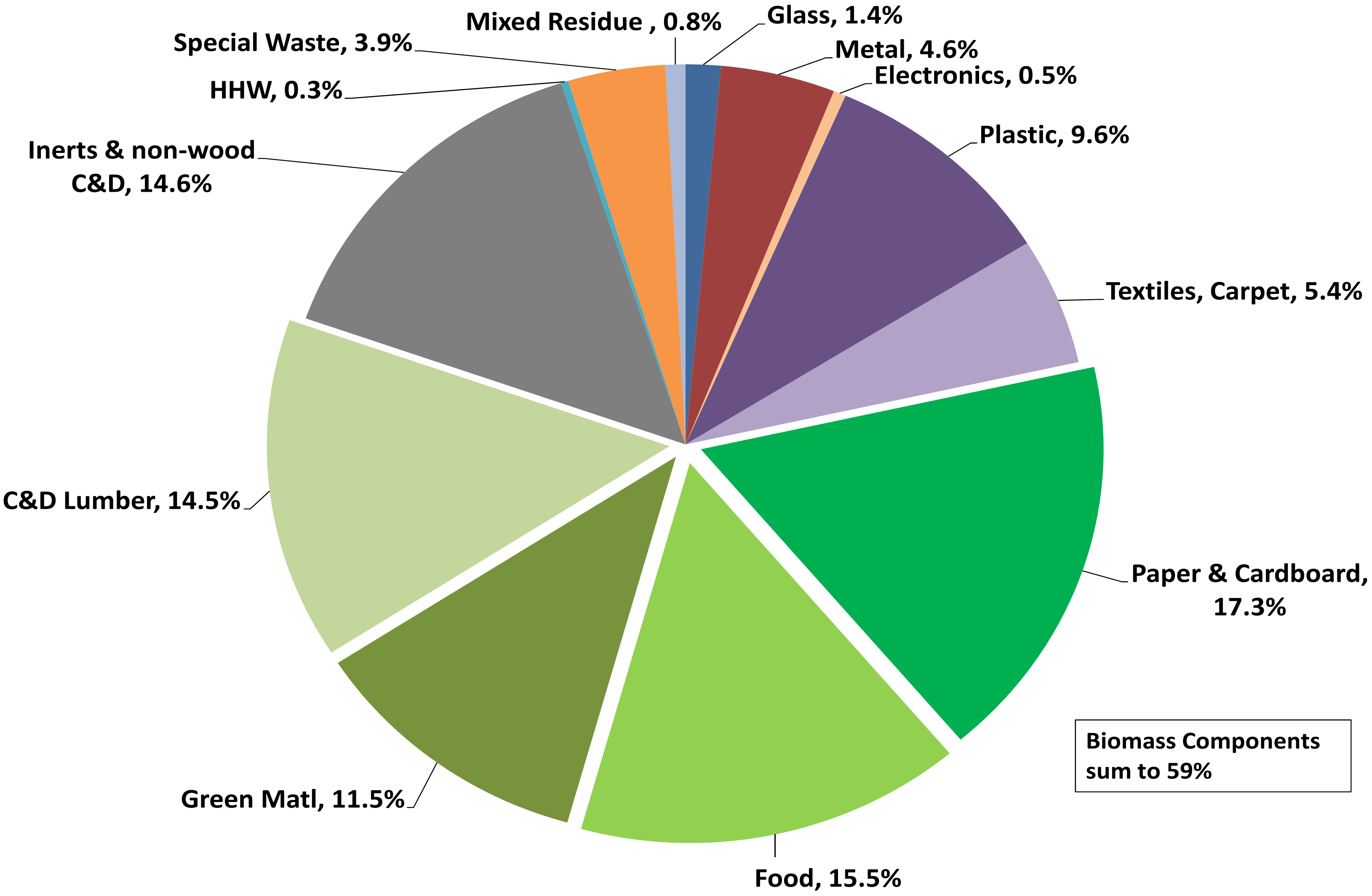
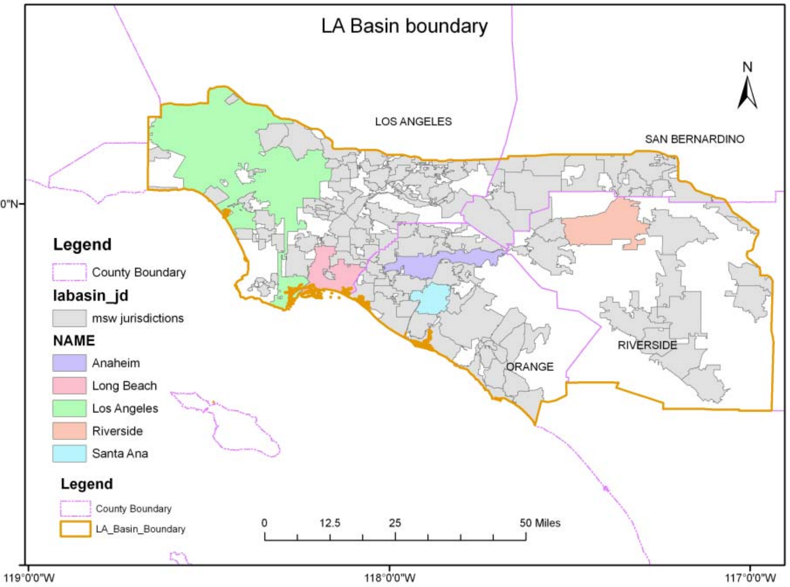
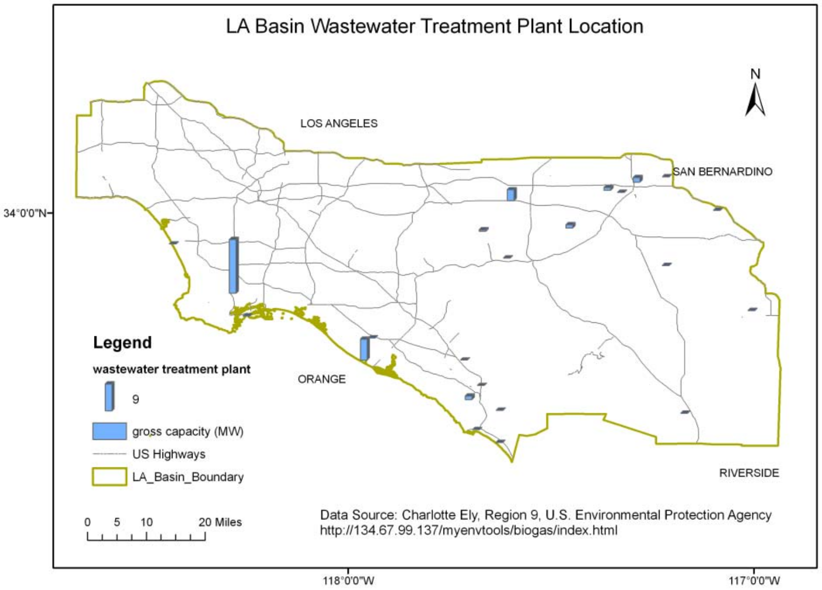
California landfilled waste stream by material type

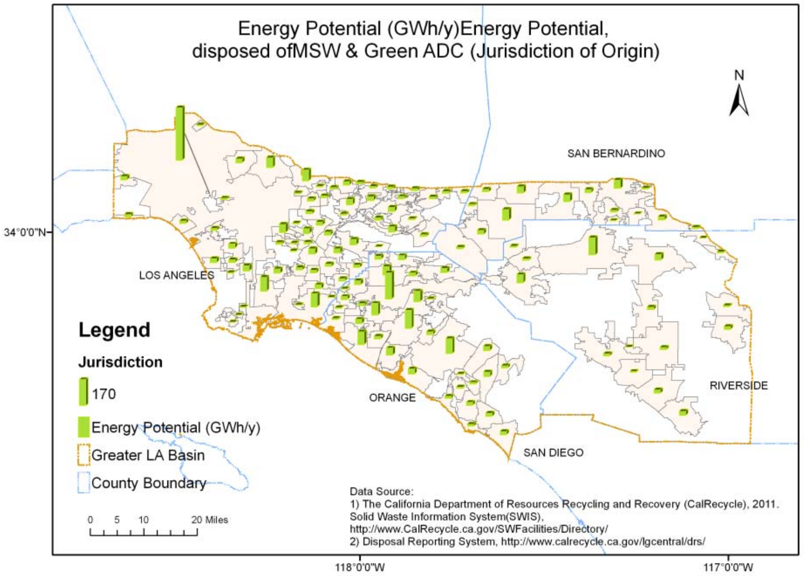


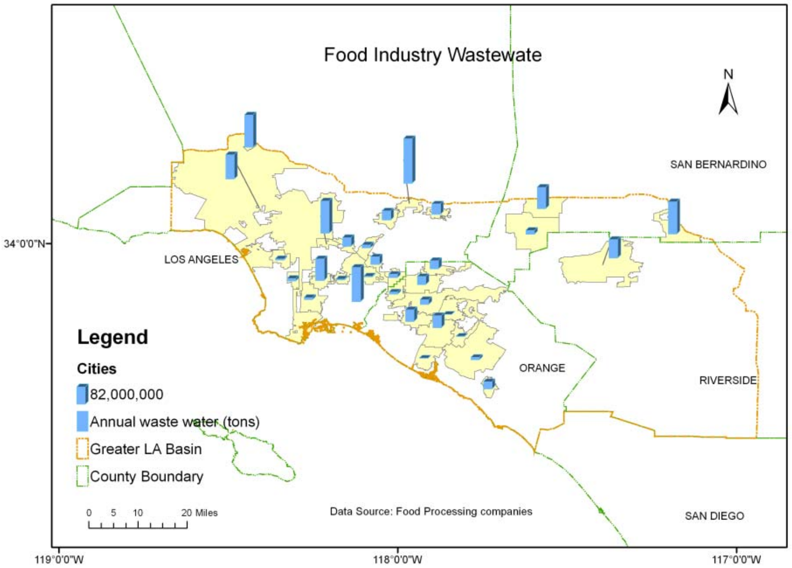
Biomass Components sum to 59%

(adapted from 2008 characterization: (Cascadia 2009))









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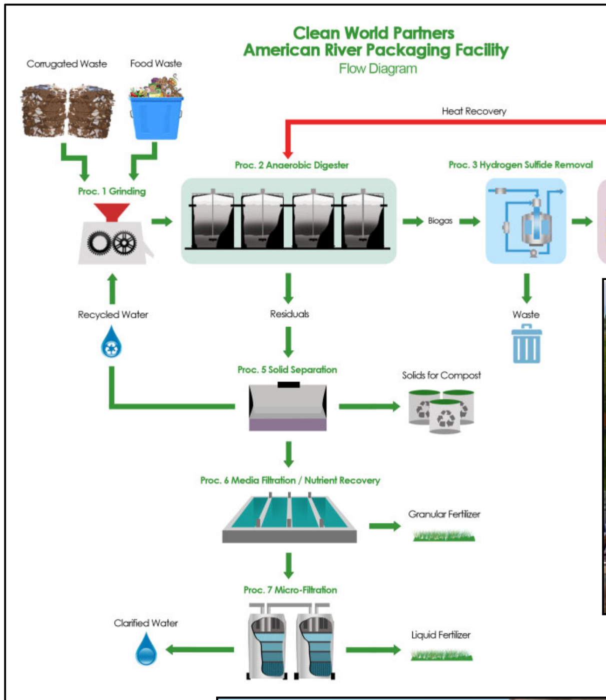

CA policy will support development of AD systems for management or organic MSW residuals, esp. the LCFS.


Landfill gas to methane


CR&R AD facility, Perris, CA
(80K to 320K t/y)

Potential energy from landfill stream

Landfill Stream, California, 2010 (post recycled and black bin)	Million Tons	% of Total	Electricity Potential		Fuel Potential (MM gge)
			(MWe)	(GWh y^{-1})	
Biogenic Material (food, green, C&D wood, paper/cardboard, other)	**17.8**	**59**	**1,230**	**10,800**	**700**
Non-Renewable Carbonaceous (plastics, textiles)	**4.6**	**15**	**670**	**5,900**	**400**
Inert (glass, metal, other C&D and mineralized)	**7.9**	**26**	**-**	**-**	**-**
Totals	**30.3**	**100**	**1,900**	**16,700**	**1,100**

CalRecycle 2010 Disposal, Composition from Cascadia (2009), Energy Characterization adapted from Williams (2003)

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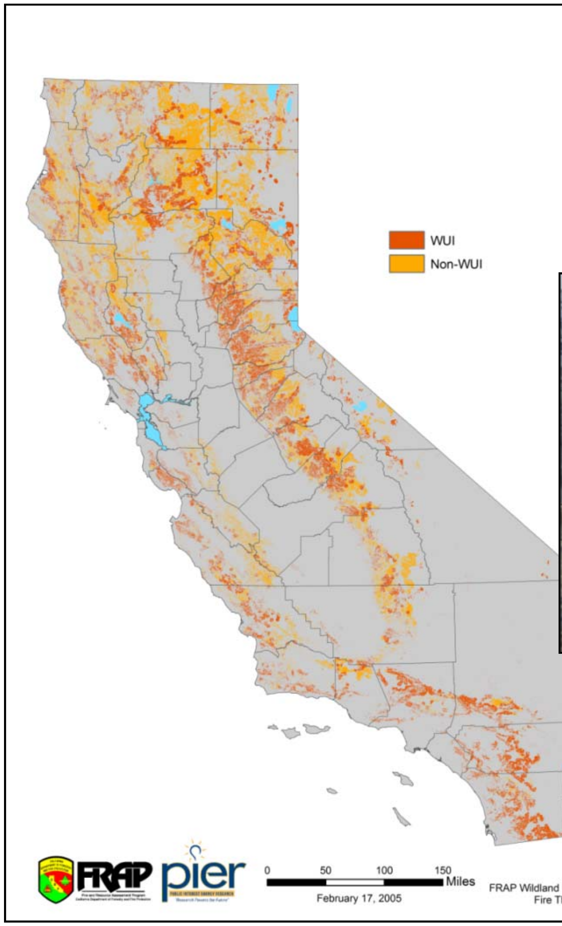
High fire risk areas in California forest and rangelands, FRAP, 2011



Alternative fates for California's forests

Biomass energy recovery from forest residuals and fuel load reduction can help preserve forest health and ecosystem function.

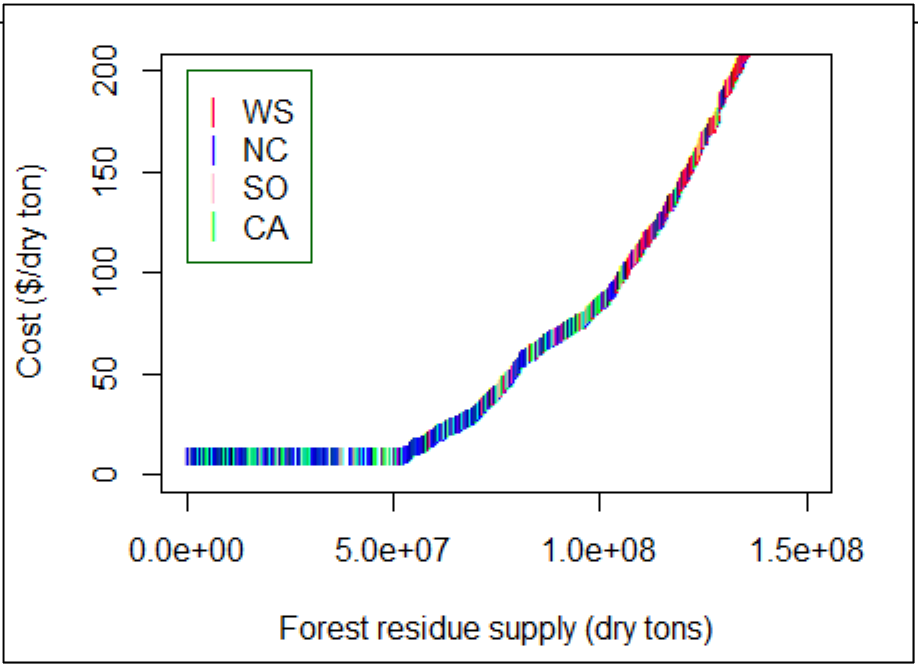
Potential for Biofuel Production from Forest Woody Biomass/ Mitchell et al., 2015 (STEPS/ITS)

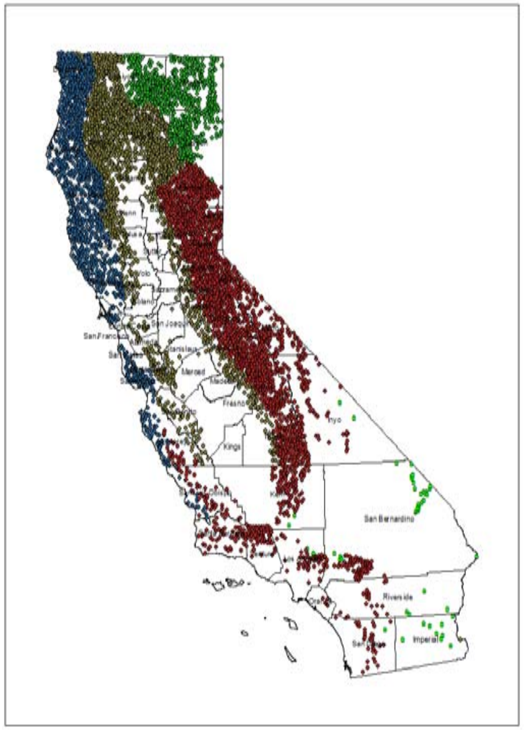
Healthy forests significantly reduce the occurrence of severe wildfire and lower wildfire suppression costs. Forest management for healthy forests, whether for harvest, restoration or fire hazard reduction goals, produces large quantities of 'waste' material suitable for biomass energy production.

Only a small fraction of the total forested landscape in California can be treated with forest management prescriptions that reduce wildfire risk via operations that generate positive net revenue. There is potential to expand treated forest area through the offset of harvest and hauling costs from the sale of forest residue for alternative fuel production. This offset might come from an increase in the value of forest residues based on demand for their use as biofuel feedstock, or from state policy that promotes their use as a low carbon fuel through carbon offsets.

Table 10b-6. Cumulative and annual forest residue amounts

Forest Variant Code and Ownership (Fig. 10b-4)	Total area treated (acres)	Forest residue cumulative total 40 yrs (BDT)¹	Forest residue annual (BDT/yr)	Forest residue cumulative per acre over 40 yrs (BDT tons/acre)	Merchantable timber cumulative per acre over 40 yrs (cu ft/acre)
Private					
WS	1,439,421	49,075,947	1,226,899	34.10	2428.82
CA	1,557,834	44,430,339	1,110,759	28.52	2221.20
NC	2,335,867	74,660,949	1,866,524	31.96	2261.29
SO	541,860	8,741,283	218,532	16.13	1554.43
Subtotal	5,874,982	176,908,518	4,422,713	Average=27.68	
Public					
WS	2,770,479	54,695,064	1,367,377	19.74	1811.00
CA	1,259,483	21,681,298	542,032	17.22	1608.71
NC	754,330	12,037,465	300,937	15.96	1265.18
SO	964,707	11,430,056	285,751	11.85	1039.14
Subtotal	5,748,999	99,843,883	2,496,096	Average=16.19	
Total	11,623,981	276,752,401	6,918,810	Average = 21.93	





CA	Inland California
NC	North Coast
SO	Southern Oregon
WS	Western Sierra
CR	Central Rockies (not included in model)

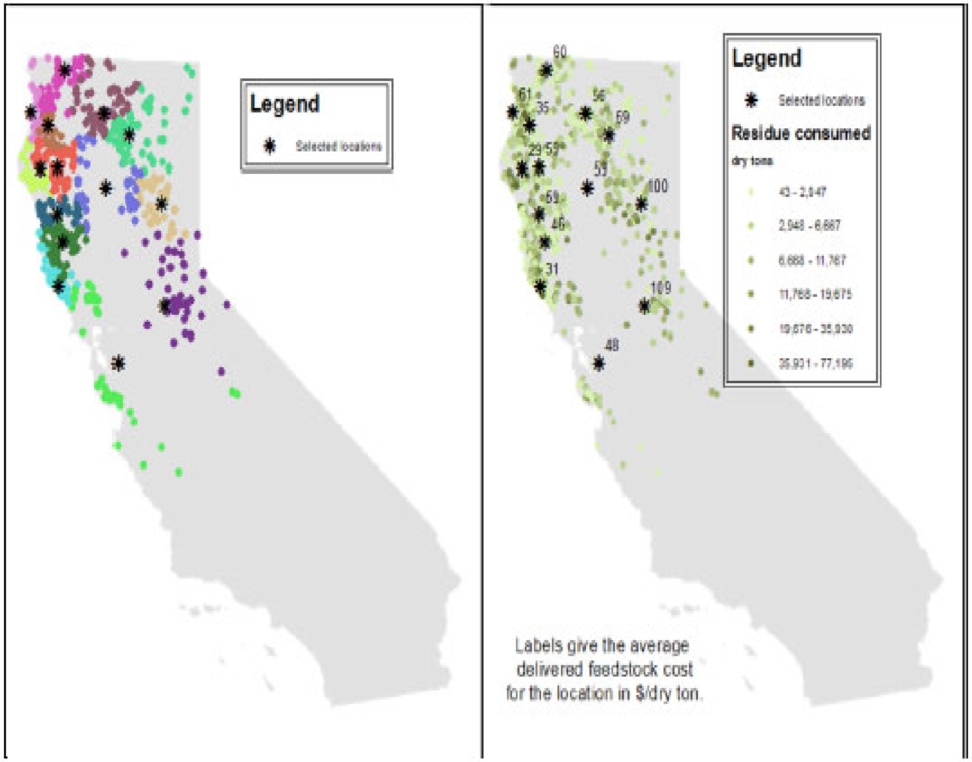
Potential for Biofuel Production from Forest Woody Biomass/ Mitchell et al., 2015 (STEPS/ITS)

The project developed a new statewide resource assessment of forest biomass feedstock. The assessment utilizes a knowledge base of forestry expertise developed at UC Berkeley, and the **Biomass Summarization Model (BioSum),** *a temporally dynamic, spatially explicit, forest stand development* ***mode*****l…that estimates …on-site woody biomass resulting from forest operations**. BioSum had not previously been applied statewide in California.

Over the **40-year simulation period**, ***California forests generate forest residue of about 177 million bone-dry-tons (BDT) on private land, and 100 million BDT on federal land, for a total of 277 million BDT. On average, this is about 7 million BDT of forest woody biomass per year across the state.***

The largest total cumulative amount of woody biomass comes from North Coast private lands, with over 74 million BDTs. Standardized on a per acre basis, Western Sierra private lands have the greatest output, 34 BDT/acre, and the Southern Oregon/Northeast California public lands have the least output, 12 BDT/acre.

Figure 11. Biorefinery Siting of a Potential Drop-In Fuel Industry. Left: biorefinery location and feedstock shed for ten biorefineries.[1] Right: the quantity of biomass supply available and the average price at delivery to the biorefinery.[2]

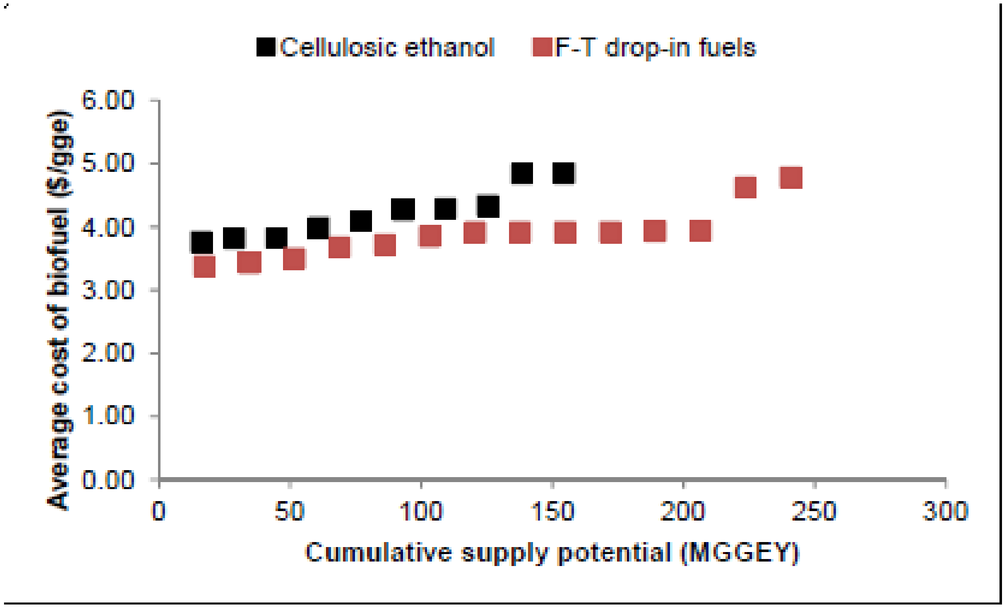


Potential for Biofuel Production from Forest Woody Biomass/ Mitchell et al., 2015 (STEPS/ITS)

GBSM was run for two conversion technologies; biochemical cellulosic ethanol and gasification-synthesis of drop-in fuels (Fischer-Tropsch, FTD). ***Cellulosic ethanol biofuel production ranged from 45 million gasoline gallon equivalents per year (MGGEY) to 154 MGGEY with minimum selling prices from $3.85/gge to $4.85/gge. FTD production estimates ranged from 17 MGGEY to 241 MGGEY with minimum selling prices from $3.40/gge to $4.80/gge.***

The value of biofuels would need to be greater than those observed in the current market to make the system profitable. However, prices of $20.00 per Low Carbon Fuel Standard credit and $0.75 per Renewable Fuel Standard cellulosic RIN would provide residue-based biofuels an additional value of roughly $1.25/gge. The best performing biorefineries analyzed here are economic with the $1.25/gge subsidy.

Figure 10. Supply Curve for Biofuels from Forest Residues[1]



[1] MGGEY is million gallon gasoline equivalent per year

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Current (2013) biofuel production in California-CBC website.

Biofuel Facilities		
	(MGY)	Facilities
Ethanol	179	4
Biodiesel	62.1	13
Totals	241.1	17

There is in-state demand for vegetables oils and other agricultural feedstocks if produced at a price that allows conversion to be profitable. The price biofuel producers can pay depends in-part on the carbon intensity of the feedstock.

California Production Differs from Other States

	California $1,000	Iowa $1,000	Texas $1,000	Nebraska $1,000	Illinois $1,000
Food-plant	**$16,490,102**	**$23,681**	**$593,523**	**$66,434**	**$116,780**
Food-animal	**$10,793,300**	**$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	$409,272	$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**

California farmers tend to produce **food crops** while in other states, more **feed** and industrial crops are produced. **Food crops are higher in value and more diverse**.

USDA, NASS, 2007 Census of Agriculture, Jenner

2010 USDA Biofuels 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

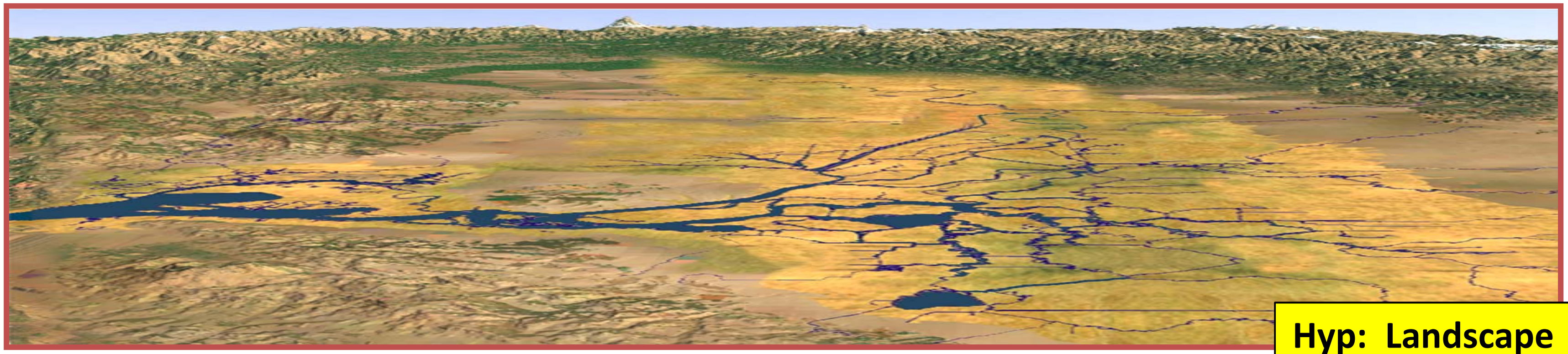
(4) Feedstocks: Perennial grasses, soyoil, biomass (sweet) sorghum, corn stover, logging residues

(5) Feedstocks: Canola,straw, logging residues

(6) Feedstocks: Biomass (sweet) sorghum, logging residues

USDA predicted little bioenergy production from crops in California or elsewhere in the western US.

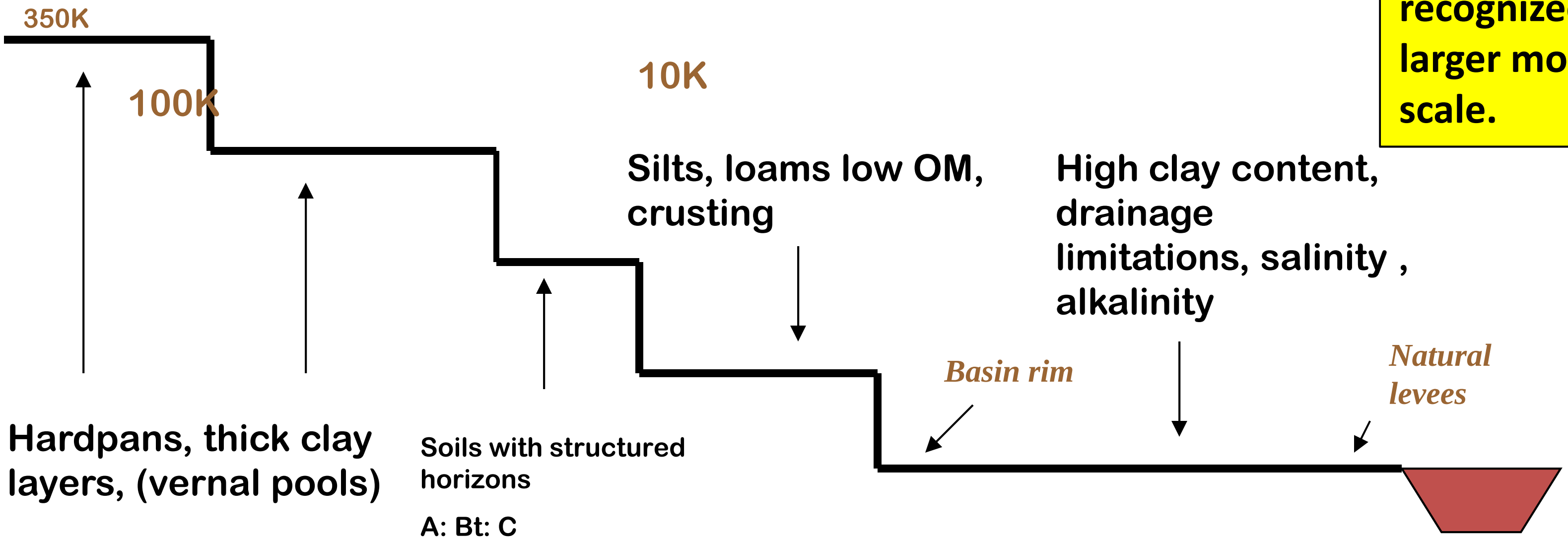
Diverse soils and landscapes lead to differing cropping systems in CA



Hyp: Landscape diversity leads to opportunities not recognized at a larger modeling scale.

Soil age: - ►

oldest 30-80K youngest



350K

100K

10K

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

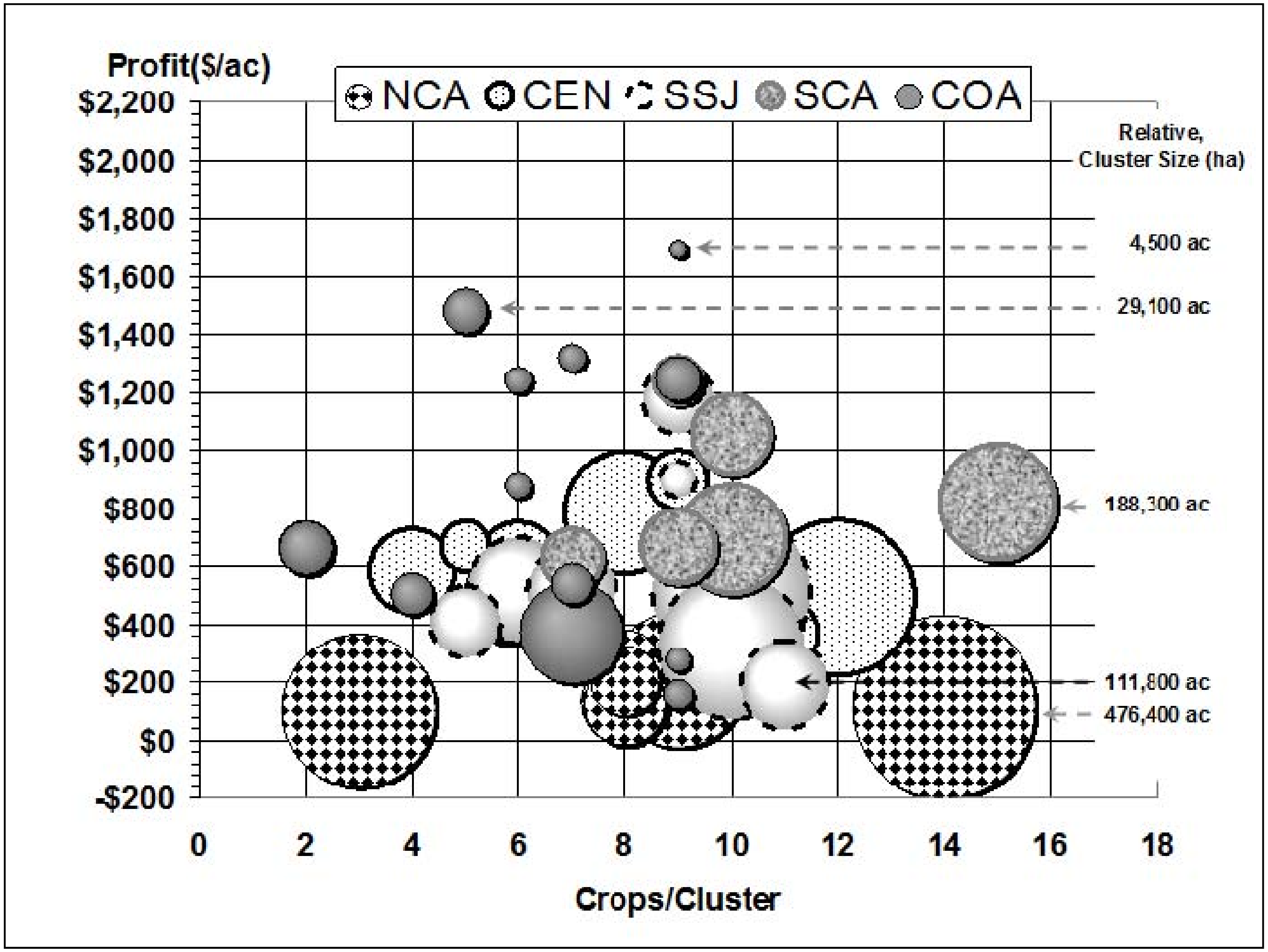
Oak-savanna/rangelands

rangeland/pasture, some perennials

perennials, annuals

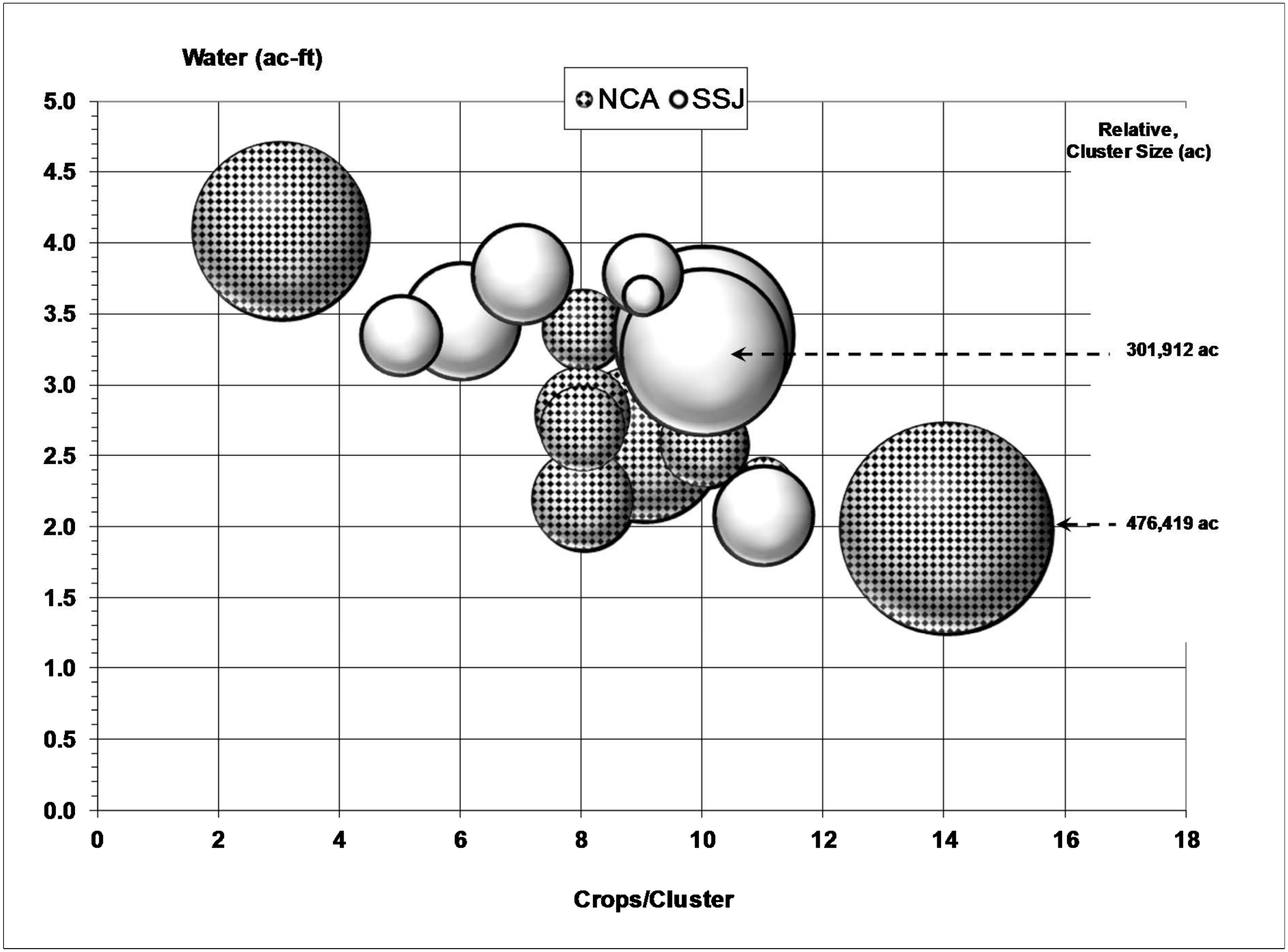
mostly annuals

Soil use ⟶

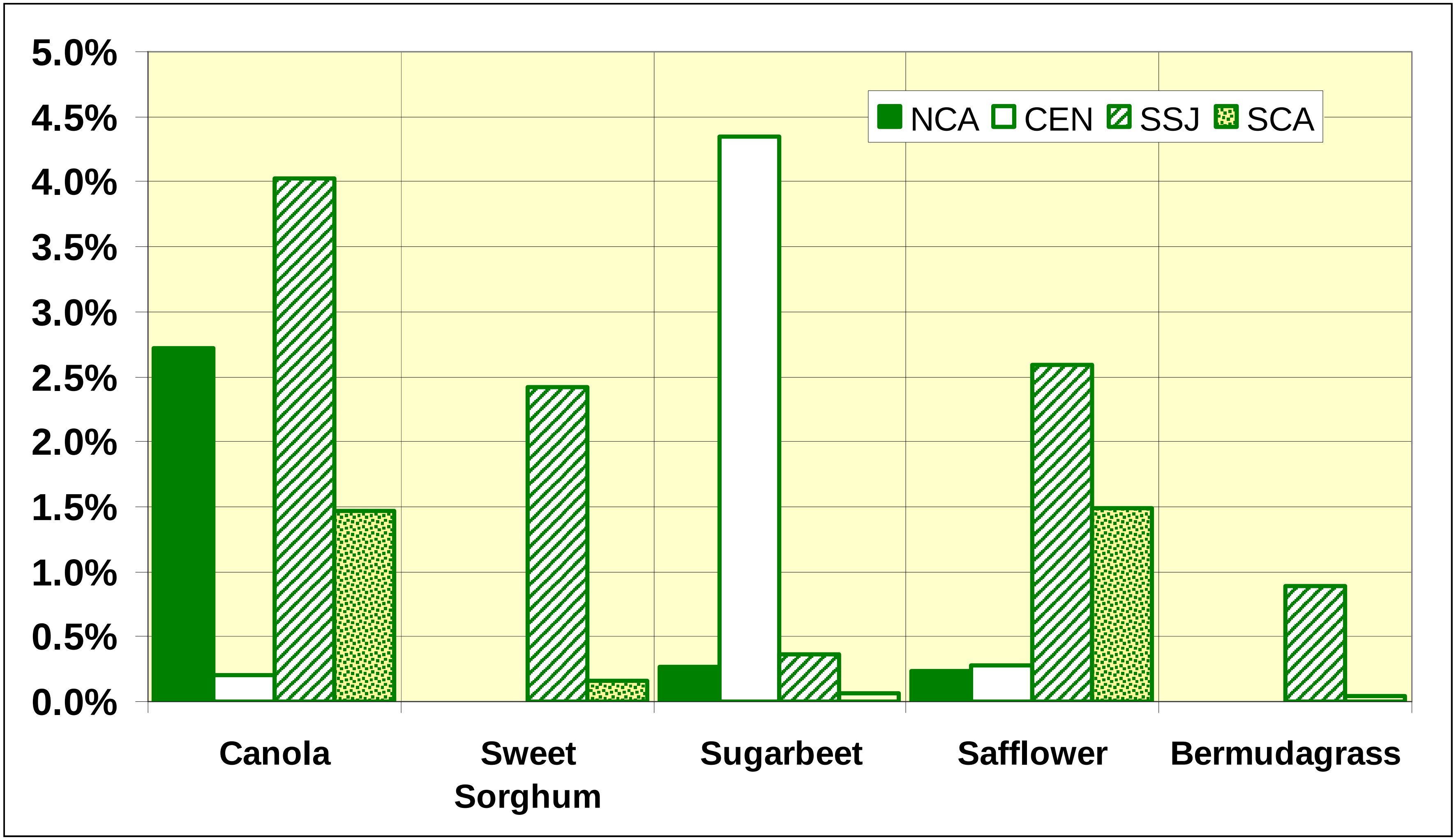


Average profit for all crops and acres of each or 45 Cropping System Clusters in five regions estimated using the BCAM model. Size reflects cropland acres in each cluster. For reference, the left-most, 3-crop, cluster contains 333,000 acres. The 11-crop, $193/acre average profit cluster contains 111,800 acres. NCA: northern California counties, CEN: San Joaquin, Merced, Madera, Stanislaus, Fresno; SSJ: Kern, Kings, Tulare; SCA: Imperial, Riverside; COA: Monterey, San Luis Obispo. (Kaffka and Jenner, 2011 www.biomass.ucdavis.edu).

Regions Have Different Characteristics



Regional differences in likely energy crop acreage adoption based on favorable price relationships with incumbents crops



Kaffka and Jenner, 2011

On an agro-ecological basis, there are many feedstock crop possibilities in California


Grain and sweet sorghum


Camelina

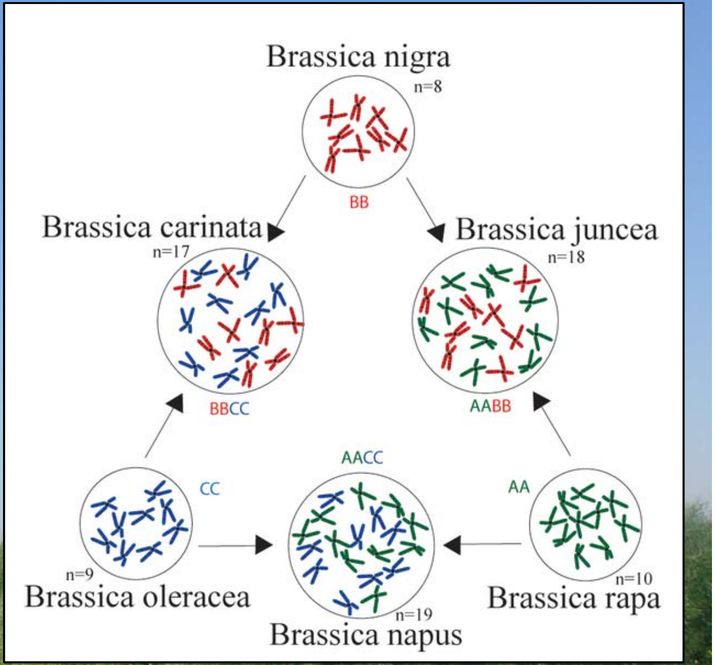

Energy beets


Canola, mustards


Salt-tolerant perennial grasses on “marginal” lands

Steve Kaffka, Nic George, Jimin Zhang, Bob Hutmacher

California Department of Food and Agriculture/California Energy Commission and ANR grants to evaluate new bioenergy feedstock crops: winter annual oilseed crops as feedstocks



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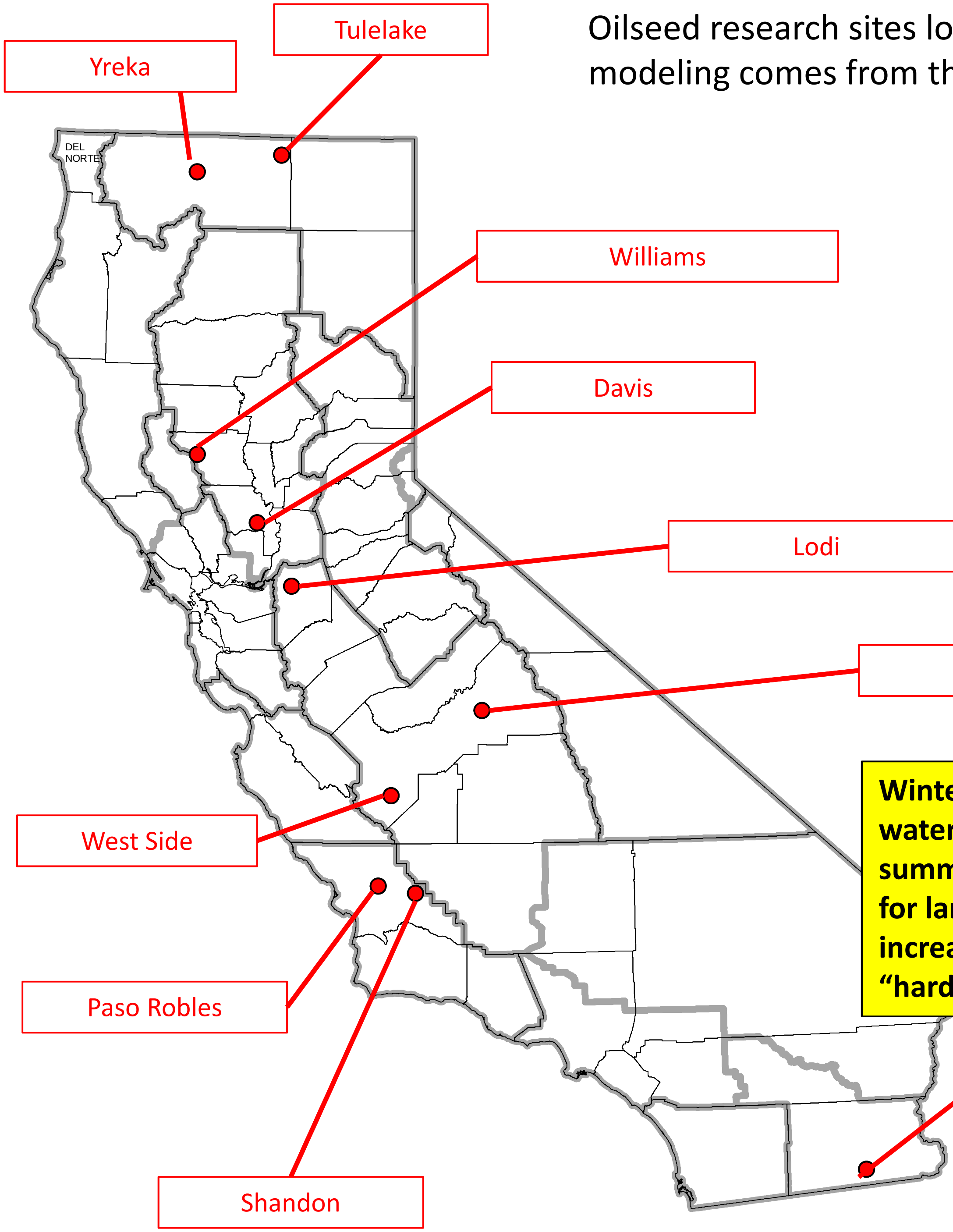
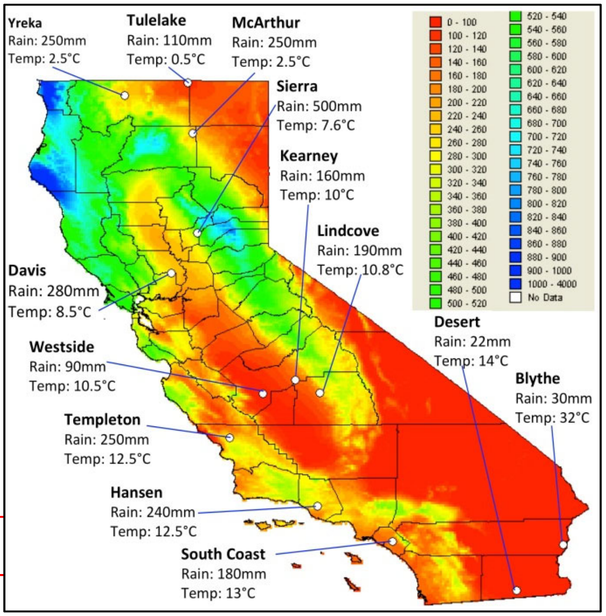
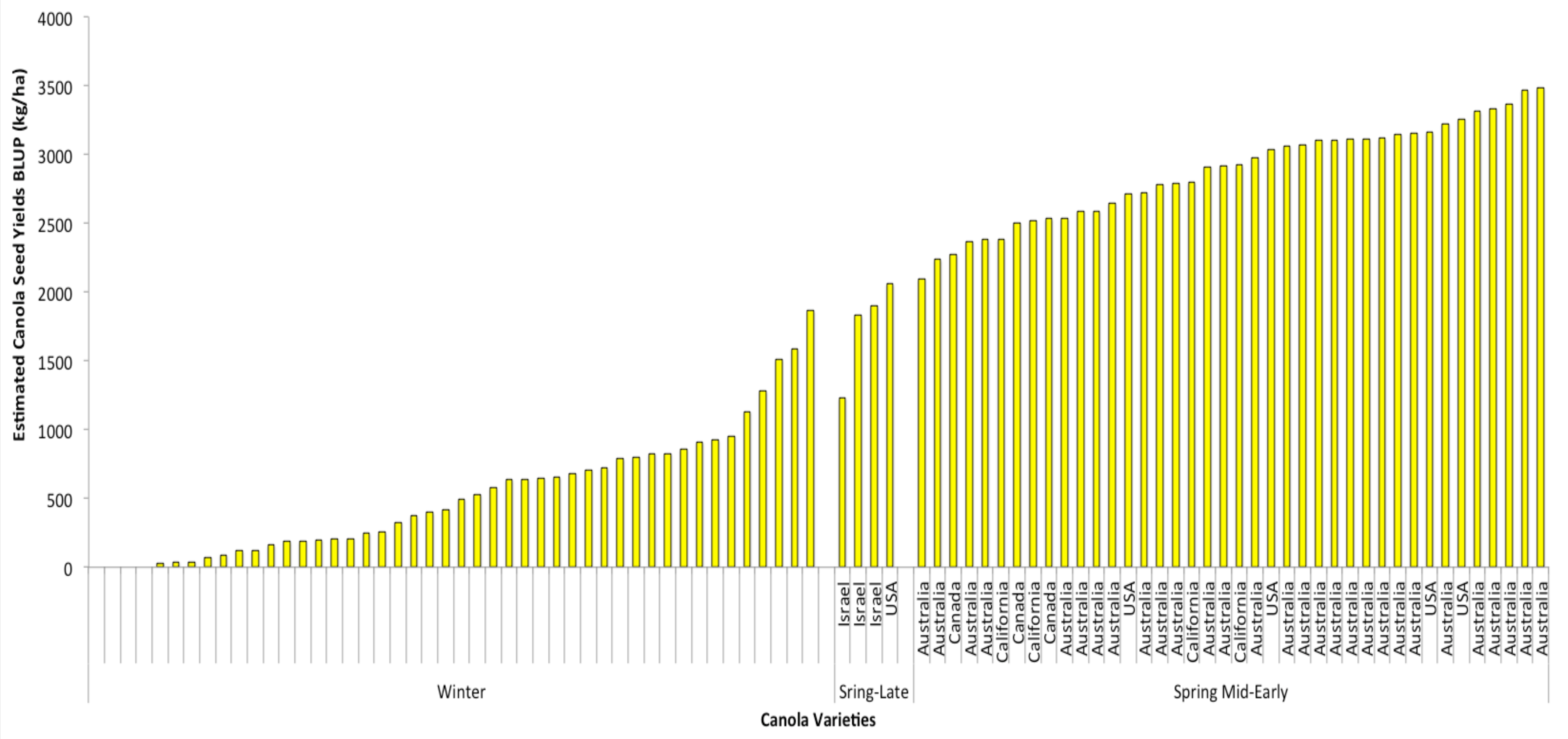
Oilseed research sites located across the state; Data for economic modeling comes from this and other types of agronomic research





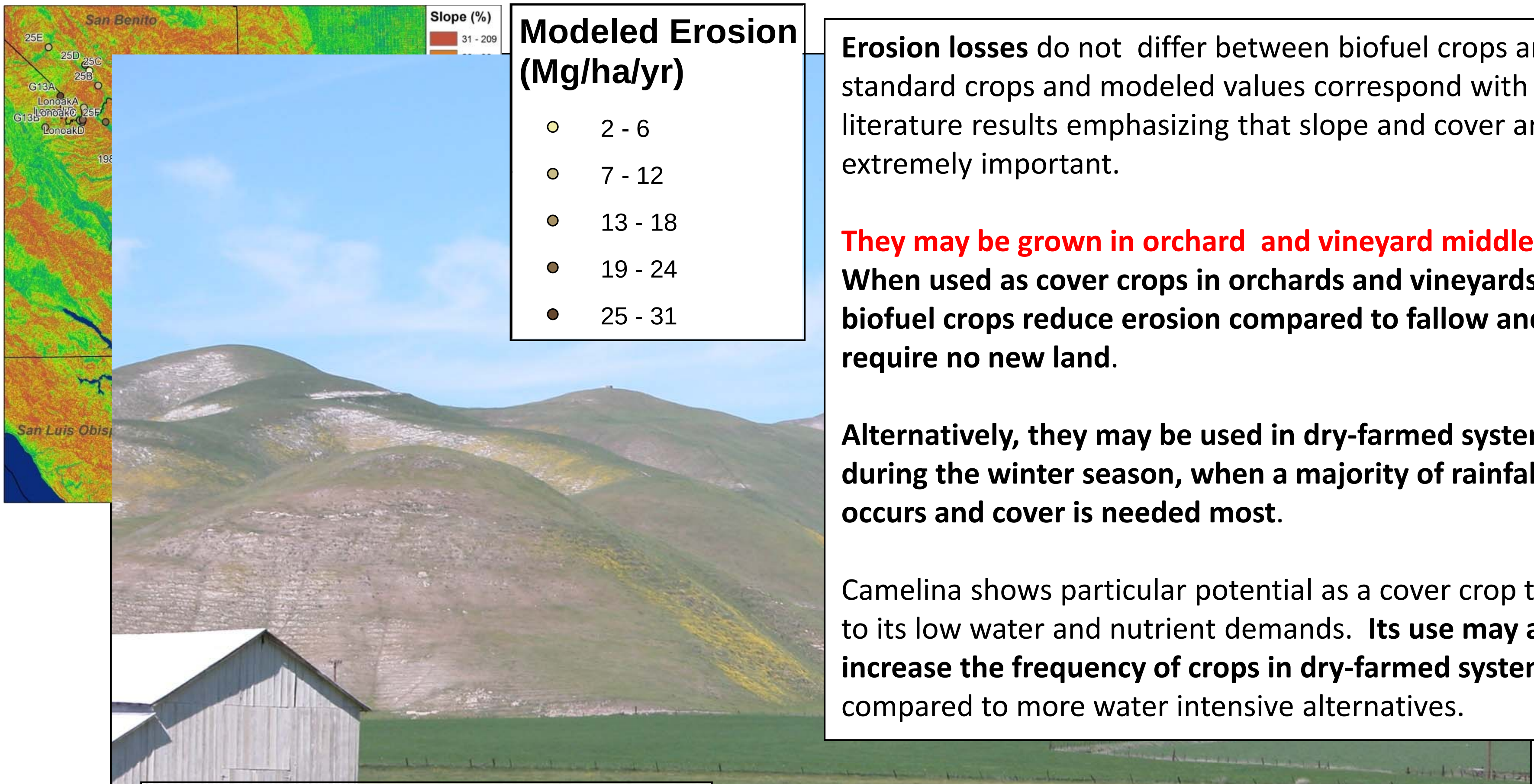
Winter annual crops require much less irrigation water per unit of economic product than most summer crops and offer production alternatives for land despite reduced water supplies due to the increase in perennial crops in California with their “hardened” water demands.

120 canola & 105 camelina varieties from 14 public & private breeding programs



The mean yield for canola in California across all locations & seasons

Canola intercropped with newly-planted pistachios in Kern County. Pistachios emerge late. There is a large amount of land potentially available in new or re-planted orchards and vineyards in California on a yearly basis that might produce oilseed crops in winter, largely on rainfall or with limited irrigation. There may be opportunities in young orchards throughout California for both Canola and Camelina winter inter-crops. Estimate: 100K acres/y

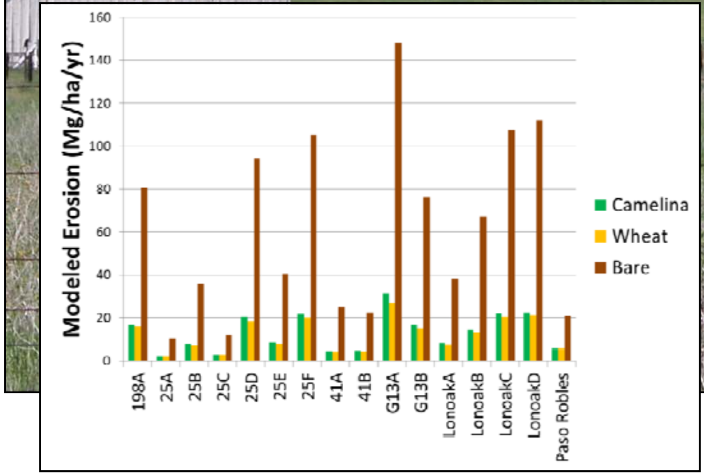


Erosion losses do not differ between biofuel crops and standard crops and modeled values correspond with literature results emphasizing that slope and cover are extremely important.

They may be grown in orchard and vineyard middles. When used as cover crops in orchards and vineyards, biofuel crops reduce erosion compared to fallow and require no new land.

Alternatively, they may be used in dry-farmed systems during the winter season, when a majority of rainfall occurs and cover is needed most.

Camelina shows particular potential as a cover crop thanks to its low water and nutrient demands. **Its use may also increase the frequency of crops in dry-farmed systems** compared to more water intensive alternatives.



Dry-farmed lands in CA/ Salls and Kaffka

California Bioenergy Crop Adoption Model (BCAM). **BCAM** is a crop rotation optimization model that estimates prices needed for new crops and crop displacement. It can work at the regional or farm level

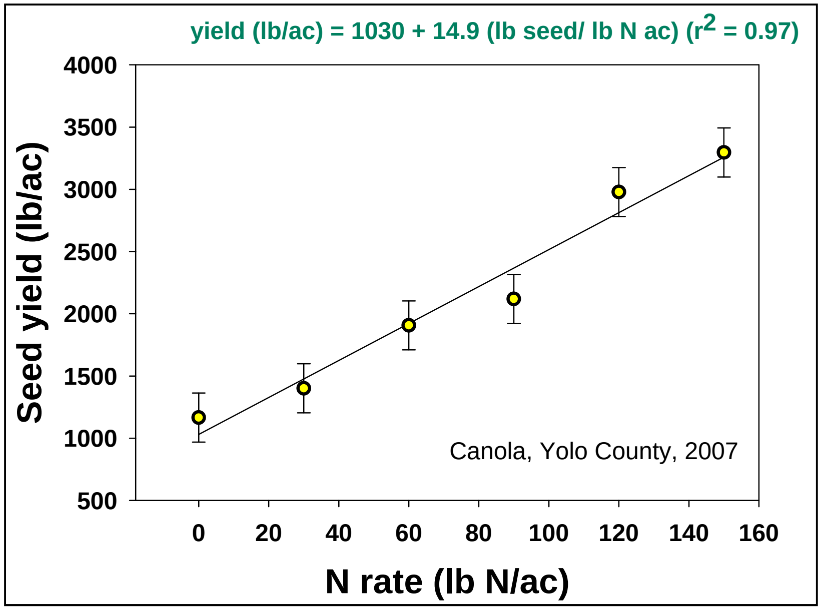
$$Max \prod_{X_{e,g,i,j}} \sum_{g} \sum_{j} \left[\begin{array}{r} \sum_{i} \left(P_{g,i,j} \times \overset{\text{Production function}}{\left(\beta_{g,i,j} - \omega_{g,i,j} X_{g,i,j} \right)} - C_{g,i,j} \right) X_{g,i,j} \\ + \sum_{e} \left(P_{e,g,j} Y_{e,g,j} - C_{e,g,j} \right) X_{e,g,j} \end{array}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

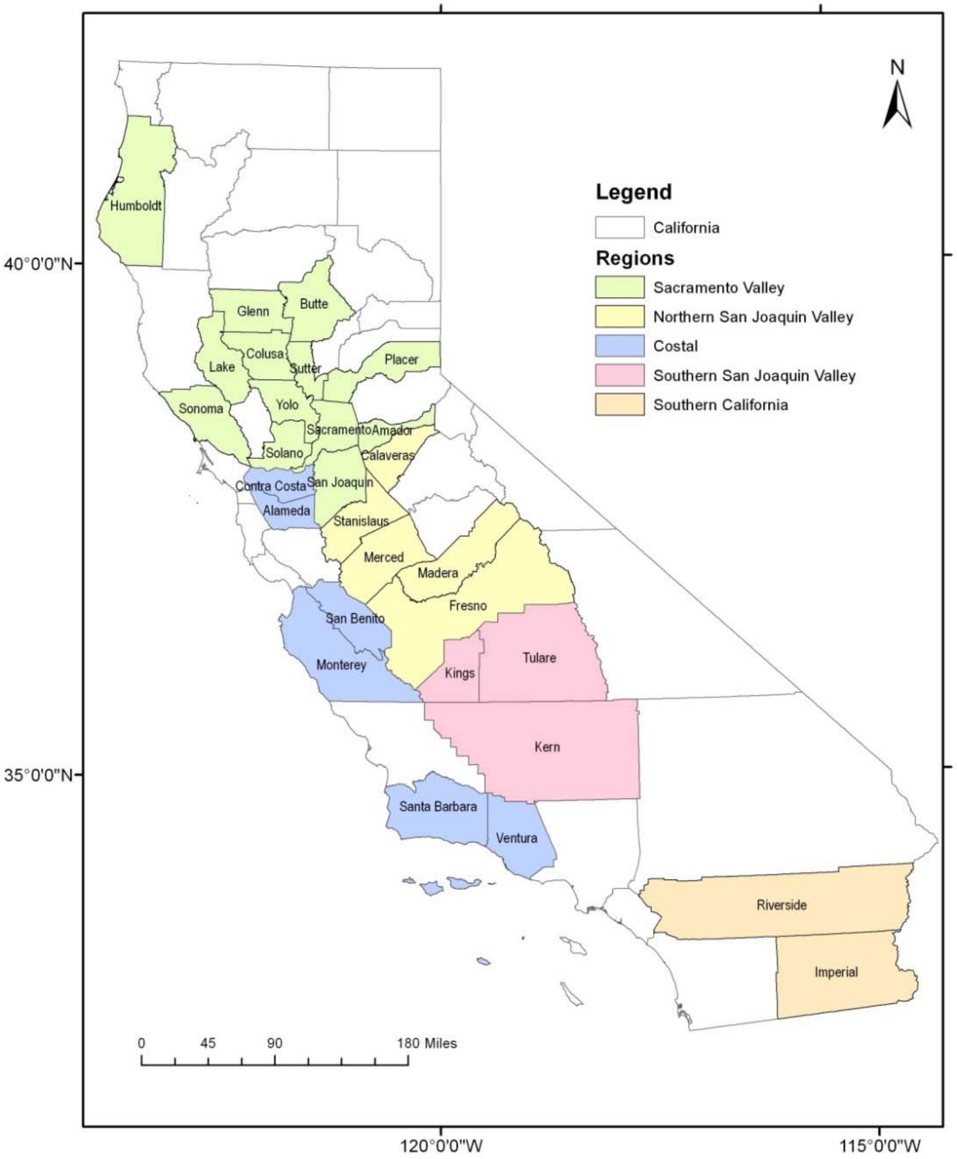
Subject to: $\sum_{\substack{i \\ \bar{A}}} \sum_{e} X_{g,i,e,j} \leq \overline{A_{g,j}}$ $\quad j = \{acres,\ ac\text{-}ft\ of\ water\}$

$P_{e,g,i,j}$ = farm price of crop *i*, and energy crop *e*, in region *g*, and resource, *j*.
$C_{e,g,i,j}$ = farm cost of crop *i*, and energy crop *e*, in region *g*, and resource, *j*.
$Y_{e,g,i,j}$ = yield of crop, *i*, and energy crop *e*, in region, *g*, and resource, *j*.
$X_{e,g,i,j}$ = level of hectares *r* applied to energy crop e, in region *g* for crop *i*.
$\bar{A}_{g,j}$ = constrained hectares of crop *j* in region *g*.
$\beta_{g,i,j}$ = intercept of the quadratic (marginal) curve of crop, *i*, in region, *g*, resource, *j*.
$\omega_{g,i,j}$ = slope of quadratic (marginal) curve of crop, *i*, in region, *g*, and resource, *j*.

Estimated cost per hectare to produce canola in California (base year: 2012).

INPUT	Quantity (per Ac)	UNIT	Cost/Unit	Total
FERTILIZER				**$227.90**
Nitrogen (dry)	175	lb	$0.74	$129.50
Phosphorous (dry)	20	lb	$0.74	$14.80
Potassium (dry)	120	lb	$0.54	$64.80
Sulfur (dry)	20	lb	$0.94	$18.80
PESTICIDES				**$56.40**
Assure II	2	pint	$20.00	$40.00
Ammonium Sulfate	4	pint	$0.35	$1.40
M90	50	ml	$0.05	$2.50
Capture	1	Ac	$12.50	$12.50
SEED				**$48.00**
Canola	6	lb	$8.00	$48.00
LABOR				**$47.17**
Labor (Machine)	2.1	hrs	16.08	$33.77
Labor (non-machine)	1	hrs	13.4	$13.40
FUEL				**$30.87**
Diesel	9	gal	$3.43	$30.87
REPAIR & MAINTENANCE				**$12.80**
Lubricants	1	Ac	$2.20	$2.20
Repair	1	Ac	$10.60	$10.60
CUSTOM & CONSULTANT				**$31.37**
Rental Sprayer	1	Ac	$2.16	$2.16
Custom Aerial Spray	1	Ac	$8.03	$8.03
Rental Ripper Shooter	1	Ac	$6.18	$6.18
Soil Test	1	Ac	$15.00	$15.00
OTHERS				**$266.53**
Overhead				$ 250.00
Crop Insurance				$ 10.00
Interest on Operative Capital				$ 6.53
Total Cost per Acre 2012				$721.04
Total Cost per Acre 2007				$659.09
Yield per Acre				2,500 lb





Geographical subsets for clustering analysis

Bioenergy Crop Adoption Model (BCAM) is based on land use patterns derived from analysis of **Pesticide Use Report data** (California Department of Pesticide Regulation) over multiyear periods.

This data reports **farmer choices about what they grew and where they grew it, and embodies all the factors used to make such decisions**.

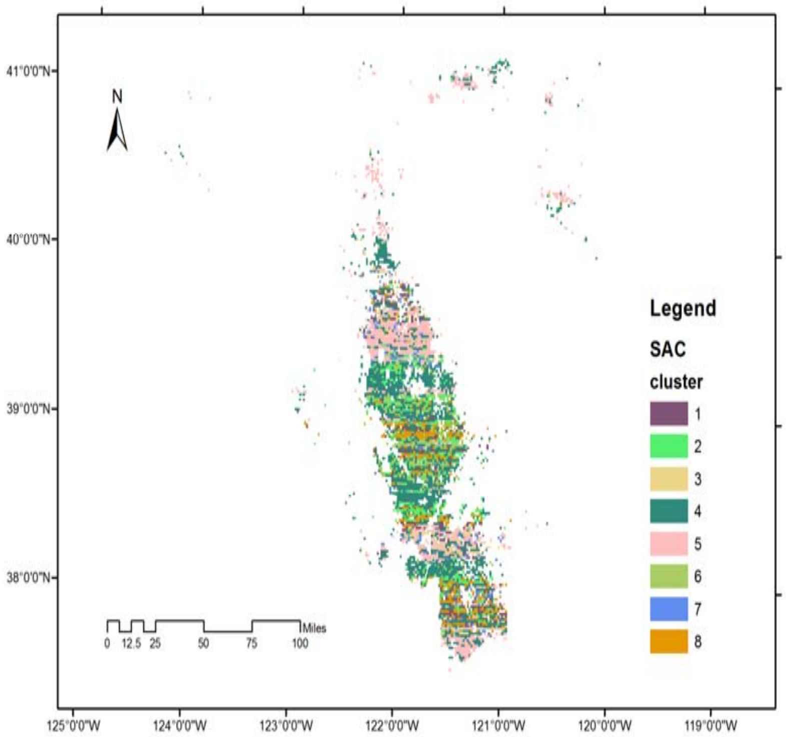
Regionalized incumbent cropping patters are derived from this data and used to estimate entry prices, location and extent of new crop adoption using BCAM.

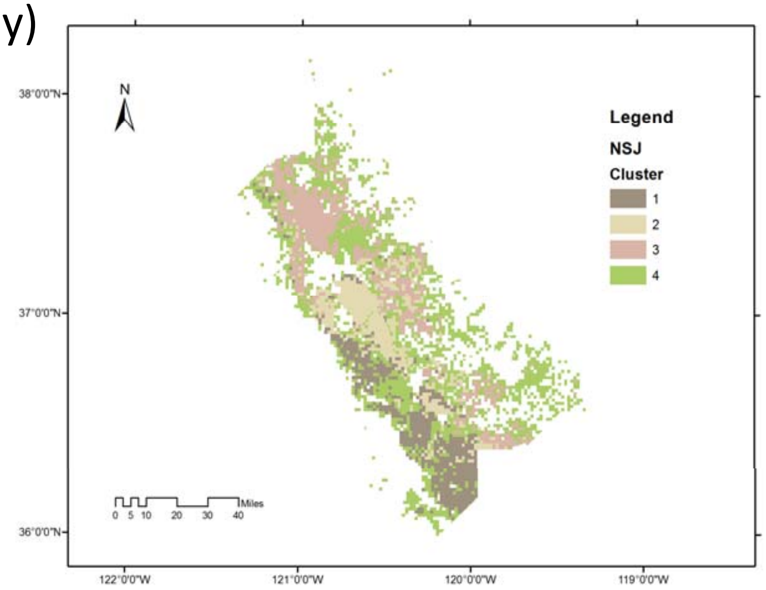
Example land use patterns in the northern San Joaquin Valley and the Imperial Valley by sub-region (2003-12 data)

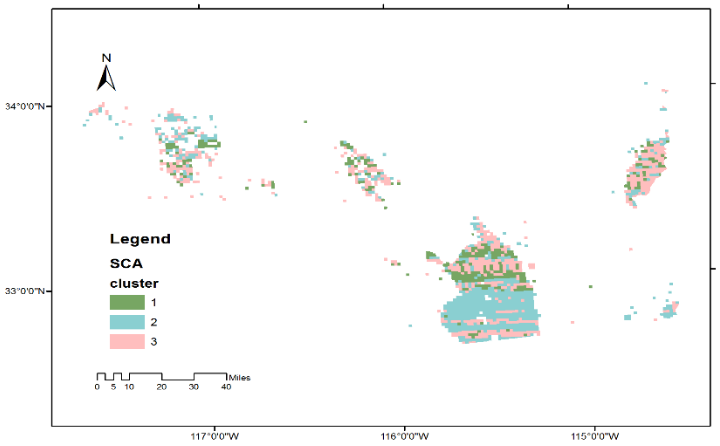
croptype	1	2	3	4
alfalfa	2.72%	**29.49%**	**25.66%**	15.99%
barley	1.06%	1.33%	0.39%	1.62%
beans	2.24%	1.15%	3.05%	7.29%
bermudagrass	0.00%	0.00%	0.00%	0.01%
broccoli	1.12%	0.20%	0.27%	2.27%
carrot	0.29%	0.23%	0.04%	0.47%
corn	2.09%	**12.67%**	**33.26%**	14.34%
cotton	**30.31%**	**25.45%**	1.80%	9.63%
foragefodder	0.05%	0.20%	0.88%	0.64%
garlic	7.19%	0.20%	0.00%	0.66%
lettuce	6.49%	0.57%	0.23%	2.36%
melon	2.43%	1.02%	0.35%	2.37%
oat	0.32%	3.27%	**17.87%**	11.91%
potato	0.00%	0.04%	2.29%	5.55%
rice	0.33%	0.71%	0.25%	1.46%
ryegrass	0.00%	0.00%	0.03%	0.06%
safflower	1.17%	0.17%	0.05%	0.32%
sorghum	0.07%	0.08%	0.25%	0.27%
sudangrass	0.03%	0.40%	1.13%	0.51%
sugarbeet	1.30%	2.24%	0.44%	0.53%
tomato	**29.74%**	**11.36%**	2.49%	10.28%
wheat	**11.03%**	9.20%	9.26%	11.47%

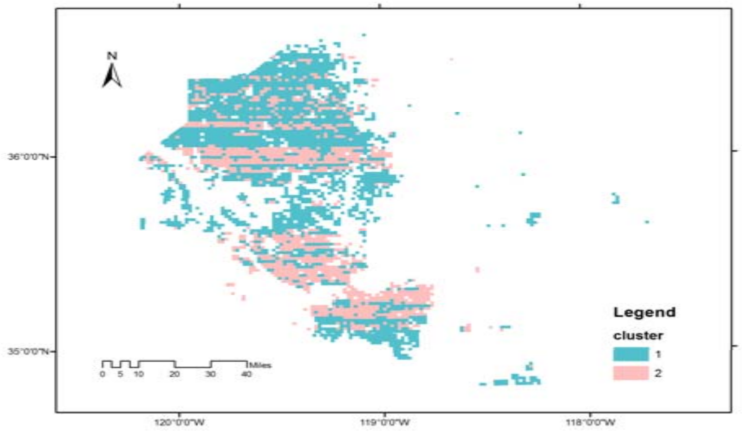
croptype	1	2	3
alfalfa	23.34%	11.17%	37.19%
barley	0.05%	0.53%	0.06%
beans	0.13%	3.68%	0.08%
bermudagrass	1.51%	6.91%	9.29%
broccoli	9.26%	7.13%	2.84%
carrot	9.05%	7.15%	1.59%
corn	5.26%	8.39%	2.27%
cotton	2.21%	1.52%	7.61%
foragefodder	0.44%	1.02%	1.82%
garlic	0.05%	0.02%	0.10%
lettuce	20.67%	15.08%	2.42%
melon	3.68%	6.03%	1.90%
oat	0.24%	2.68%	0.95%
potato	1.01%	6.05%	0.29%
rape	0.23%	0.35%	0.63%
rice	0.00%	0.02%	0.00%
ryegrass	0.03%	0.41%	0.20%
safflower	0.01%	0.67%	0.00%
sorghum	0.05%	0.83%	0.47%
sudangrass	2.39%	1.36%	1.96%
sugarbeet	6.35%	2.05%	13.74%
tomato	0.35%	1.22%	0.15%
wheat	13.70%	15.73%	14.45%

Cluster analyses identifying incumbent (baseline) land use patterns, considered as cropping systems in different parts of the state (SAC: Sacramento Valley; NSJ: northern San Joaquin Valley; SSJ: southern SJV; SCA: Imperial Valley/Palo Verde Valley)

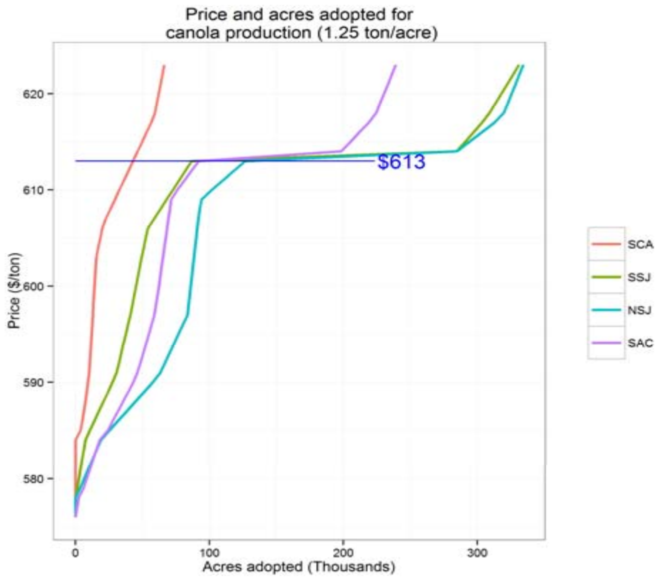


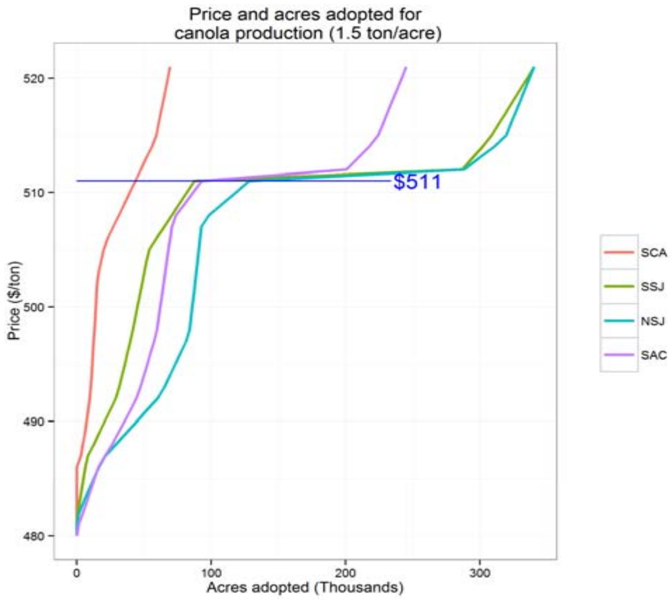


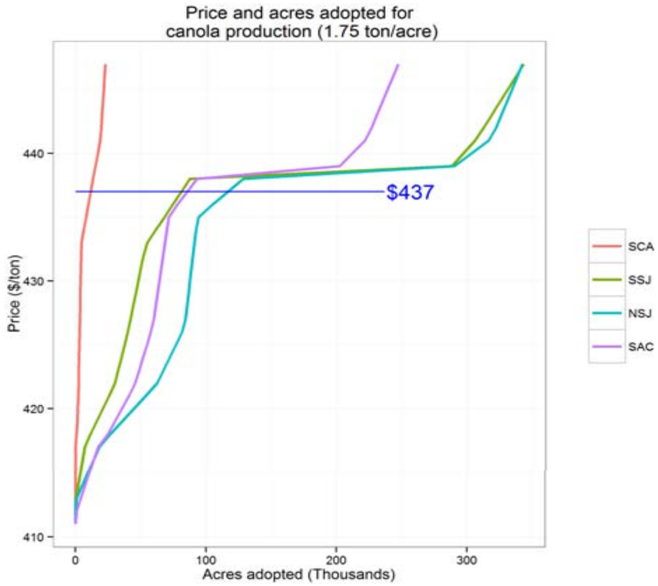


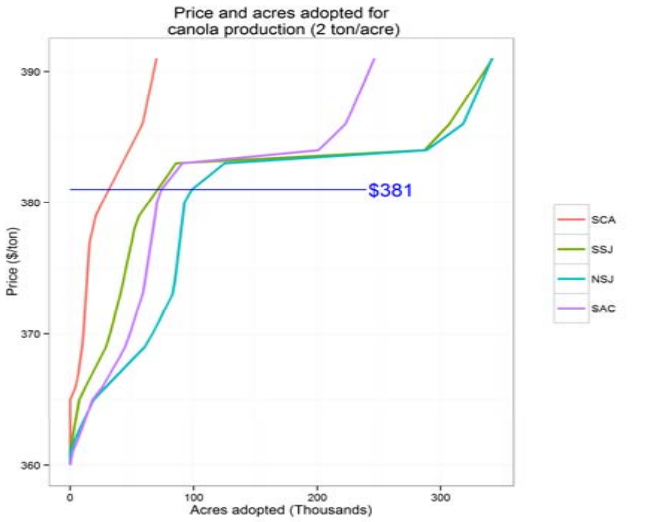


Entry prices and adopted acres of canola (Yeo and Kaffka, draft CEC report).

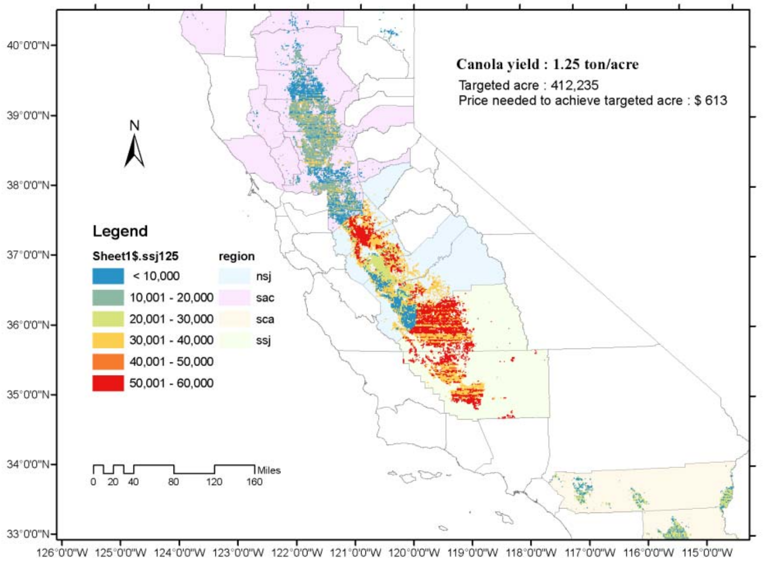






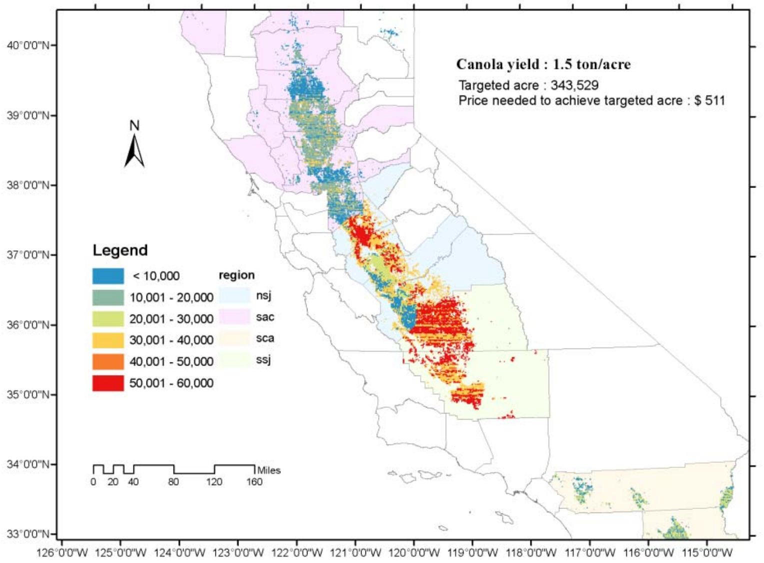


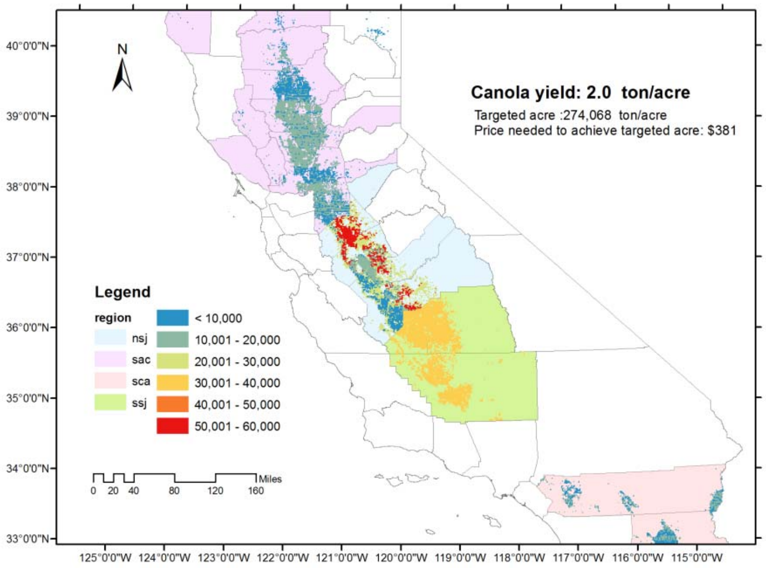
High yields are important for canola adoption



As yield increases, crops become profitable at a lower yield and entry price declines. The land needed to meet feedstock demand declines and locations where feedstock is produced to meet demand in the state change.

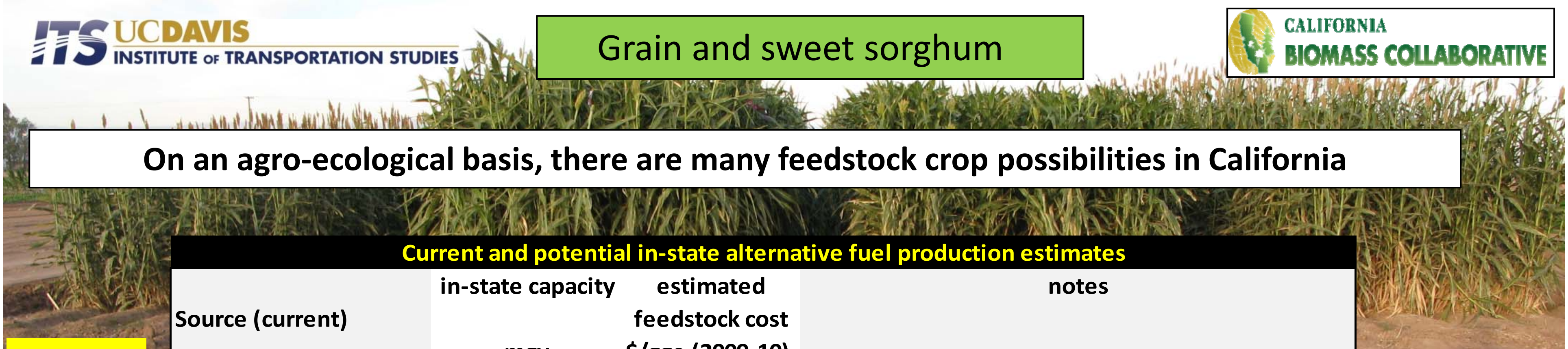
Canola yield (t/ac)	Canola yield (lb/ac)	oil fraction	lb oil/ac	gal biodisel /ac	acres needed for 60Mg/y
1	2000	0.425	850	116	515294.1
1.25	**2500**	0.425	1062.5	146	412235.3
1.5	3000	0.425	1275	175	343529.4
1.75	3500	0.425	1487.5	204	294453.8
2	4000	0.425	1700	233	257647.1





ITS UC DAVIS INSTITUTE OF TRANSPORTATION STUDIES

CALIFORNIA BIOMASS COLLABORATIVE


Grain and sweet sorghum

On an agro-ecological basis, there are many feedstock crop possibilities in California

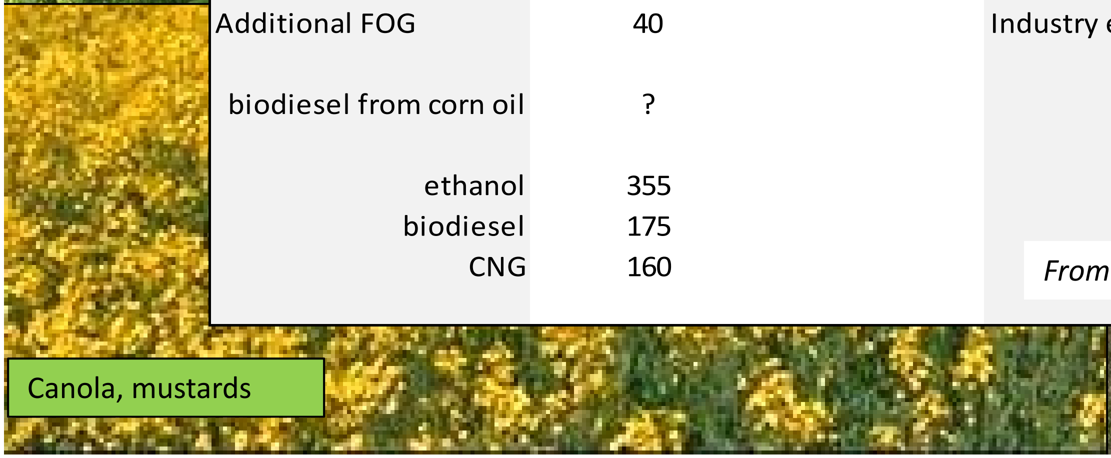

Camelina

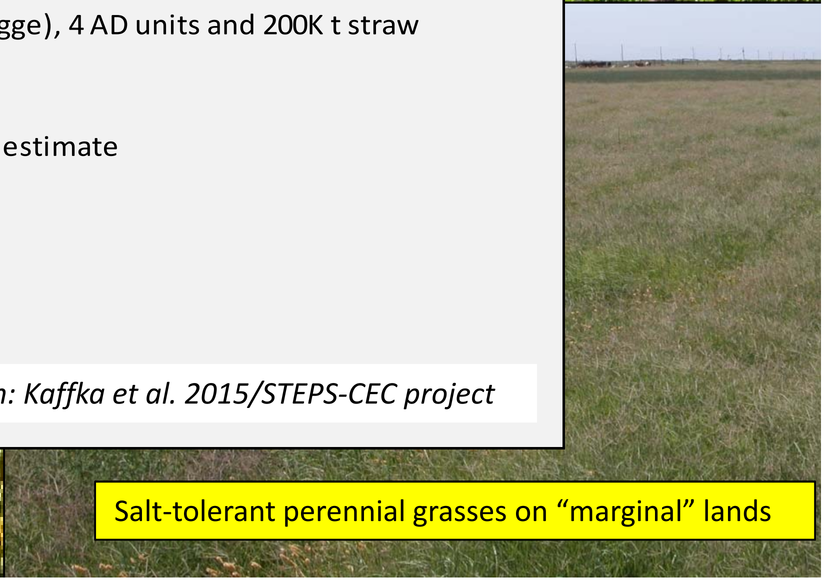

Energy beets

Current and potential in-state alternative fuel production estimates

Source (current)	**in-state capacity mgy**	**estimated feedstock cost $/gge (2009-10)**	**notes**
Grain-based ethanol	205		currently mostly corn grain based
Biodiesel	55-60		mostly FOG
Other			
(potential new in-state)			
New agricultural crops			
ethanol	150	0.90 to 3.90	Grain sorghum, sugarbeets, sugarcane and energy cane , use of approximately 500K ac
biodiesel	75	2.82	oilseeds (canola, Camelina)
Agricultural residues			
rice straw	6.8		as CNG (gge), 4 AD units and 200K t straw
dairy manure	155		as CNG
Additional FOG	40		Industry estimate
biodiesel from corn oil	?		
ethanol	355		
biodiesel	175		
CNG	160		

From: Kaffka et al. 2015/STEPS-CEC project

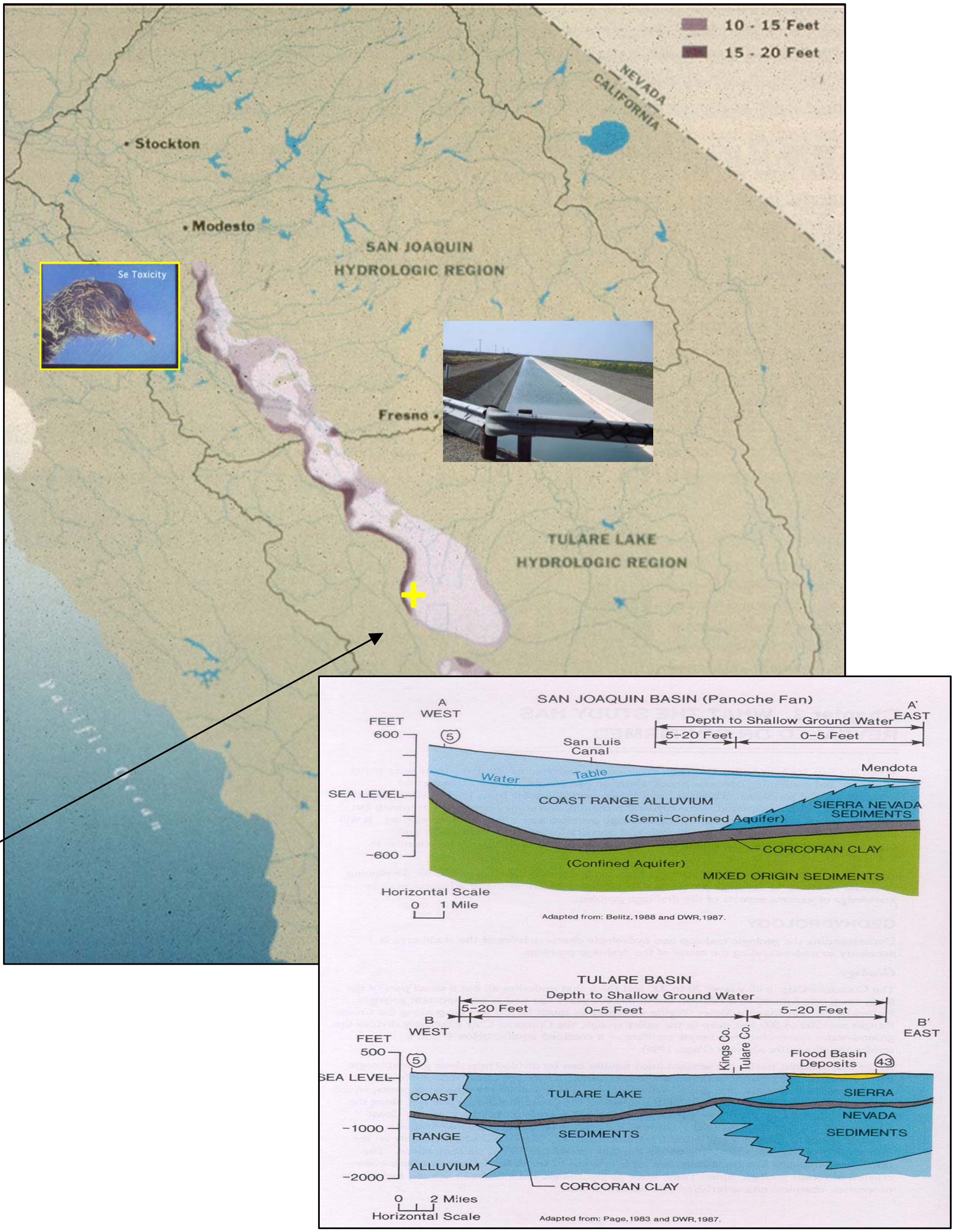

Canola, mustards


Salt-tolerant perennial grasses on “marginal” lands

Biomass Resources in California: Potential for Economic Use

- Policy support (briefly)
- Urban biomass resources
- Forest biomass resources
- Agricultural biomass resources
- Marginal lands
- Biogas

Drainage from saline, perched water tables, was a significant issue in the western San Joaquin Valley



CALIFORNIA BIOMASS COLLABORATIVE

Integrated Assessment of Agricultural Biomass Derived Alternative Fuels and Power : Use of marginal lands in California for biomass feedstocks

Lucia Levers , Taiying Zhang, Stephen Kaffka

Due to a long history of irrigated agriculture and natural characteristics, the West Side of the San Joaquin Valley contains a large amount of salt affected land with shallow water tables. **Using this land to produce biofuel/bioenergy feedstocks could keep this land in production, potentially remediate it, find a beneficial use for saline drainage water, and support ultimate disposal of brines and trace elements and create businesses and jobs in disadvantaged areas.** Location and amounts of **marginal land** are estimated using DWR data for groundwater table height. Marginal Land is categorized as Highly Marginal (Water table is <= 5 feet to surface) and Moderately Marginalized (Water table is <= 20 feet to surface). The WSJV is divided into sub-regions, based on groundwater sub-basins: Grasslands, Kern, Tulare, and Westlands.

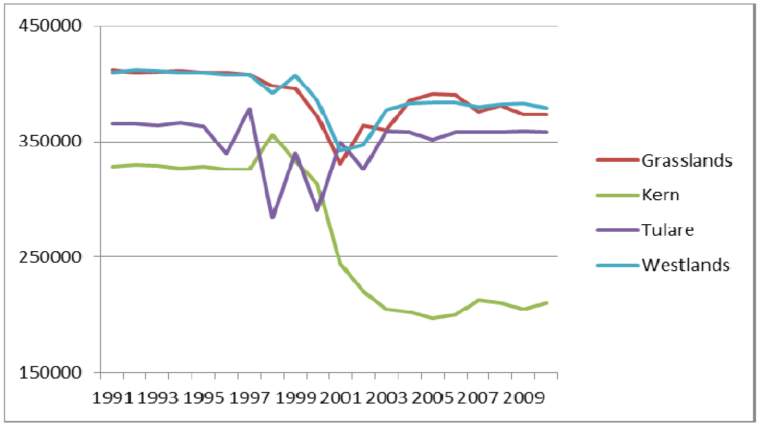


Figure 1: Total Marginal Land Drainage (ac ft/y) over Time

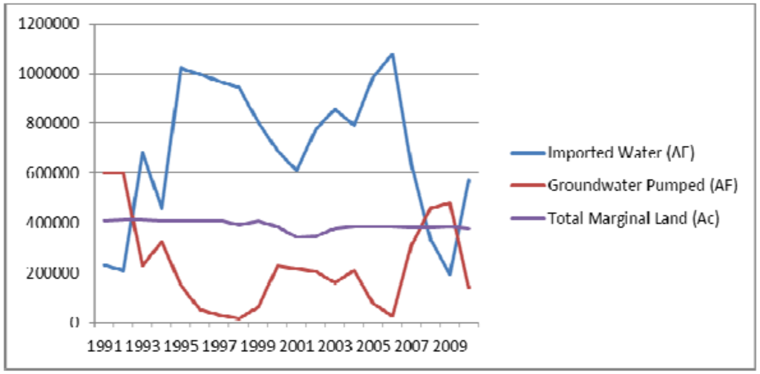
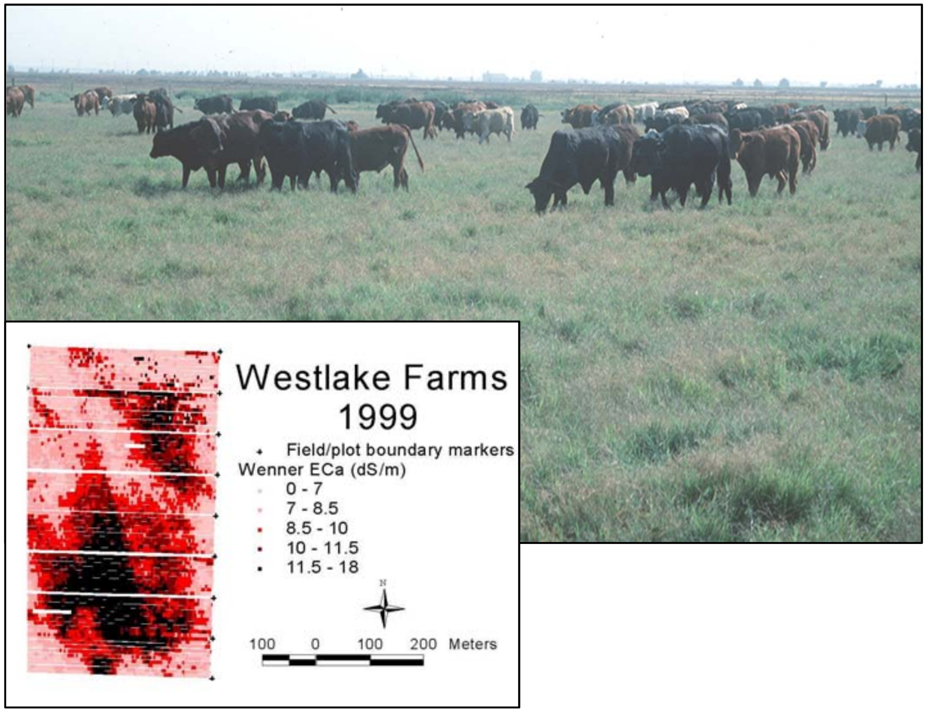
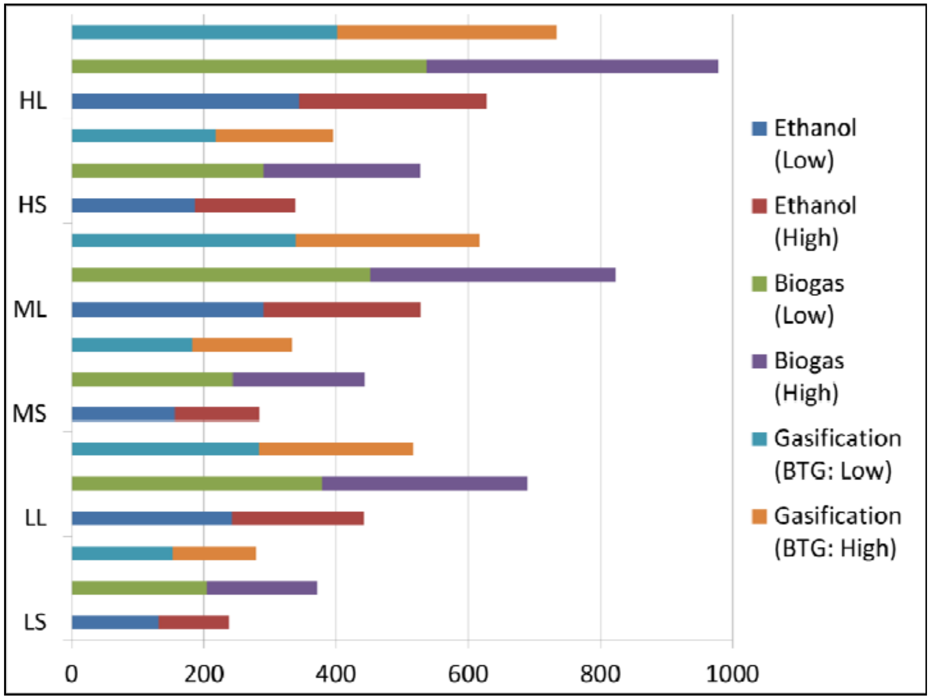


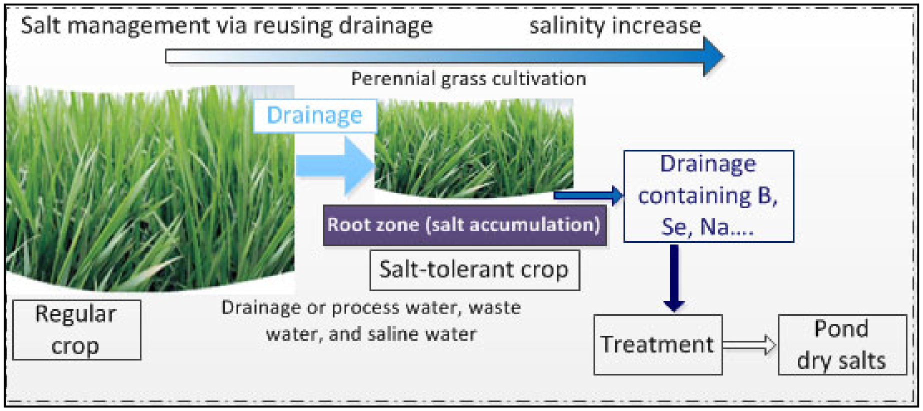
Figure 2: Imported Water, Groundwater Used, and Marginal Land in Westlands sub-basin over time (ac ft/y)



ECw (dS/m)	Low Yield	High Yield
6	4.6	8.3
10	2.5	4.5



Potential Energy Production (10^5 Gal of Gas Equivalent). Low and High indicate different potential Dry Ton/Ac yields.



Salt management via reusing drainage

salinity increase

Perennial grass cultivation

Drainage

Drainage containing B, Se, Na....

Root zone (salt accumulation)

Salt-tolerant crop

Regular crop

Drainage or process water, waste water, and saline water

Treatment

Pond dry salts

METHODS

We used conversion rates for three biomass conversion processes: **Gasification, cellulosic ethanol, and biogas**. Estimates were made for two drainage salinity levels: 6 and 10 dS/m, and for three sub scenarios: 50% Highly Marginal Land, 100% Highly Marginal Land, and 100% Moderately Marginal Land. **For each scenario, we estimated results for three drainage water amounts: Low (low surface water due to drought - 2001 data is used), Med (med surface water – mean of 2000 to 2010 is used), and High (surface water in a high precipitation year – 2006 data is used).** We assumed 100% of drainage water was available. We also used two conversion rates from dry matter to energy: low and high.

CONCLUSIONS

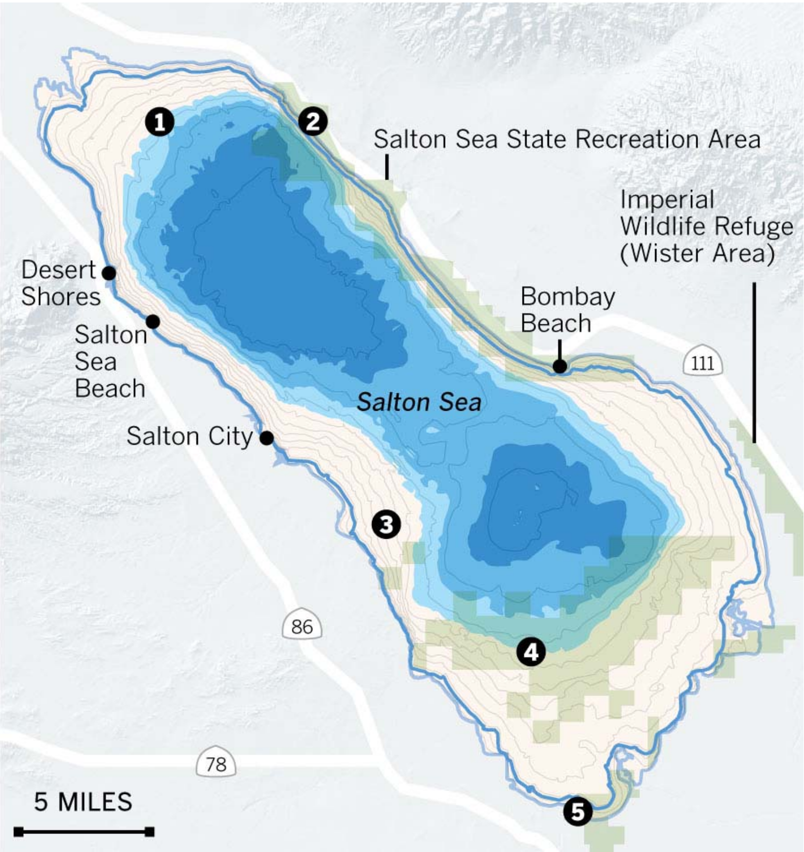
Perennial grasses, like Bermuda can be grown on marginal land in the WSJV as part of an IFDM (Integrated Farm Drainage Management) system using primarily drainage water.

Doing so will help remediate marginal lands, provide energy or income to help with final disposal of residual brines, and create new biorefineries in disadvantaged communities. they may provide remediation to the soil and wildlife benefits.

There is more marginal land in the study area than can be used for perennial grasses grown with drainage water, due to drainage water limitations.

Substantial energy production is possible, but further analysis is needed, particularly a bio-economic regional optimization model, in order to look for economic feasibility.

Potential future land area for salt-tolerant biomass production?



http://www.latimes.com/local/california/la-me-g-drought-drawdowns-and-death-of-the-salton-sea-20141021-htmlstory.html ;
Sources: Tim Krantz, professor of environmental studies, Salton Sea Database program director, University of Redlands; Lisa Benvenuti, GIS analyst, University of Redlands; California State

Biomass Resources in California: Potential for Economic Use

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- Marginal lands
- **Biogas**

Table ES.2. Biogas Technical Potential from California Resources

Feedstock	Amount Technically Available	Biomethane Potential (billion cubic feet) CNG (gge)	Fraction in use
Animal Manure	3.4 MM BDT	19.7 (155 Mgge)	< 1%
Landfill Gas	106 BCF	53 (420 Mgge)	~60 %
Municipal Solid Waste (food, leaves, grass fraction)	1.2 MM BDT	12.6 (I00 Mgge)	< 1%
Waste Water Treatment Plants	11.8 BCF (gas)	7.7 (60 Mgge)	
Total		93 (735 Mgge)	

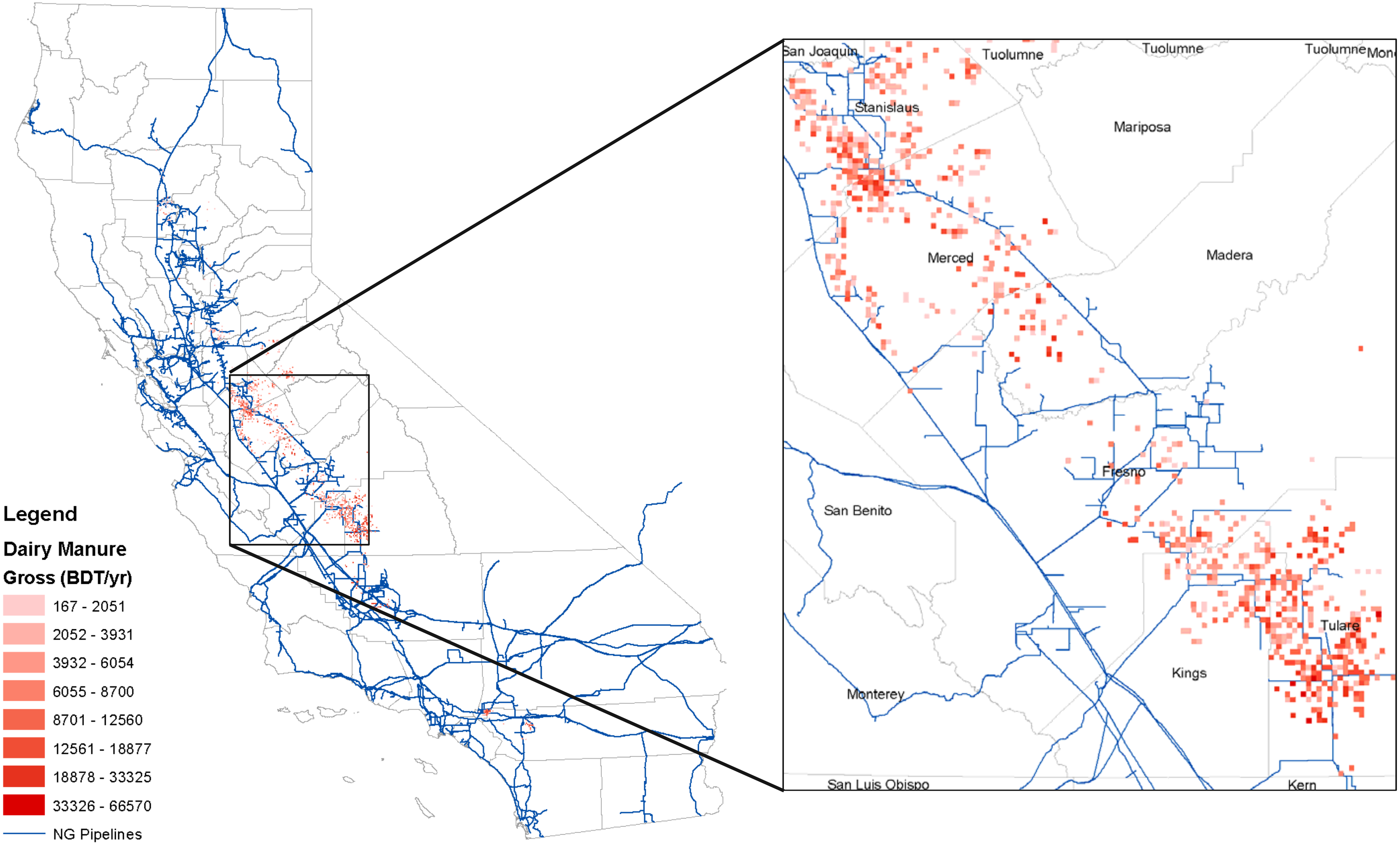
Williams et al., CBC, 2015.; (7.74 GGE/MMBTU)

The potential for urban organic residue and manure-based AD systems is large and likely to expand.

Williams et al., 2015. Draft Report to CRC.

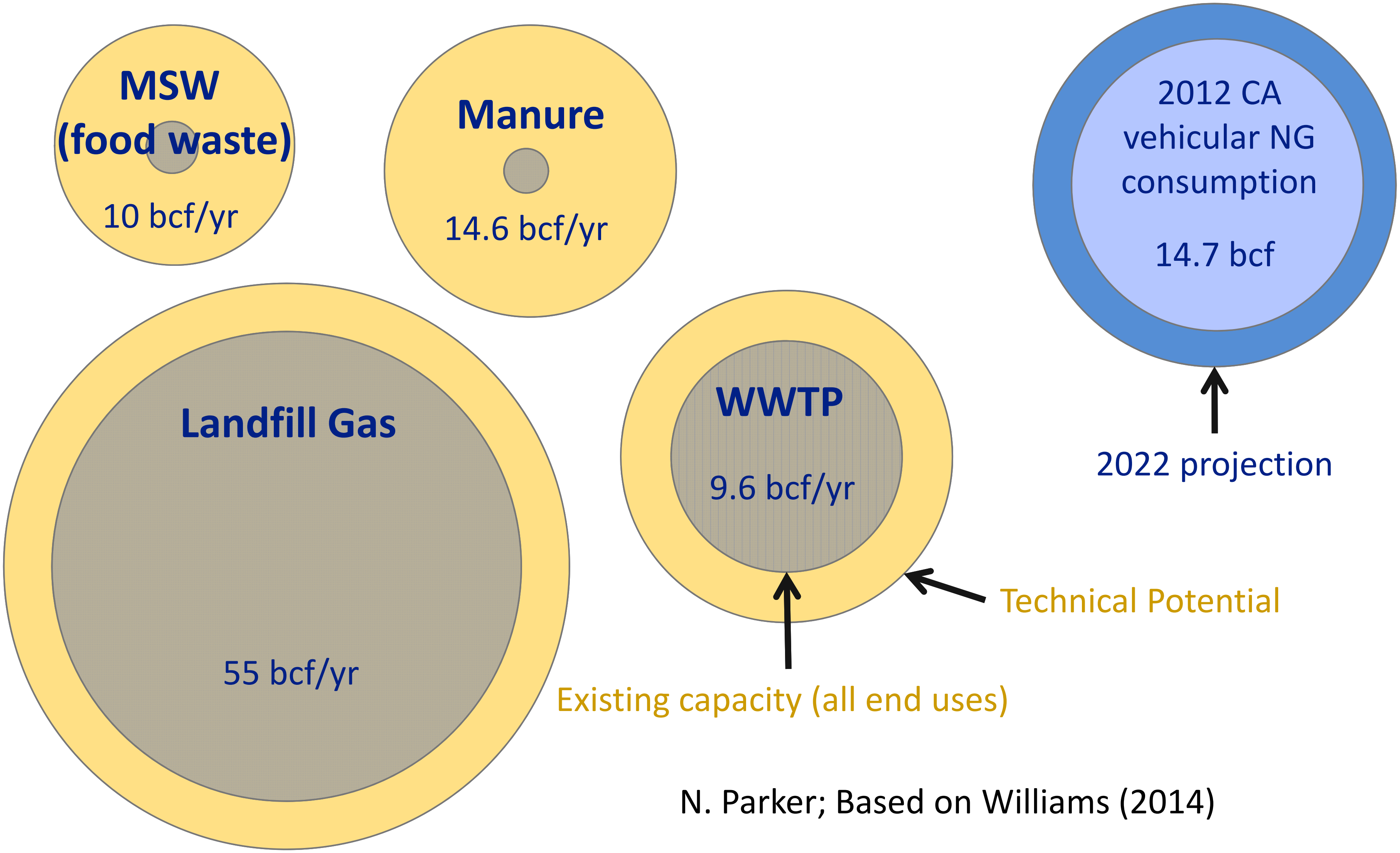
CALIFORNIA BIOMASS COLLABORATIVE

Spatial distribution of dairy manure and the NG transmission network



Renewable natural gas potential in California

CA Production Potential



N. Parker; Based on Williams (2014)

California Food Processing Industry Organic Residue Assessment

Amon et al., 2011

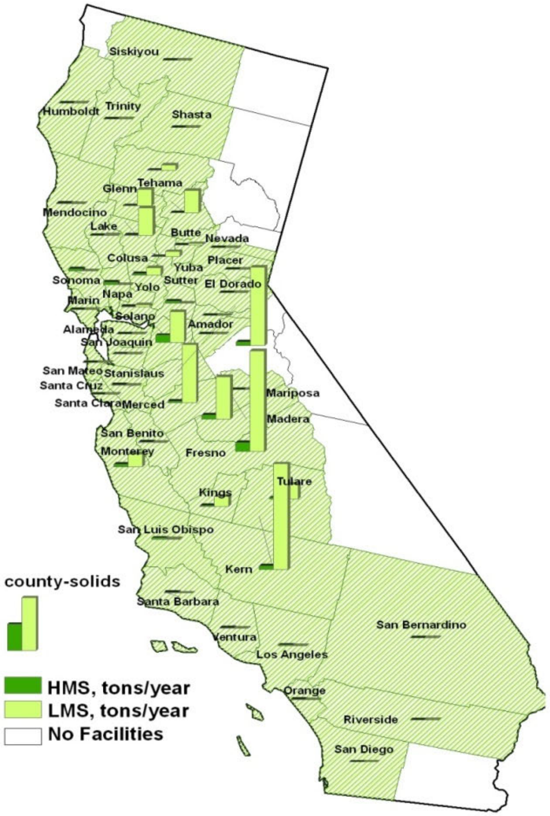
SUMMARY: Approximately 26.3 billion gallons of wastewater and 3.5 million dry tons of solid residues are produced annually…

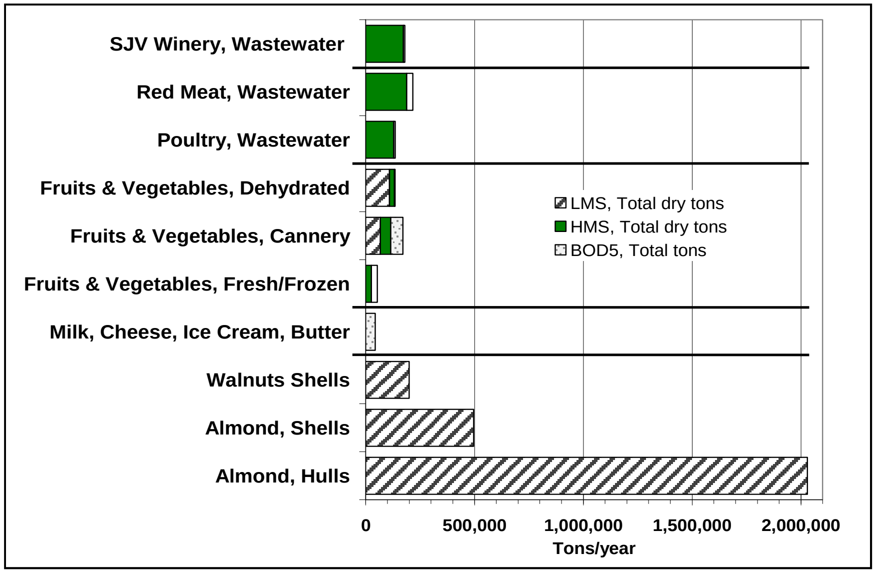
Approximately 55 percent of the wastewater is from canneries... and fruit and vegetable processing with another 20 percent each from creameries and meat processing…

Almond hulls account for nearly 60 percent of solids residue (dry basis) with almond and walnut shells contributing another 20 percent…

Solids from fruit and vegetable processing (canneries, dehydrators, fresh and frozen), meat processing, wineries and creameries contribute about 760,000 dry tons solid residue (approximately 20% of total solids)…

California Food Processing Industry Organic Residue Assessment, **Amon et al., 2011**





Food Processing Sector	BOD_5 Biogas		Solids Biogas		LMS Thermal		Potential Residue Availability
	Power (MW)	CHP (MMBtu)	Power (MW)	CHP (MMBtu)	Power (MW)	CHP (MMBtu)	
Cannery F & V	7.2	257,480	11.1	394,600			High
Dehydrated F & V	0.4	12,530	12.7	451,460			High
Fresh/Frozen F & V	3.6	129,500	2.5	88,360			High
Winery	0.9	31,080	16.7	592,960			High
Creamery	5.7	202,770					None
Poultry	1	35,410	12.3	438,590			None
Red Meat	3.8	134,790	18.1	643,670			None
Almonds					427.4	19,545,260	Hulls Low; Shells medium
Walnuts					33.7	1,541,902	High
							Total CHP
Power Total (MW)	22.6		73.3		461.1		557
Recovered Heat (MMBtu)		803,560		2,609,640		21,087,162	24,500,362

CALIFORNIA BIOMASS COLLABORATIVE

pier
PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

STATE OF CALIFORNIA ENERGY COMMISSION

Colony, Tulare AD Project

(500 tons per day)

Combined food processing wastes with current AD system at a waste water treatment plant

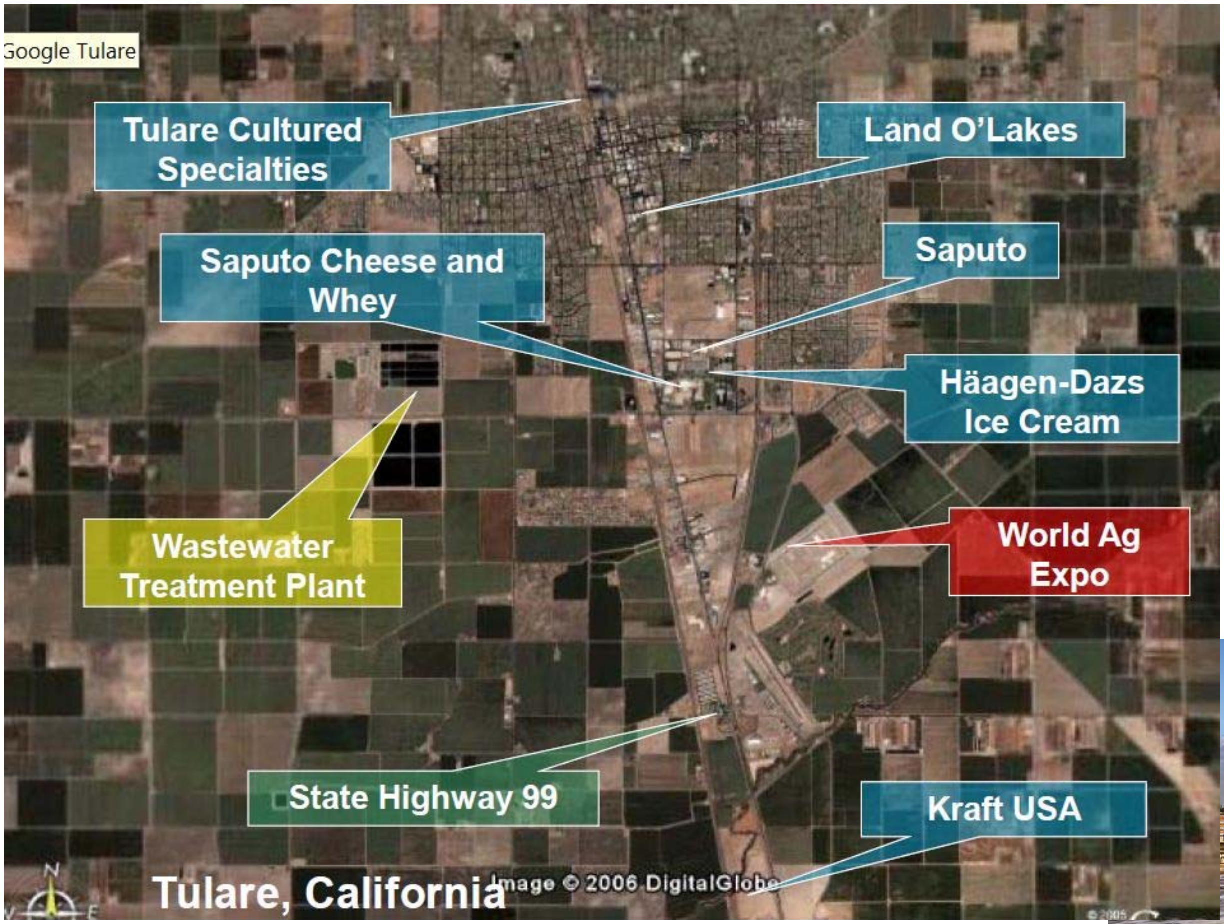


Photo credits: City of Tulare Public Works; source: Jacques Franco; UC Davis - Public Institute for Energy, Environment and the Economy; jzfranco@ucdavis.edu