California Air Resources Board/Sustainability Assessment

Sustainability Assessment for Agricultural Biofuels in California

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CALIFORNIA BIOMASS COLLABORATIVE

UCANR MAKING A DIFFERENCE
UNIVERSITY OF CALIFORNIA AGRICULTURE AND NATURAL RESOURCES • Cooperative Extension • Agricultural Experiment Station

Outline

- What do we mean by agricultural sustainability?
- Mendota Advanced Beet Energy Coop and an example_using a cropping system optimization model for multiple purposes
- Sustainability and Certification
- Proposed Actions

Sustainability and Best Management Practices: Policy implications

1. Change is the constant characteristic of agricultural practices
2. New technology and learning occurs constantly, but unevenly.
3. Sustainability assessments will vary locally
4. Policies, social preferences and external influences are in flux, and the most important ones are unpredictable

How can we define/measure sustainability?

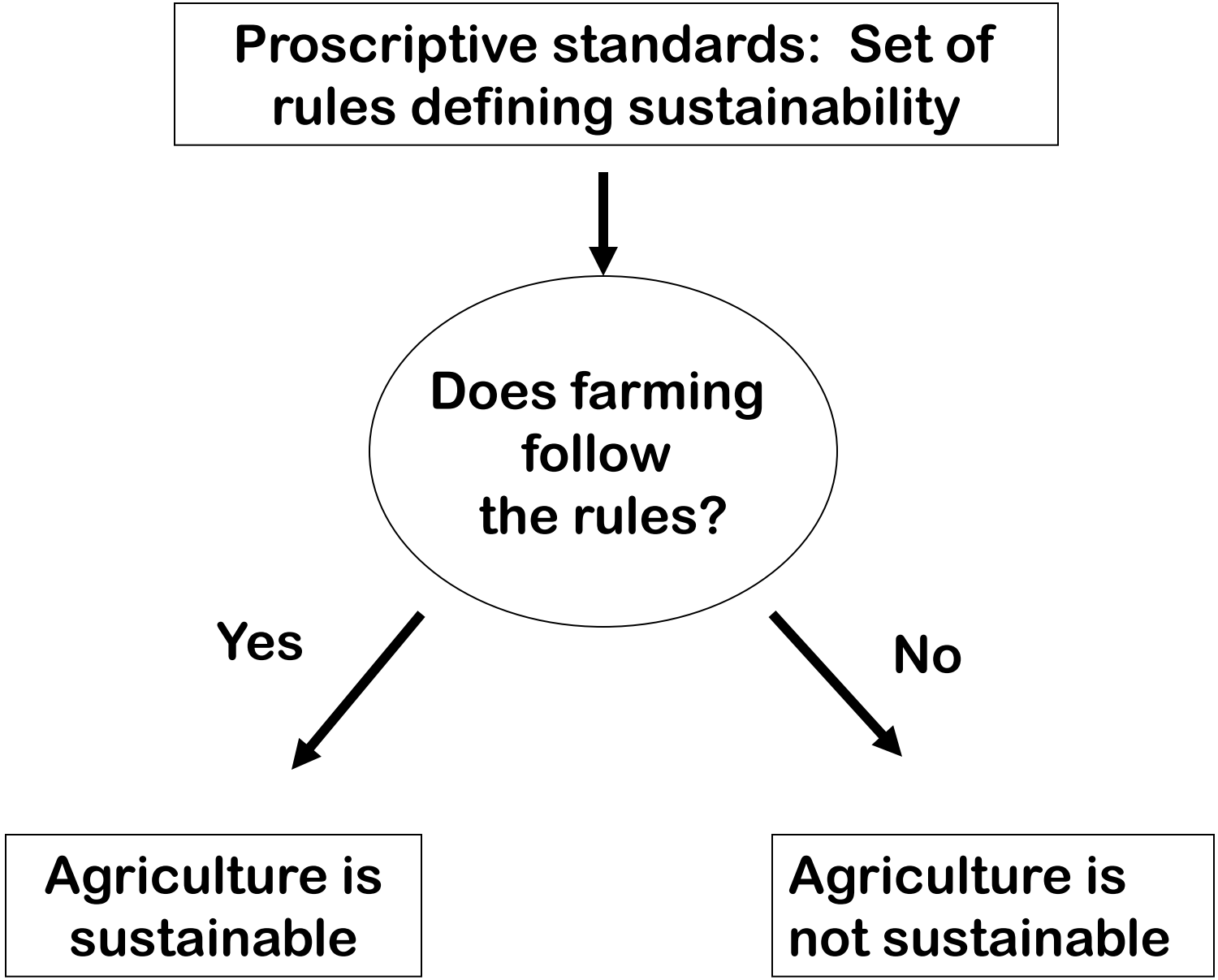
In discussing agricultural sustainability, we must use language carefully. We must be careful to define our boundary conditions. We should not use qualitative terms for quantitative phenomena.

Hansen, J. W. (1996). Agric. Systems, 50:117-143

Types of definitions of sustainability:

- A philosophy or ideology
- A set of strategies
- The capacity to fulfill a set of goals
- The ability to continue over time

Hansen, 1996


Proscriptive standards: Set of rules defining sustainability
Does farming follow the rules?
Yes
No
Agriculture is sustainable
Agriculture is not sustainable

But if sustainability is determined by definition, then it is logically impossible to evaluate how sustainable farming practices actually are, if adherence to a set of predetermined rules or standards is the criteria for evaluation. This circularity makes definitions of sustainability poor guides for research.

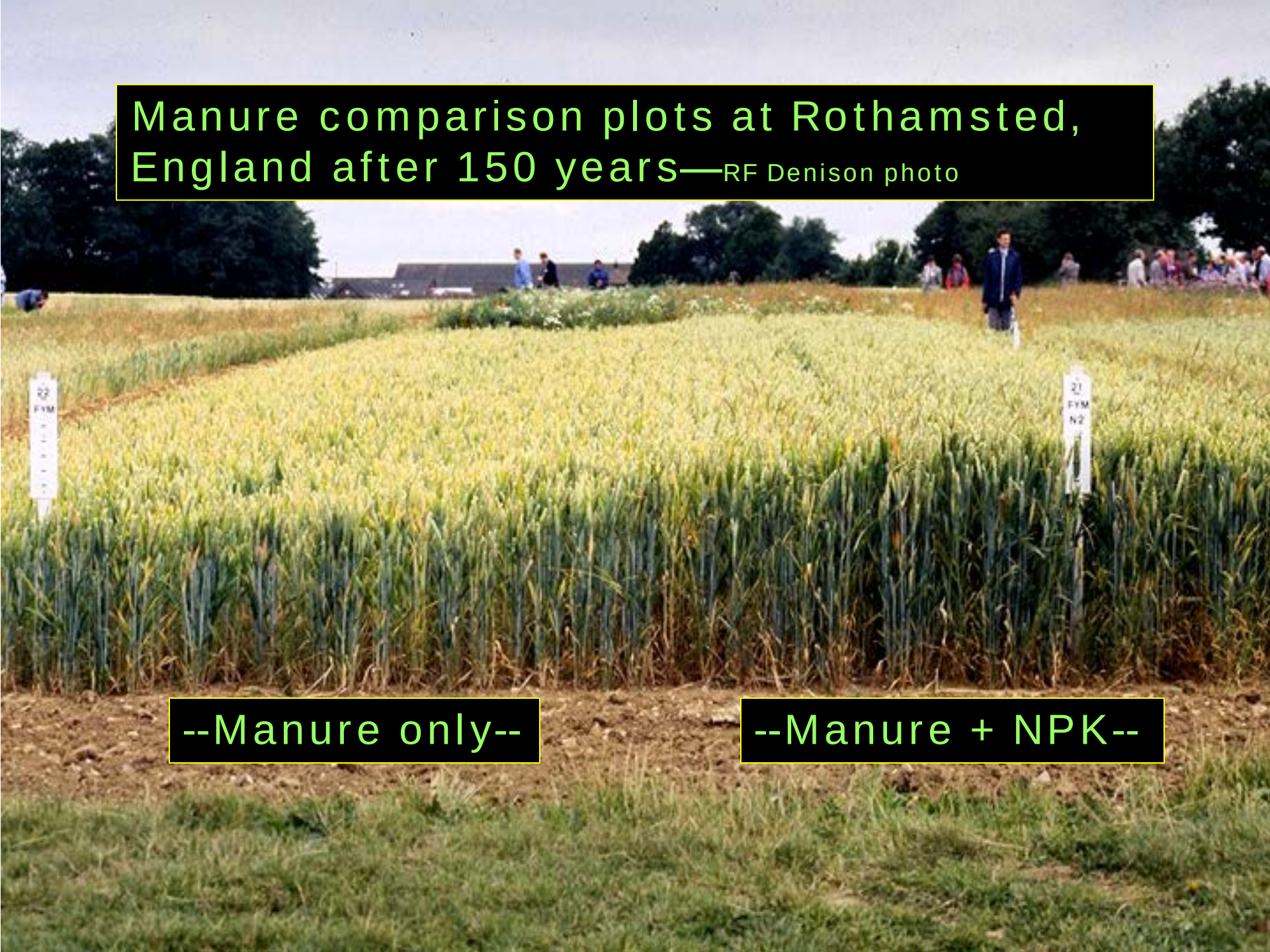
Hanson, 1996

Useful ways to characterize sustainability at the field and farm scale —Hanson, 1996

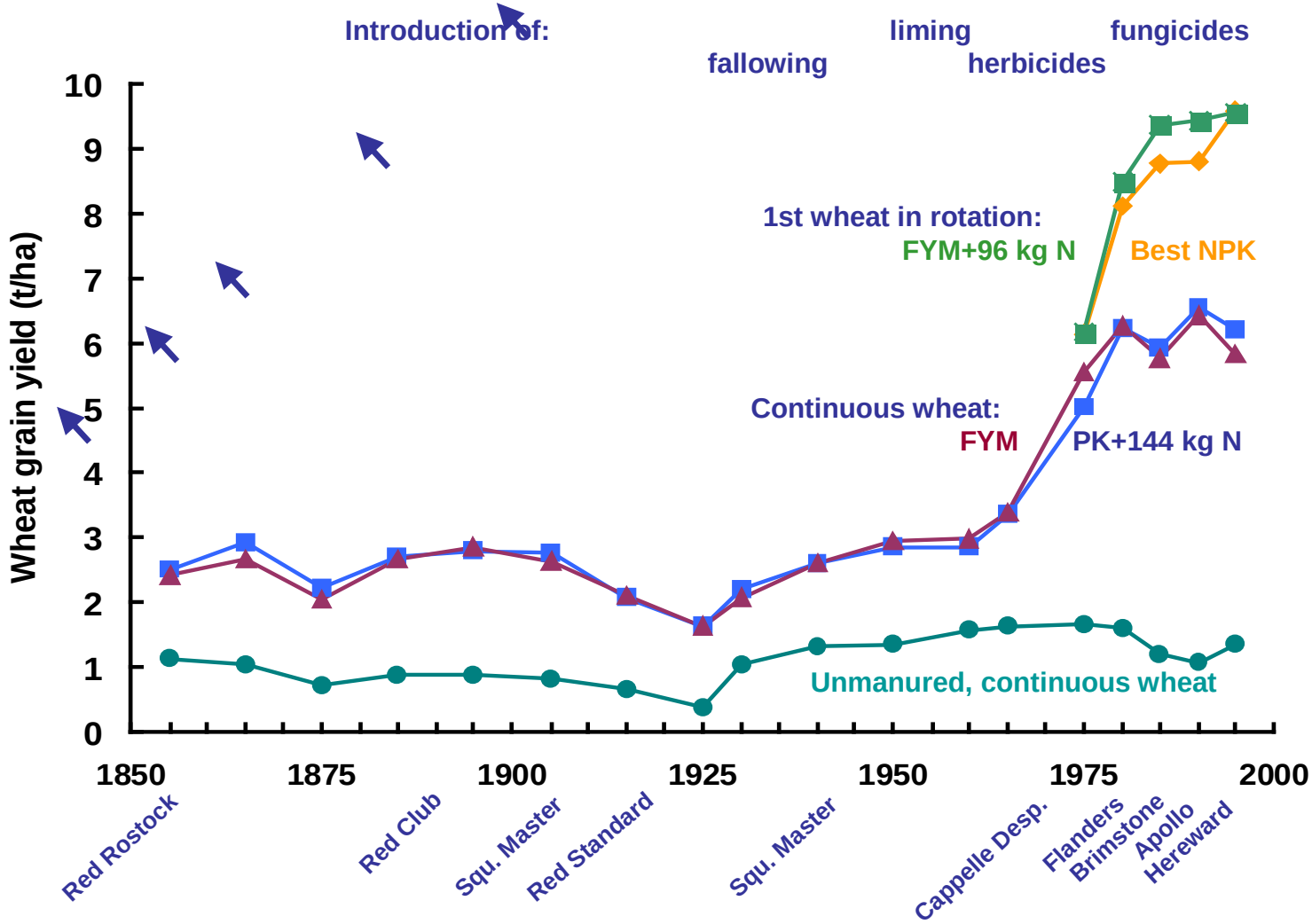
Element	Definition
Literal	**An ability to continue through time**
System-oriented	An objective property of a particular agricultural system whose components, boundaries and hierarchy are specified
Quantitative	A continuous variable(s), permitting comparisons of alternative systems or approaches
Predictive	Focuses on the future, not the present or past
Stochastic	Variability is a determinant of sustainability and a component of prediction
Diagnostic	Can be used to identify and prioritize constraints on a system that limits its sustainability

“...long term experiments ... provide data on which to base rational judgments about the biophysical aspects of sustainability.”

D.S. Powlson, 1996


Manure comparison plots at Rothamsted, England after 150 years—RF Denison photo
--Manure only--
--Manure + NPK--

Long-term winter wheat yield trends, Rothamsted, England



Powlson and Poulton, 2003

A long-term experiment in California: Russell Ranch , UC Davis

Cropping system comparisons

H_2O

System	Irrigation	N source	Pesticides
Corn/tomato	Irrigated	Manure+ WLCC	Organic
Corn/tomato	Irrigated	Fertilizer+ WLCC	As needed
Corn/tomato Wheat/tomato	Irrigated	Fertilizer	As needed
Wheat/fallow	Irrigated	WLCC	As needed
Wheat/fallow	Irrigated	Fertilizer	As needed
Wheat/fallow	Irrigated	None	As needed
Wheat/fallow	Dry land	WLCC	As needed
Wheat/fallow	Dry land	Fertilizer	As needed
Wheat/fallow	Dry land	None	As needed

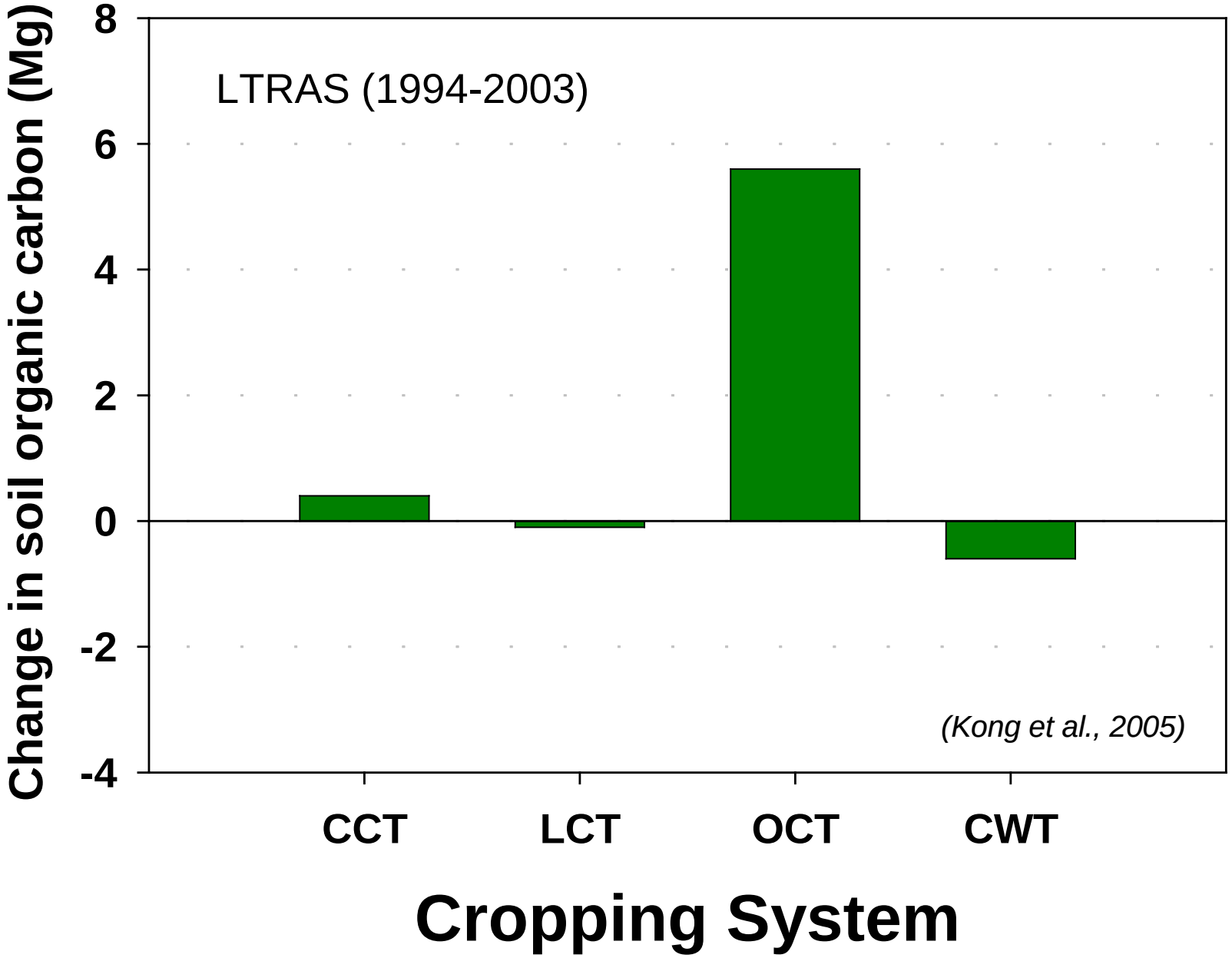
N/C

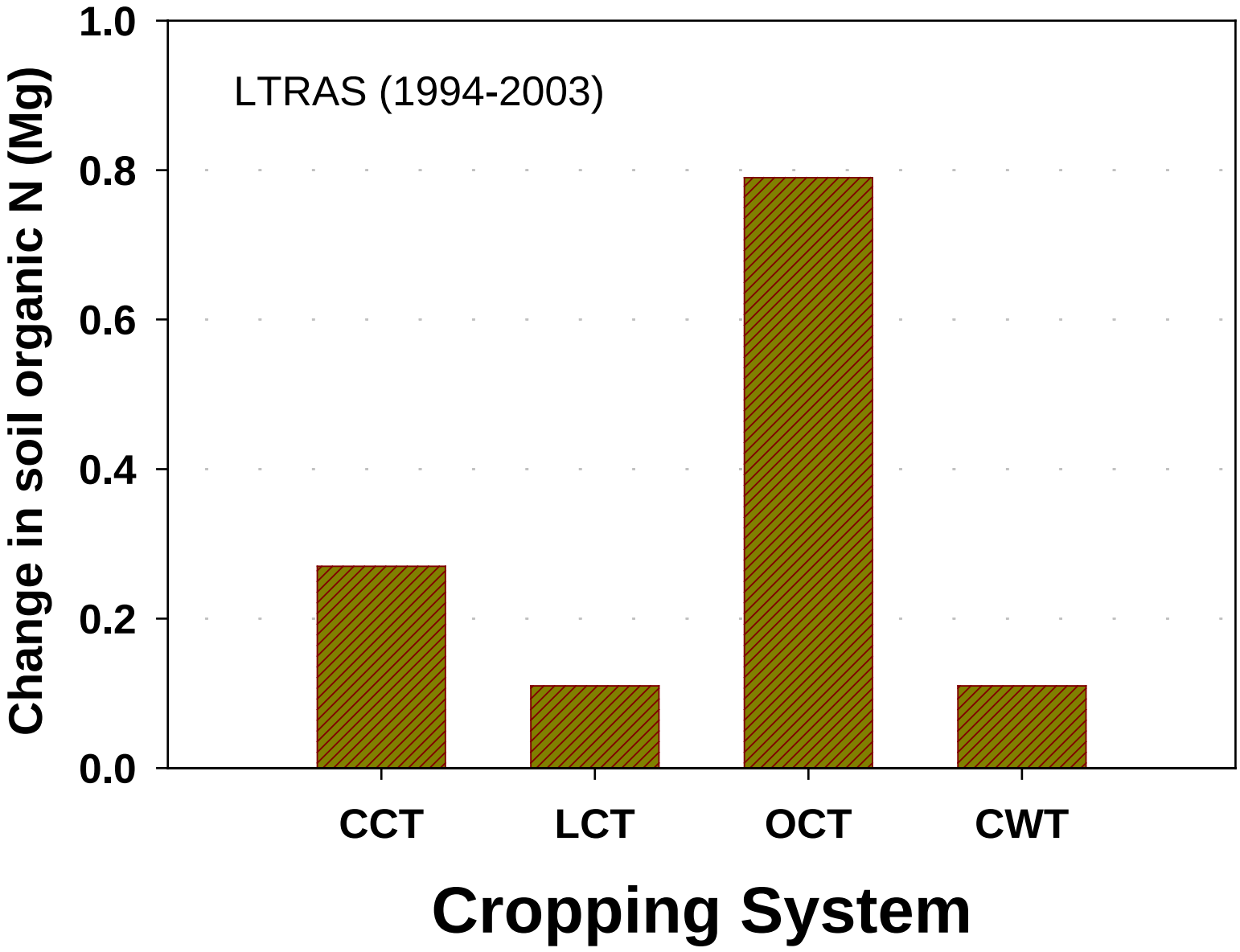
Conventional

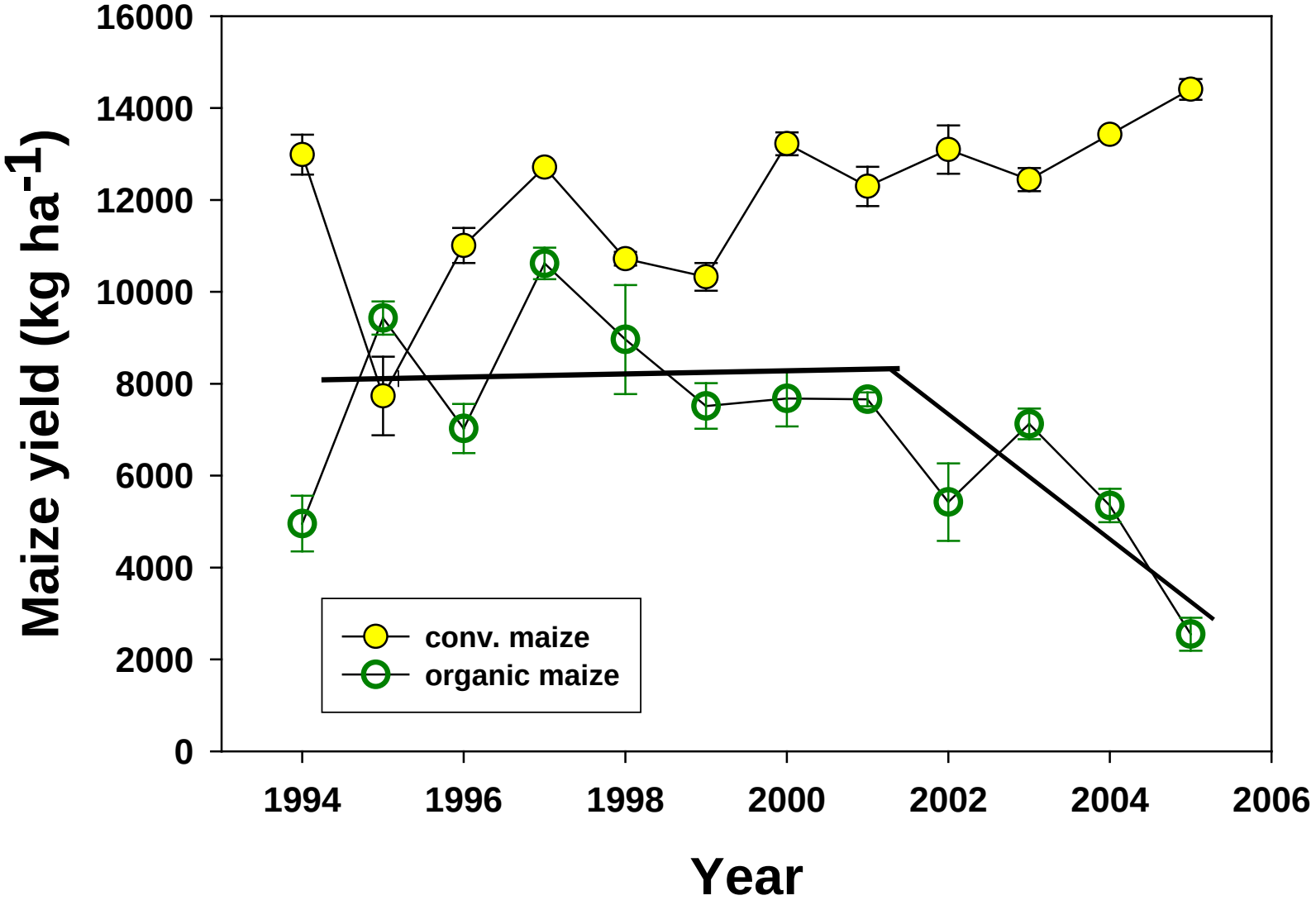
Organic

Maize Treatments, 2004/5

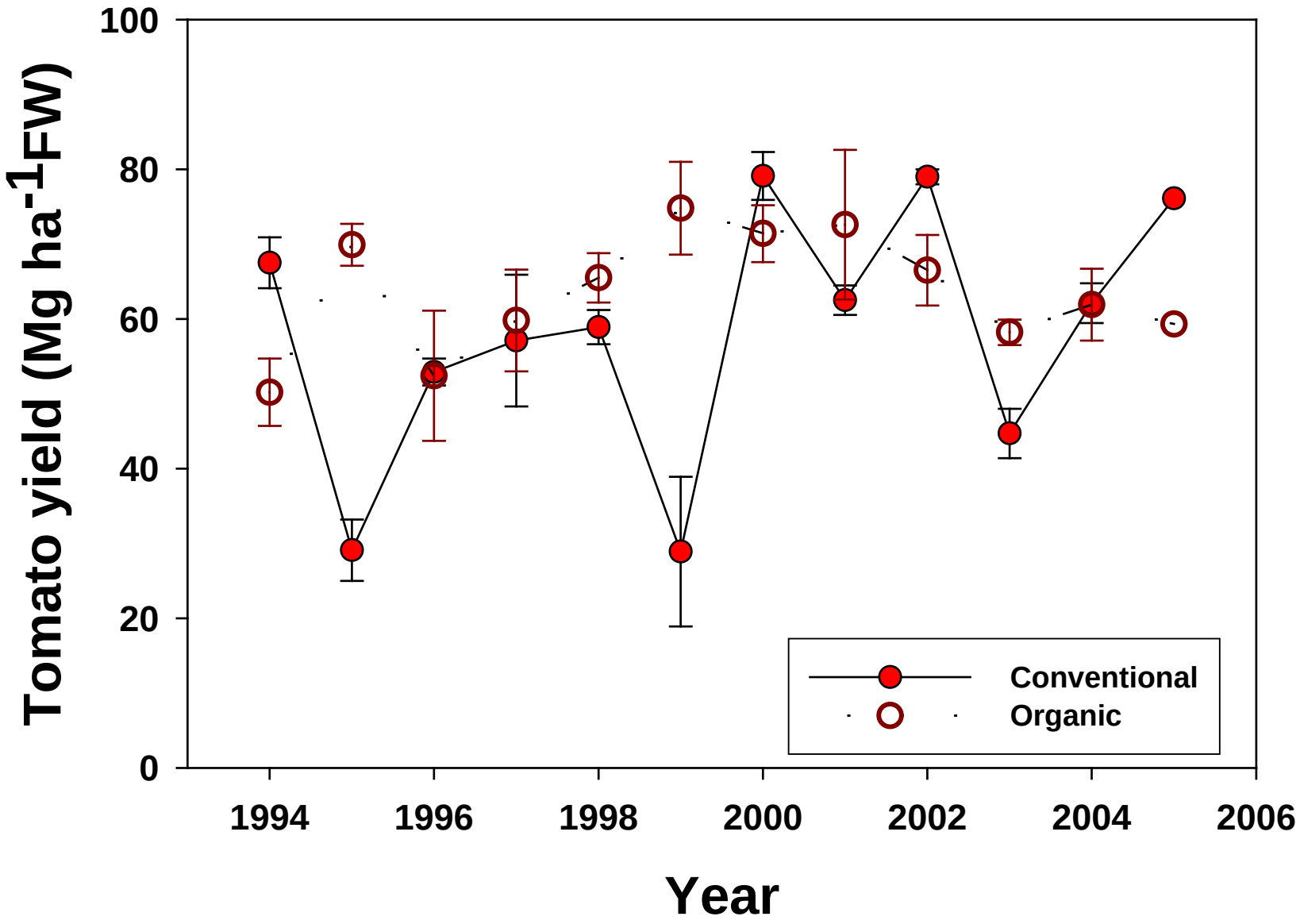
	Conventional	Organic
Variety	ST 7570RR	ST 7570
Seed rate (per ha)	80,250	80,250
Herbicides/ Pesticides	Yes	No
Nutrient inputs	50 kg/ha NPK + 185 kg N	Vetch+ pea CC (180 kg N/ha)+ Compost (4 t wet wt): 240 kg N/ha


LTRAS (1994-2003)
(Kong et al., 2005)
Change in soil organic carbon (Mg)
8
6
4
2
0
-2
-4
CCT
LCT
OCT
CWT
Cropping System


LTRAS (1994-2003)
Change in soil organic N (Mg)
1.0
0.8
0.6
0.4
0.2
0.0
CCT
LCT
OCT
CWT
Cropping System

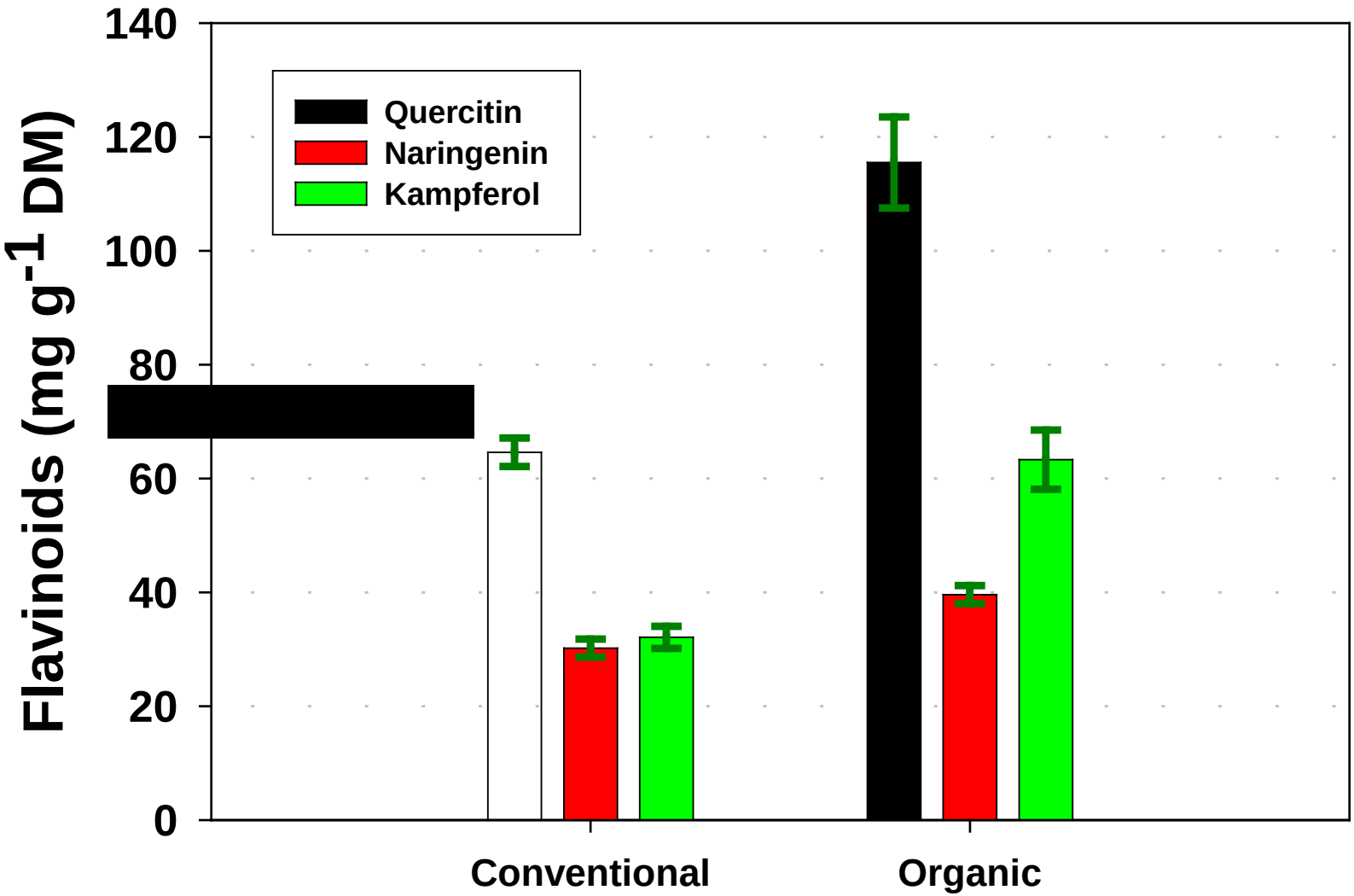


Maize yields, 1994-2005, LTRAS



Tomato yields (1994 to 2005) LTRAS

Tomato Fruit Quality, LTRAS (1994-2004)

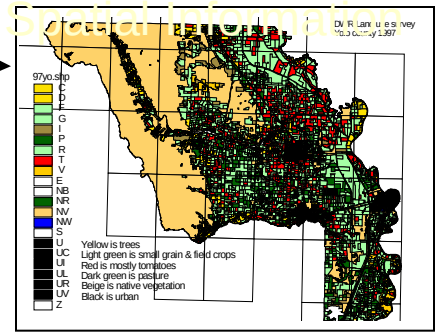


Mitchell et al., 2009

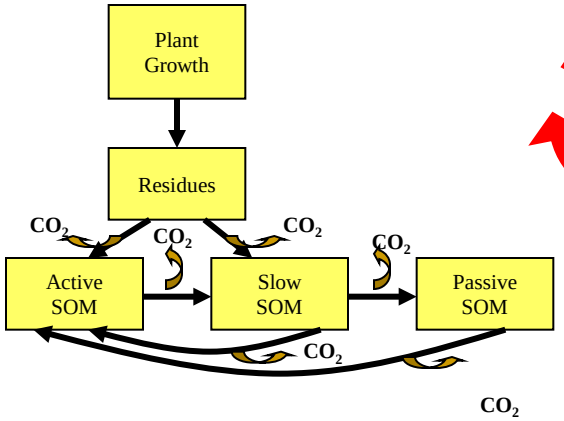
Integration of ecosystem and economic models with Long Term Research

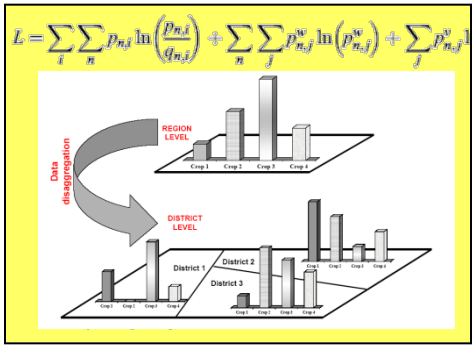
Long-term field experiments

Land use and management identification



Ecosystem model





Dynamic economics

Decision support

With uncertainty estimates

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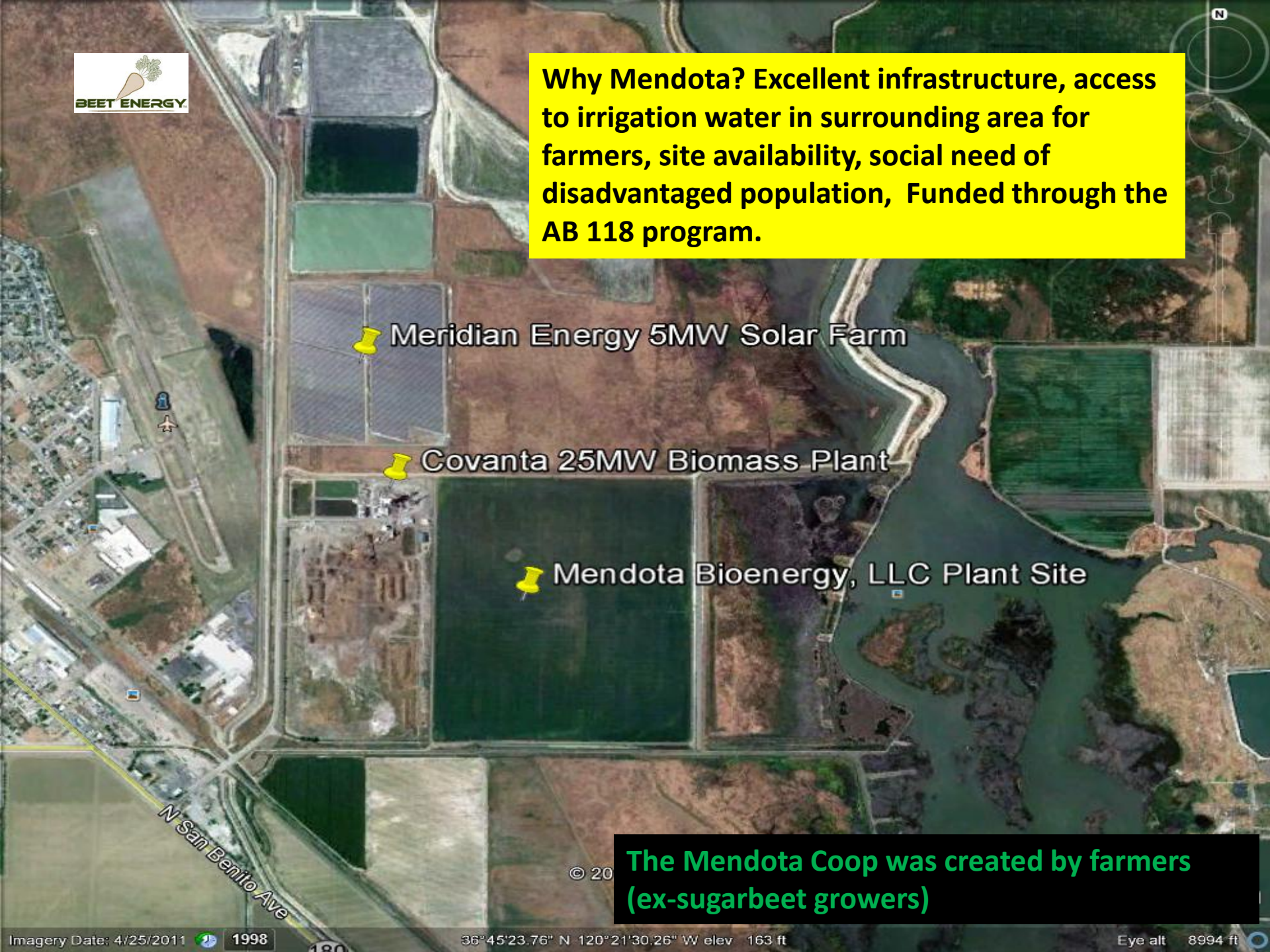
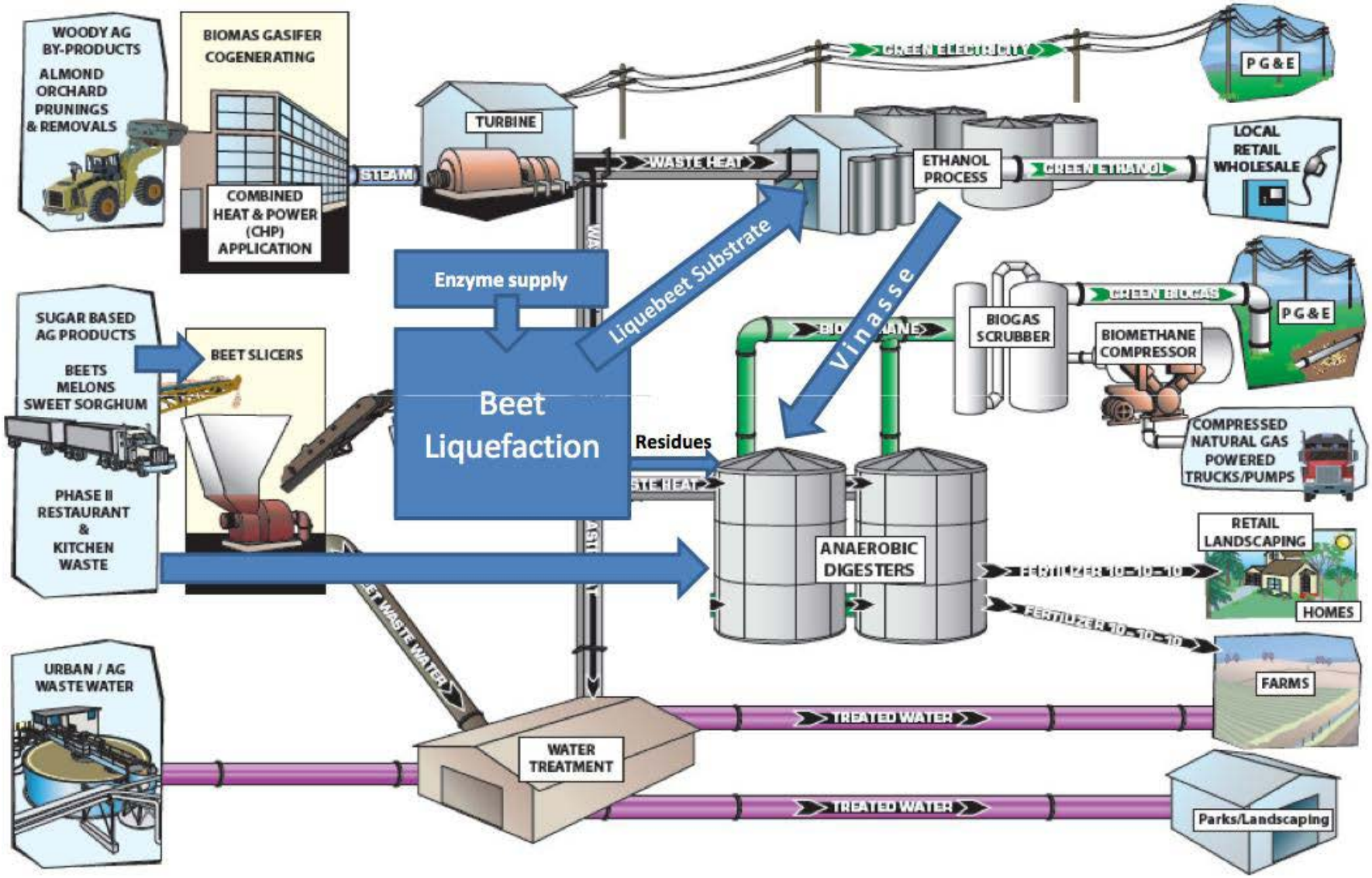

BEET ENERGY
Why Mendota? Excellent infrastructure, access to irrigation water in surrounding area for farmers, site availability, social need of disadvantaged population, Funded through the AB 118 program.
Meridian Energy 5MW Solar Farm
Covanta 25MW Biomass Plant
Mendota Bioenergy, LLC Plant Site
N San Benito Ave
The Mendota Coop was created by farmers (ex-sugarbeet growers)
Imagery Date: 4/25/2011
1998
36°45'23.76" N 120°21'30.26" W elev 163 ft
Eye alt 8994 ft

Acknowledgements

- Alissa Kendall (Civil and Env. Eng; UCD)
- Ruihong Zhang (Bio &Ag Engineering, UCD)
- Mark Jenner (California Biomass Collaborative)
- Mendota Advanced Beet Energy Coop
- Cliff Ohmart (Sure Harvest)



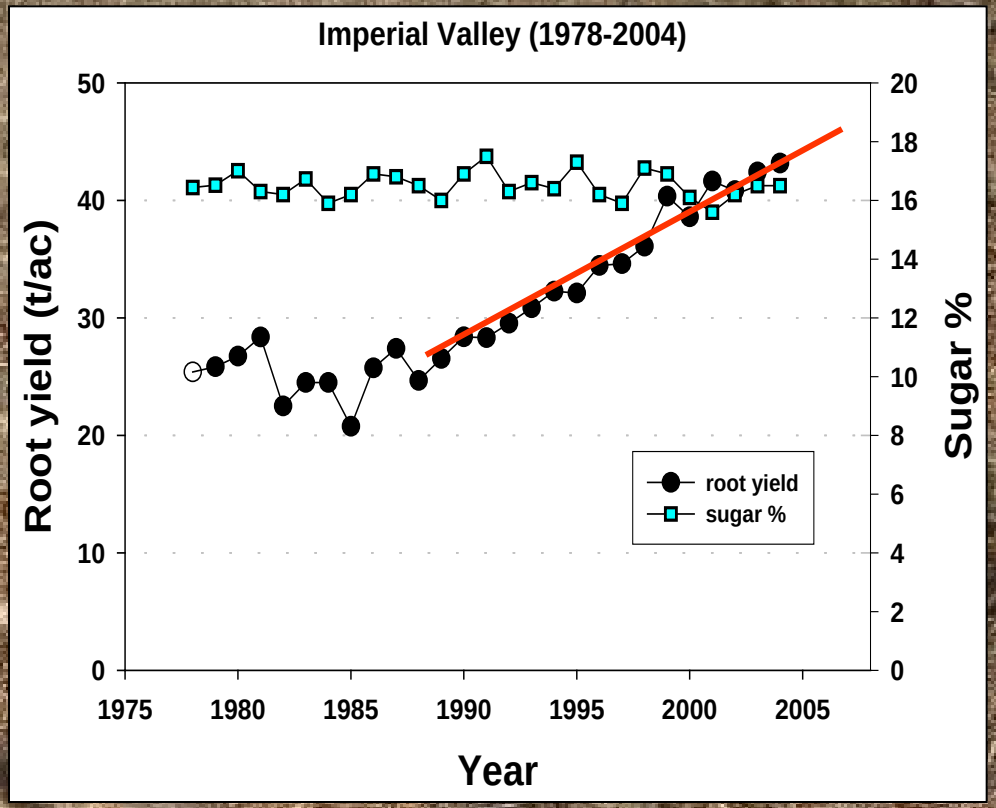
Integrated biorefinery, Jan. 2012

BEET ENERGY

Imperial Valley, August 2011 harvest

157 t/ha roots and 27 t gross sugar/ha

Beets grow better in CA, including the SJV, than anywhere else in the world



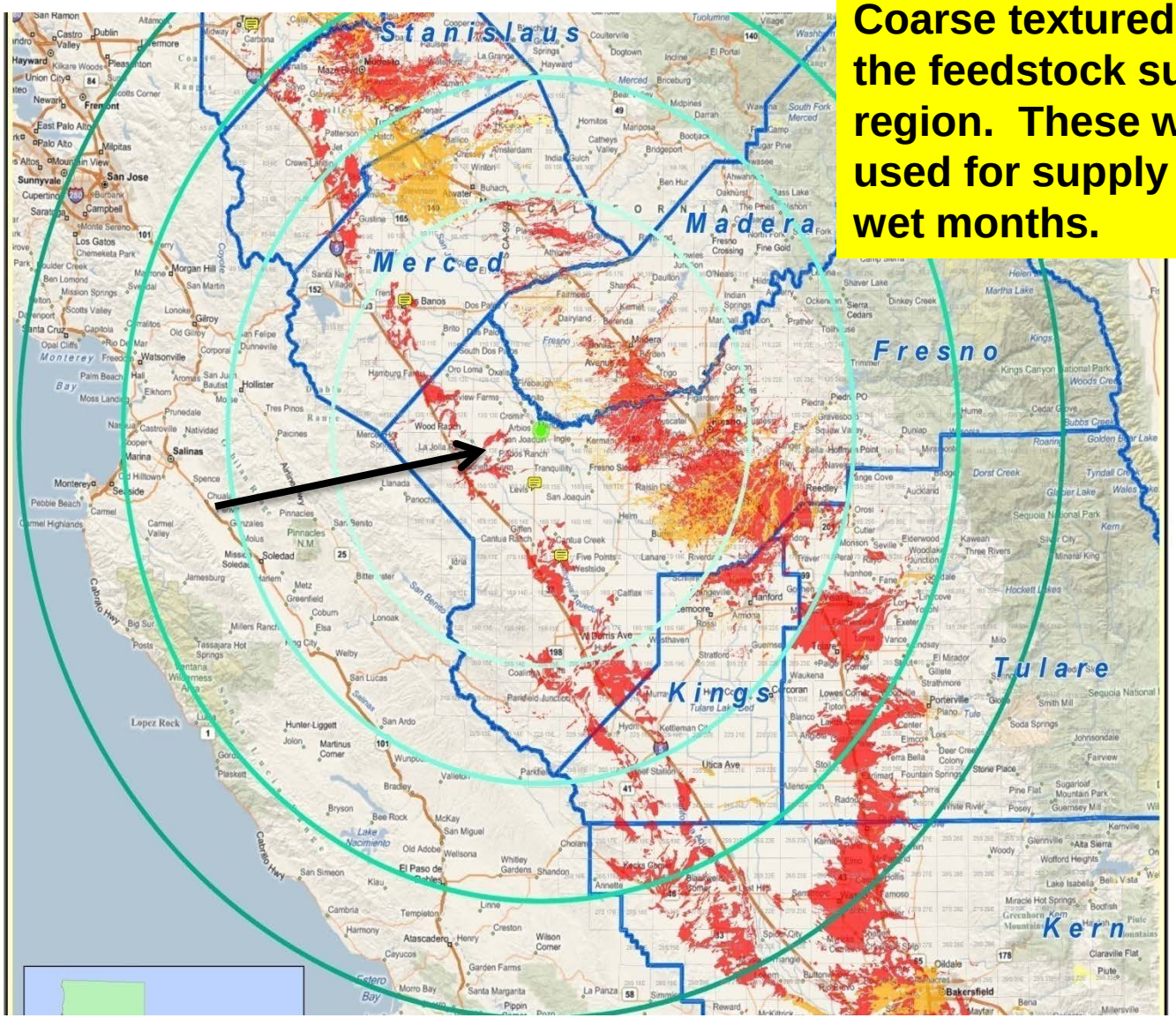
Mendota Advanced Energy Beet COOP

Management challenges:

- Must manage multiple pathogen vectors
- Beet root quality varies over the season
- Deliver (unstorable) beets year round via a complex planting and harvest system. A twelve month harvest is unprecedented in the world, but has been adopted. New harvest equipment should make this possible.

ROPA Harvester:

Coarse textured soils in the feedstock supply region. These will be used for supply during wet months.

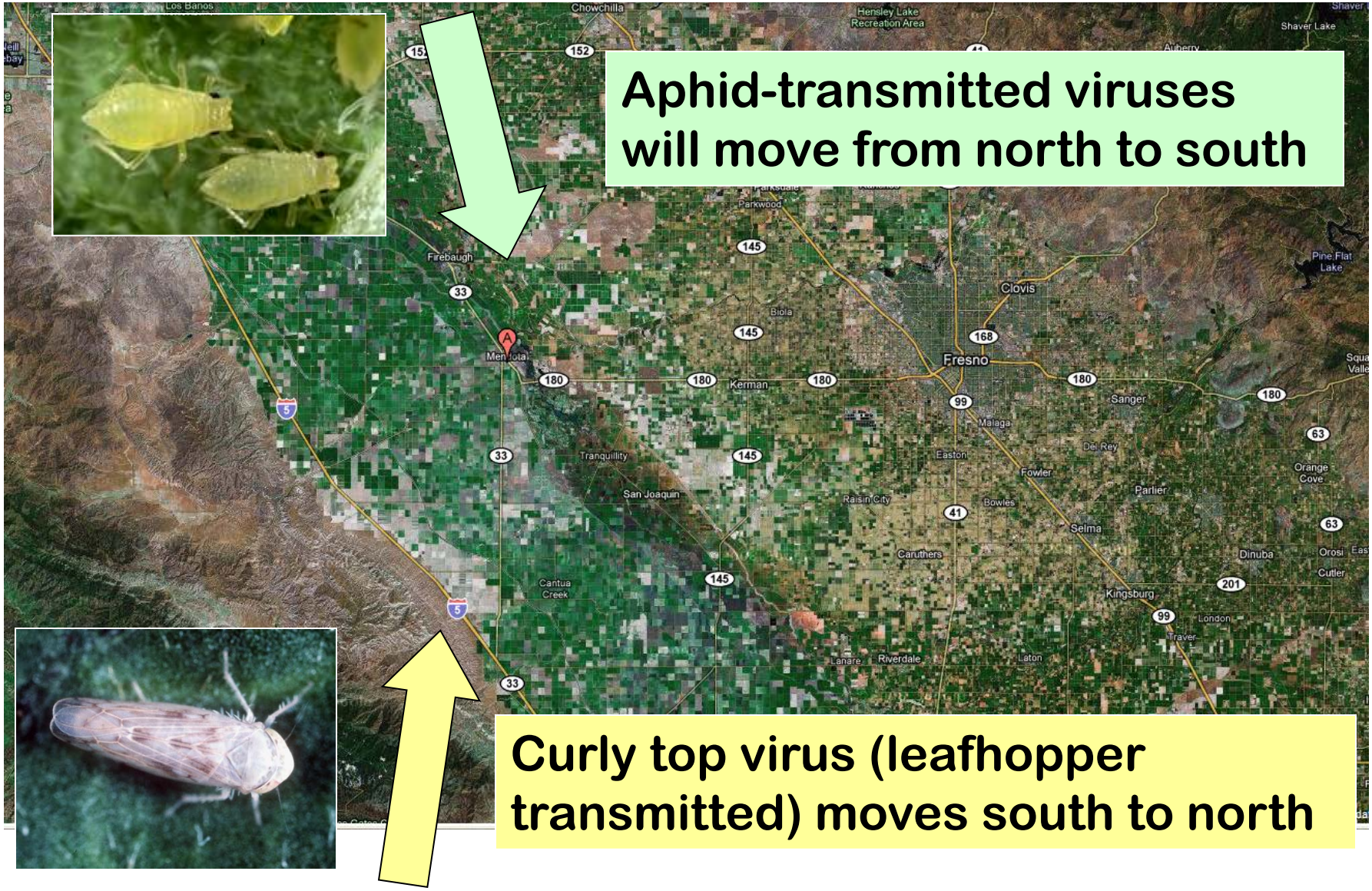


Mendota Bioenergy LLC Harvest Area

Beet Supply From Different Regions

Harvest Areas	1#	2#	3#	4 A&B#	4C#	4D#	4E#	TOTALS
Harvest (ha)	2,700	2,877	4,200	400	2,300	1,600	1,000	15,200 ha
Median Distance	50 km	40 km	32 km	100 km	80 km	50 km	110 km	
1Q Jan-Mar	24,000				228,000	124,000		376,000 t 342,000 mt
2Q Apr-June	244,000	127,600						371,600 t 338,000 mt
3Q July-Sept.		156,900	214,000					371,100 t 337,7002 mt
4Q Oct-Dec			204,000	40,000				360,000 t 327,670 mt
TOTALS	268,000 t 243,880 mt	284,200 t 258,600 mt	420,000 t 380,600 mt	40,000 t 36,400 mt	228,000 t 254,800 mt	160,000 T 145,600 mt	100,000 t 91,000 mt	1,498,400 t 1,363,600 mt

Beet Field Locations Require Careful Siting



Mendota Advanced Energy Beet COOP

Policy Challenges:

- There is no Renewable Fuel Standard (EPA) pathway
- There is no Low Carbon Fuel Standard (CARB) pathway
- Beet LCAs for CA cannot be extrapolated from existing analyses and are not included in large-scale economic models used for LCA and ILUC estimates.
- To be successful, biofuels must be produced with very low CI. Biomass production, logistics and delivery have to be efficient. A single average value will not account for variance in such a system.
- Several different types of biomass energy systems must be integrated into an integrated biorefinery. LCA's for such an analysis are unprecedented.

Mendota Advanced Bioenergy Beet Cooperative

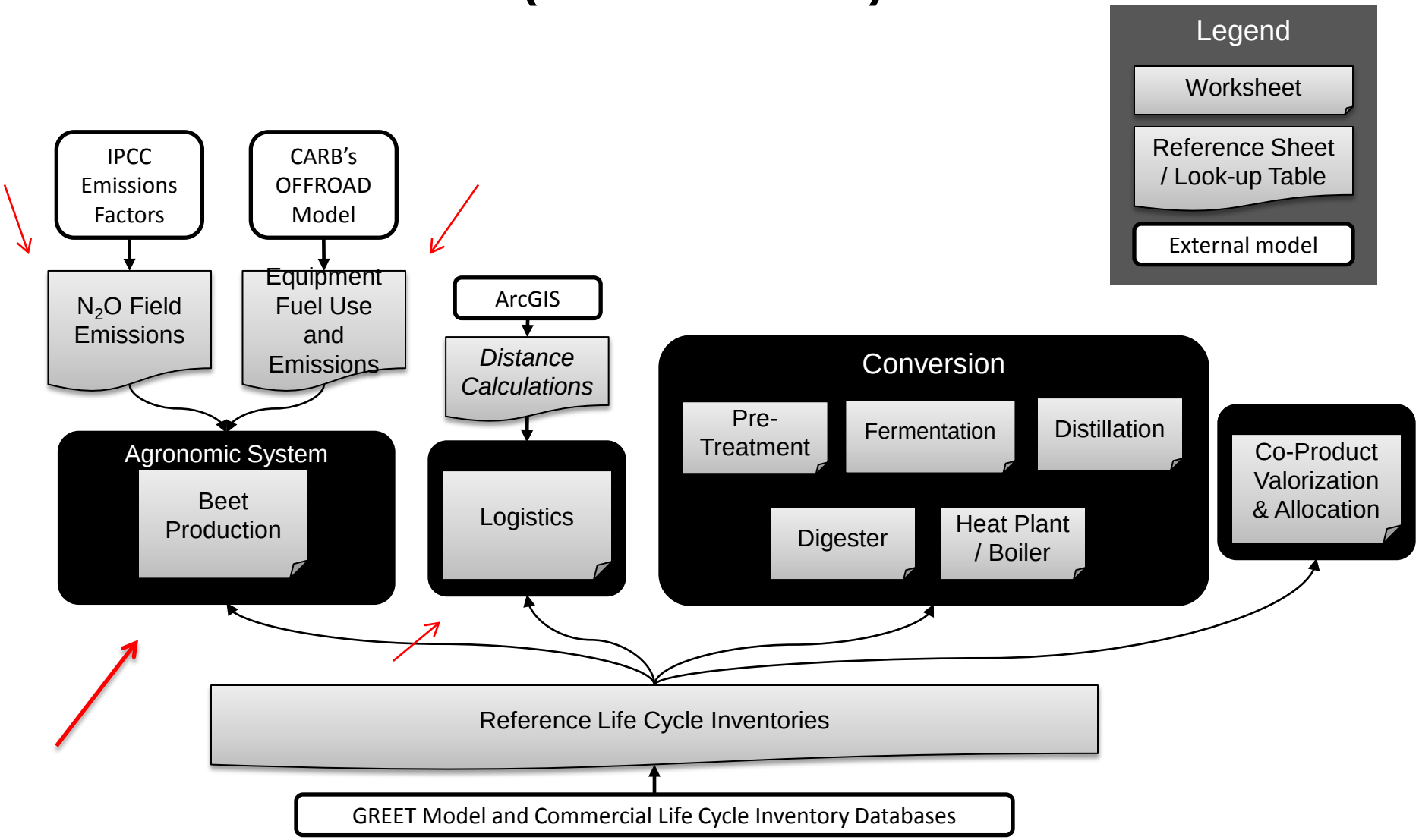
Estimated Use:

- 1 million tons of local ***energy beets***
- 80,000 tons of ***agricultural residue***

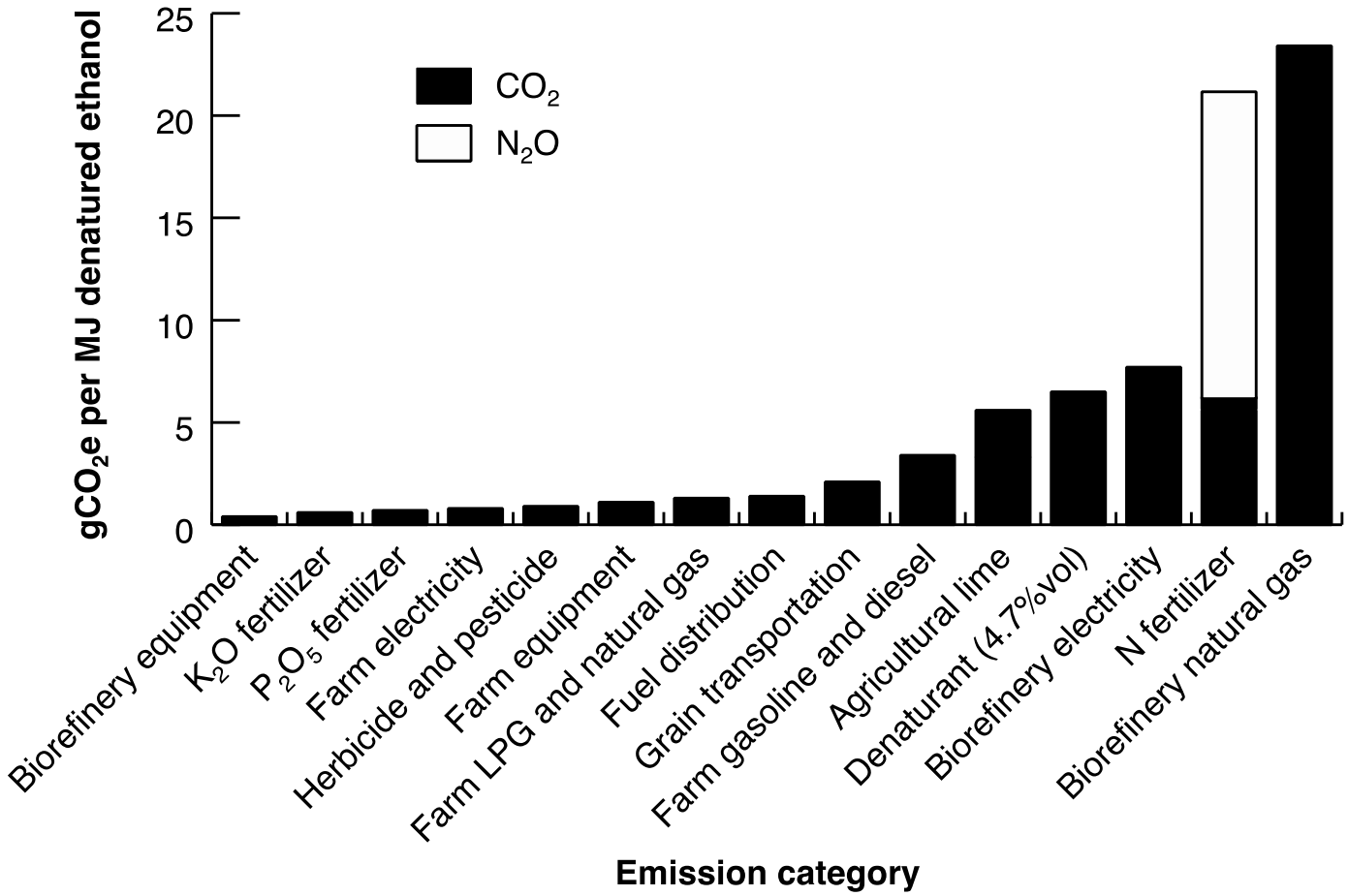
Generate

- 6.3 MW of certified Green-e ***electricity***
- 33.5 million gallons of ***advanced ethanol***
- 1.6 million standard cubic feet of ***biomethane***
- 365 acre-feet of ***irrigation water*** recycled from the City of Mendota's ***wastewater***
- $90 million of direct economic activity and ***jobs*** in a community of over 40 percent unemployment

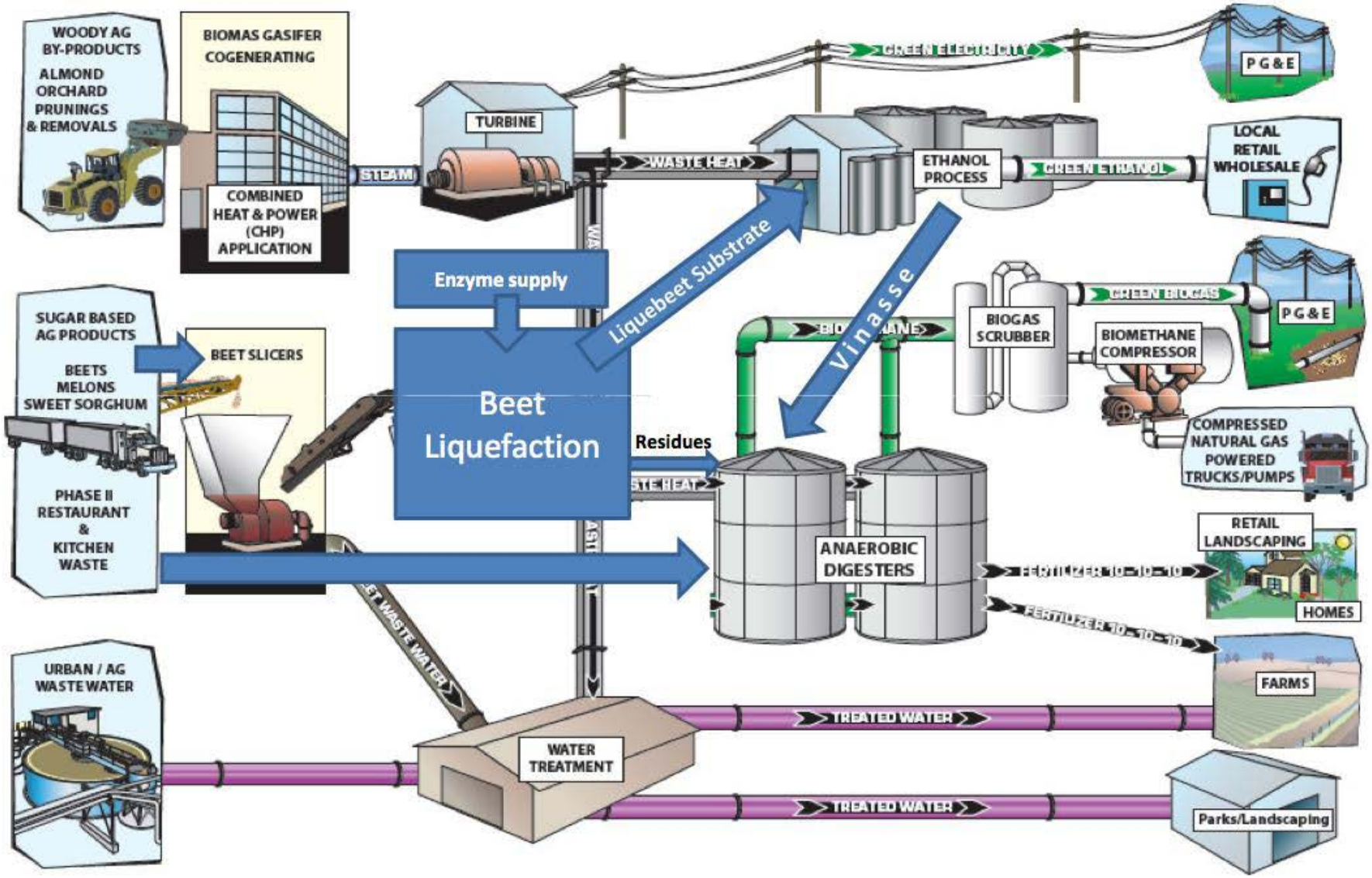
Operational Framework for Beet-Ethanol LCA Model (Alissa Kendall)



Life Cycle Assessment (LCA) is required for both the RFS2 and California's Low Carbon Fuel Standard (LCFS)



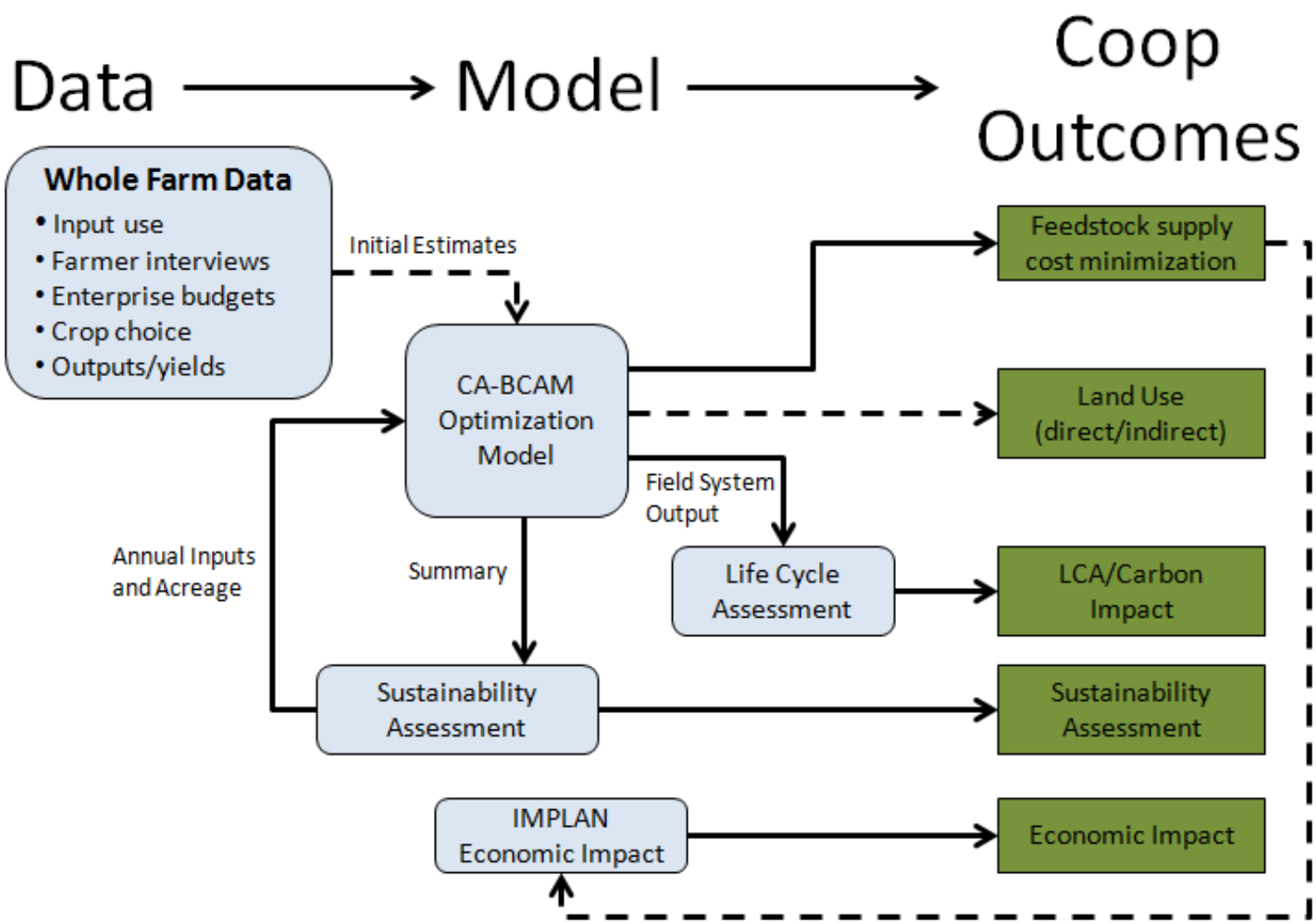
Some values from direct or attributional (LCA) assessment of GHG costs for maize-based ethanol biofuel **Source: NRC, 2011**



Integrated biorefinery design (2012)
Portions of the ethanol will be cellulosic

BEET ENERGY

Information transfer/systems analysis/LCA/ and sustainability, Jan. 2012



It is not Food vs. Fuel:

Crops have multiple roles, and multiple effects in cropping systems, both positive and negative. In general, having more crop alternatives benefits agriculture and is widely considered to be a feature of agricultural sustainability.

It is essential to think of biofuel crops as part of optimized cropping systems.

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Estimating Biofuel Carbon Intensity and Minimizing GHG Emissions Using Economic Models

Steve Kaffka, Mark Jenner

Department of Plant Sciences &

California Biomass Collaborative

The California ENERGY COMMISSION

pier PUBLIC INTEREST ENERGY RESEARCH "Research Powers the Future"

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The Challenge:

- **Is there potential in CA for producing biofuel feedstocks on farms? How can we accurately estimate the true potential of purpose-grown crops and crop residues for biomass energy in CA cropping systems.**
- **Existing large scale (national) models do not reflect CA well (REAP, POLYSYS, GTAP, FASOM). How can we do this better?**

Estimating fuel CI

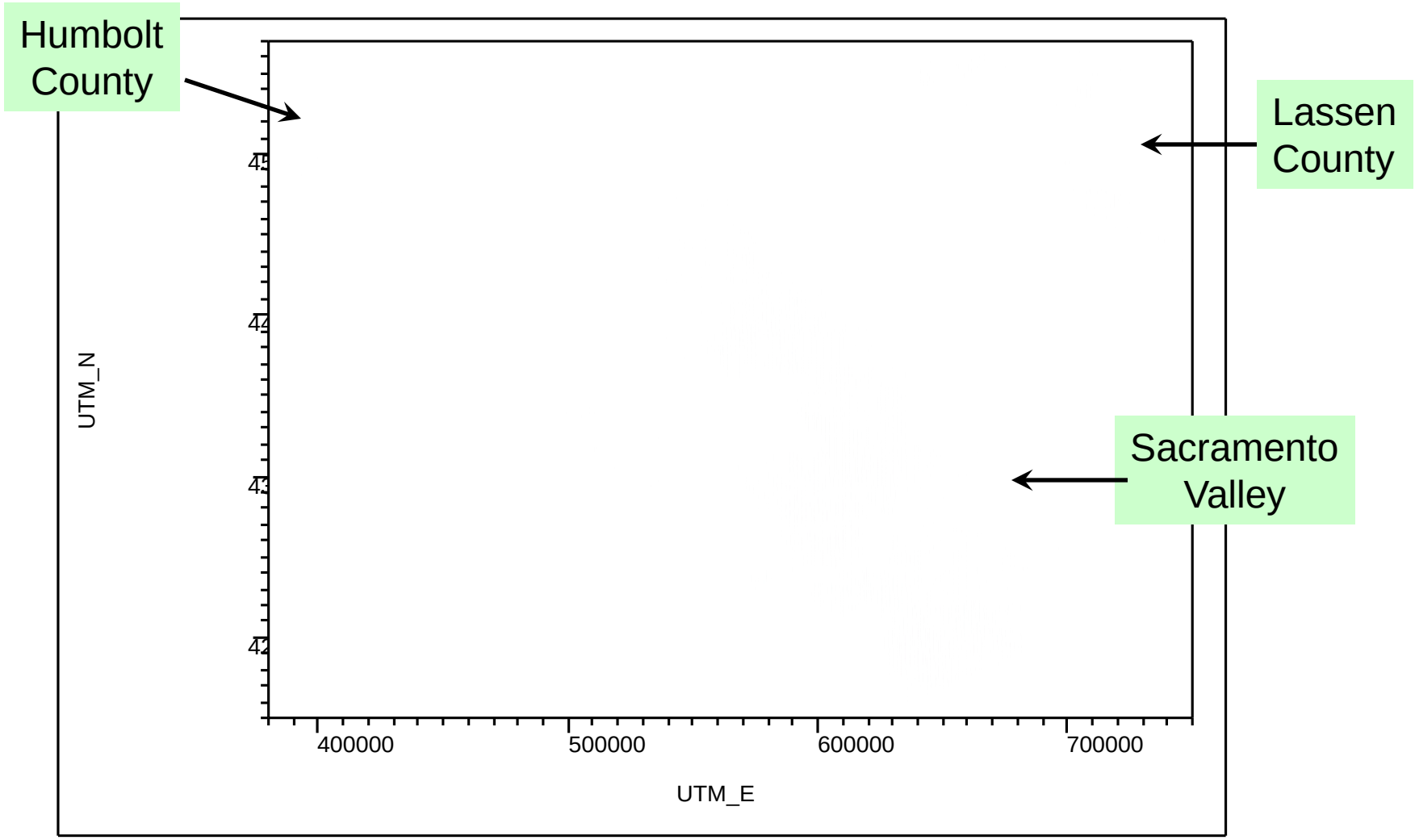
Since California's soils, water, related natural resources, and associated biomass production potentials are highly diverse:

- One **California Biomass Collaborative** objective is to fill in the resource 'gaps' in national-scale 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.
- A third is to support the development of beneficial biomass based businesses.

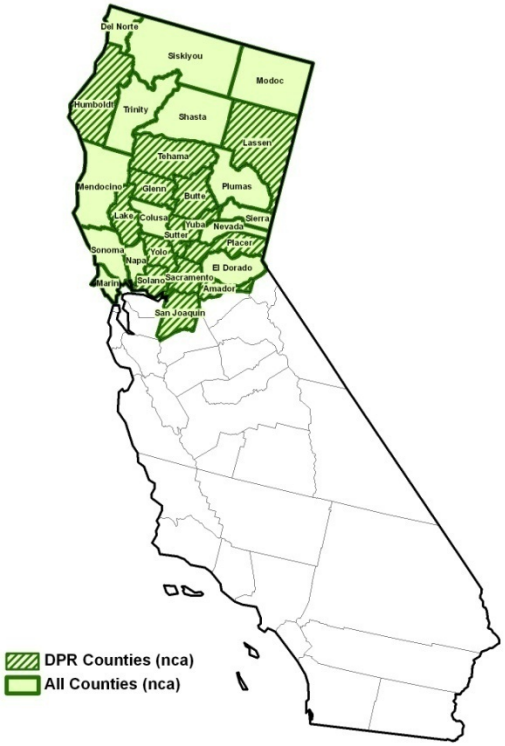
Defining representative cropping systems

- 10 years of pesticide use/crop choice data for most of the crop producing areas of California from CA DPR.
- DPR data is for 1-section units (640 acres).
- Naturally occurring cropping patterns on 17,000 sections within five macro-regions of California were used in Multidimensional Scaling, Cluster Analysis.
- 45 individual cropping systems were identified.

Northern California – 9 Clusters of Cropping Systems

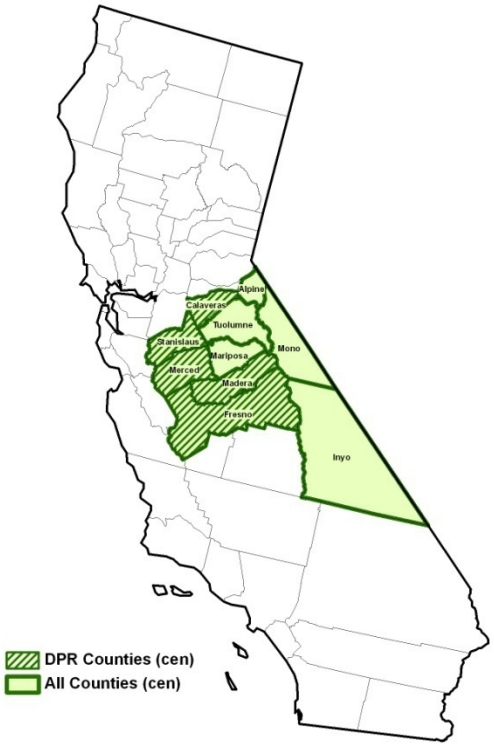


Counties in Analysis Regions



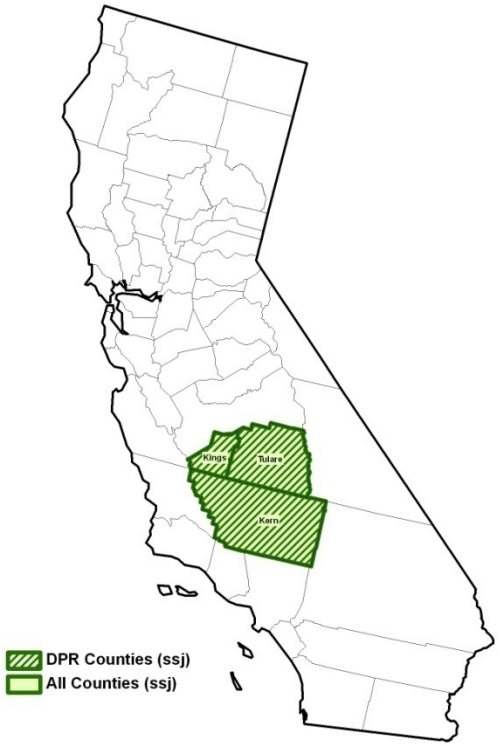
Northern California (NCA)

9 Cropping Clusters



Central California (CEN)

9 Cropping Clusters



South San Joaquin (SSJ)

8 Cropping Clusters

Crop Data Coverage

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 or irrigated pastures.
- DPR data was calibrated with historical County Agricultural Commissioner crop data.

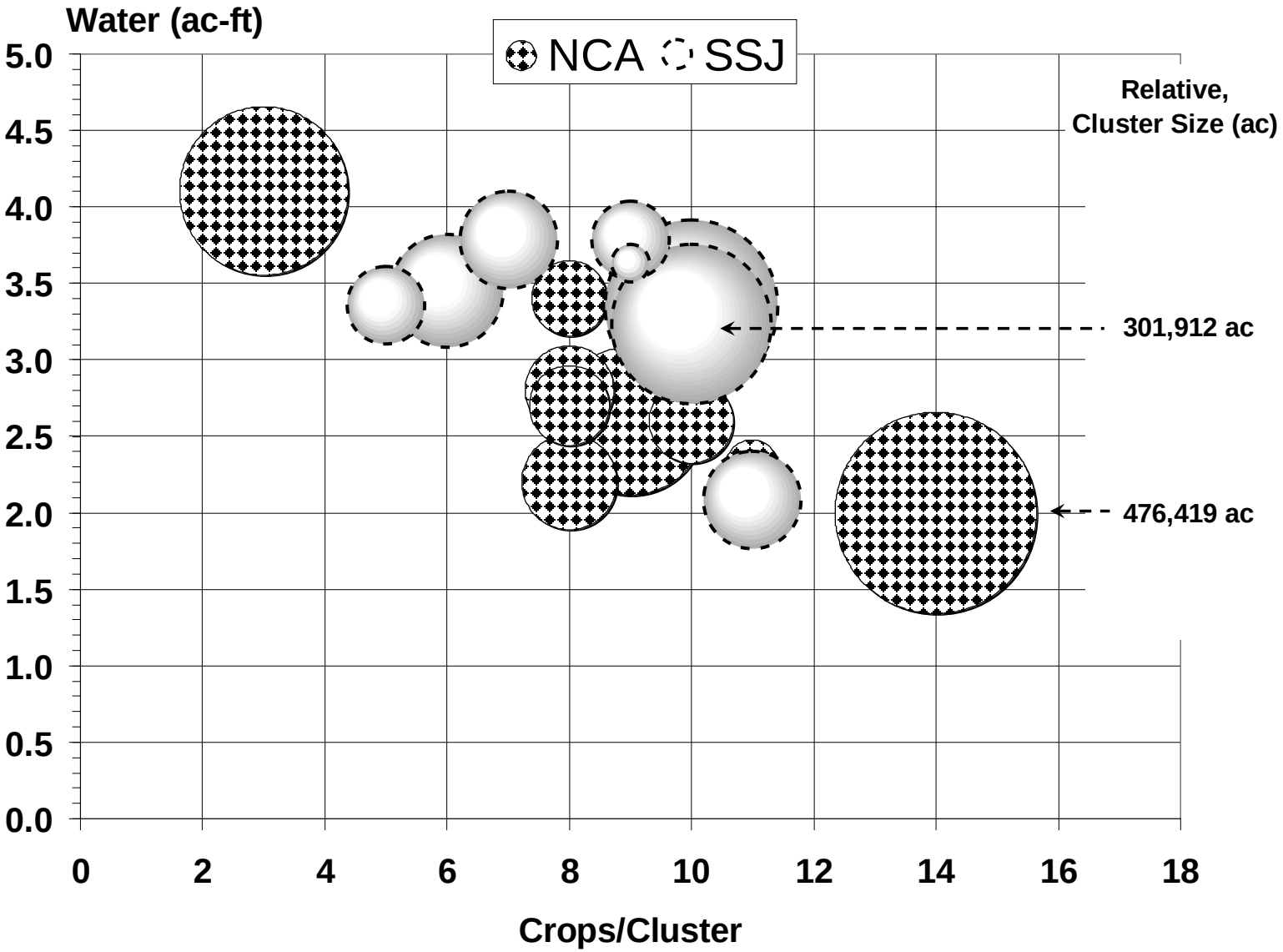
Example: Northern CA (C7)

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%

Minor crop acres, shifting acres

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

Regions Have Different Characteristics



Approach: PMP model development

- Develop a cropping systems optimization model with sufficient detail to capture the effects of region and landscape position.
- Run the model on as small a unit as the data allows, and then sum the results to aggregate regional and state level potential.

CBC Optimization Model

Production function

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

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

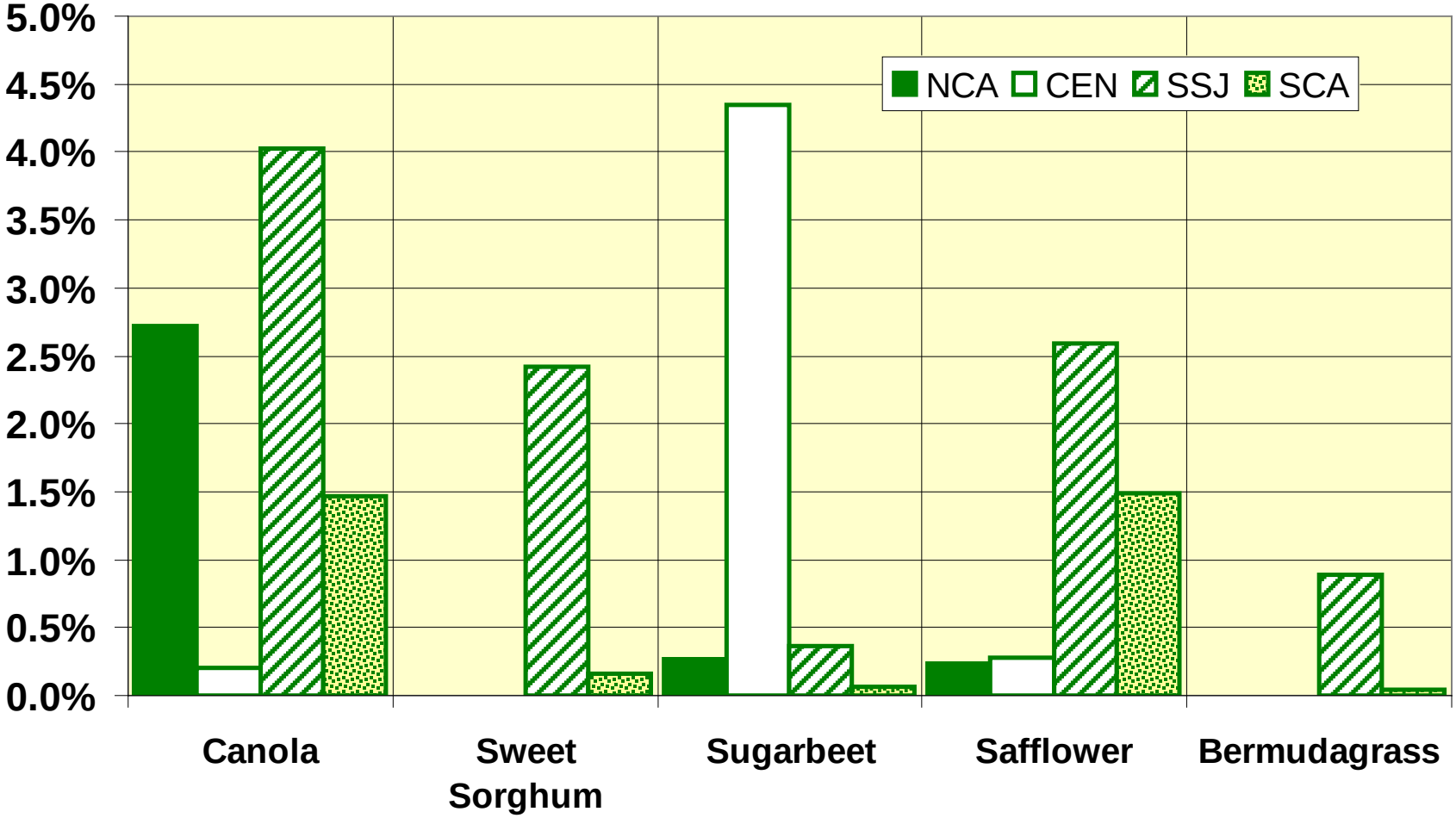
$P_{e,g,i,j}$ = farm price of crop *i*, and energy crop *e*, in region *g*, and resource, *j*.
$C_{e,g,i,j}$ = farm cost of crop *i*, and energy crop *e*, in region *g*, and resource, *j*.
$Y_{e,g,i,j}$ = yield of crop, *i*, and energy crop *e*, in region, *g*, and resource, *j*.
$X_{e,g,i,j}$ = level 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*.

Each crop activity has an associated resource use budget, so resource use can be calculated and compared for a cropping system with and without the energy crop.

Assumptions and Caveats

- **'Profit' in this model refers to the incremental increase in profit for the crop analyzed. For example: a '$20/acre profit' level refers to an additional $20 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 (a contract price).***
- **All prices and costs were set at 2007 price levels for consistency across all crop budgets. They are currently being modified.**
- **Water use is consistent with allocations during the period for which DPR data was acquired (1999-2008).**

Acreage shifts (%) in each aggregated region at $20/acre increase in profit. This indicates where crop adoption is most likely



Increases in profit were tested over the range: $0 to $40 per acre.

Conclusions

- **Local effects make a large difference**
- **Model can be tailored to very specific applications, including individual farms**
- **Actual data can be used for LCA GHG calculations, not estimates, at the COOP scale**
- **The crops displaced in California may have limited international impact (ILUC)**

On-going work

- **Collect data on cropping systems from individual growers who are representative of the potential grower community likely to participate in the COOP from across the supply region.**
- **Model the costs and resource use of beet production by grower and production/harvest area.**
- **Model the effects of differing planting/harvest patterns on the cost of beet production and on other crops, resource use and crop displacement. Convert these estimates to CI values.**

Outcomes

- **Robust estimates of costs across the supply area and year. Everyone will know in general what it costs to deliver beets on a daily basis at different times during the year. CI for biofuel produced can be optimized (minimized).**
- **Robust estimates of the resource use efficiency of beet production for the entire production region and year.**
- **Robust estimates of alternative crops displaced and comparative resource use. This is unprecedented and will help create superior LCAs, support an individual fuel pathway, and inform CARB.**

CALIFORNIA
BIOMASS COLLABORATIVE

Outline

- What do we mean by agricultural sustainability?
- Mendota Advanced Beet Energy Coop and an example_using a cropping system optimization model for multiple purposes
- Sustainability and Certification
- Proposed Actions

What do we mean by sustainability?

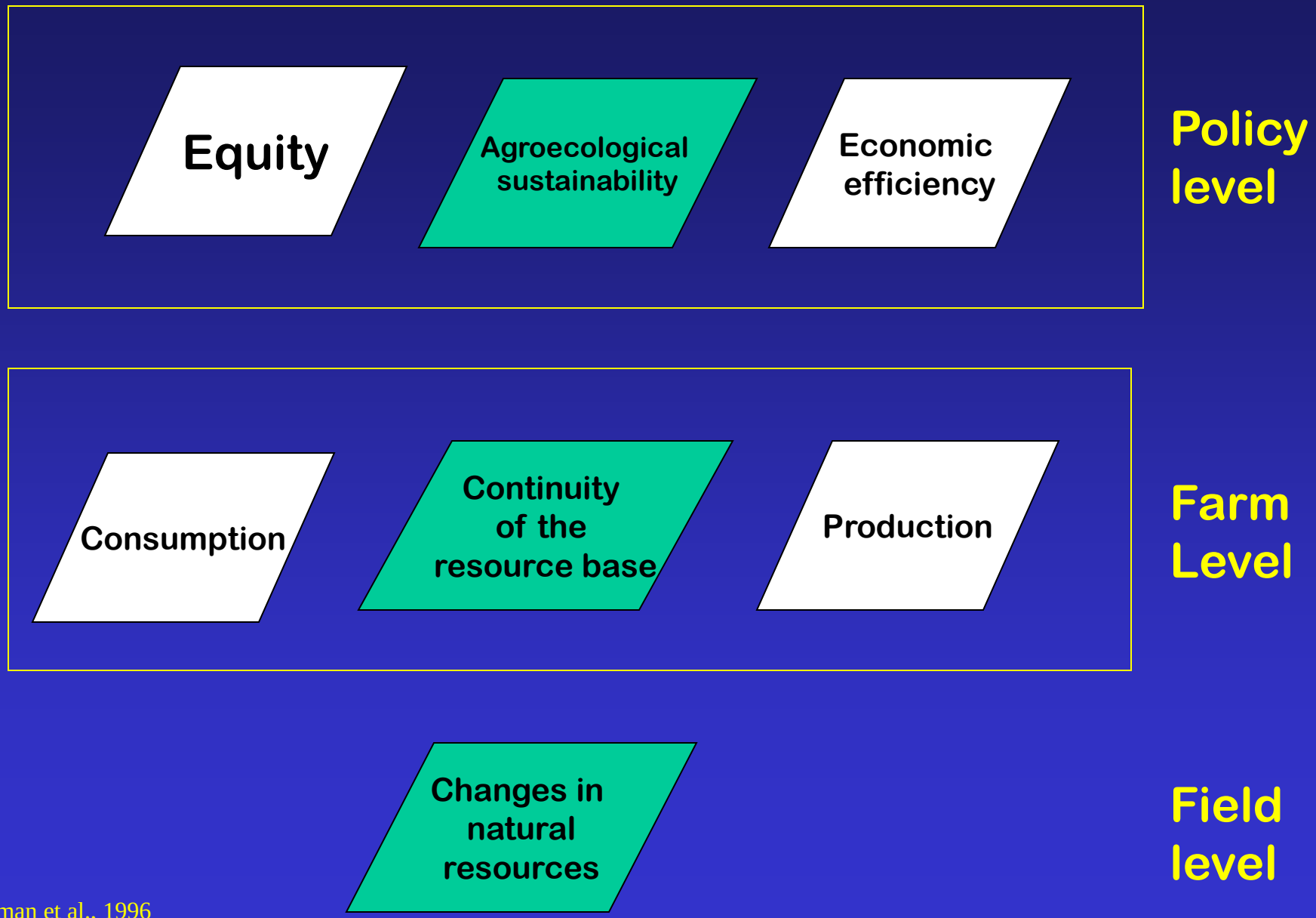
The Easy Part:

- Environmentally sound
- Economically profitable
- Socially just

The objectives of agriculture (multifunctionality):

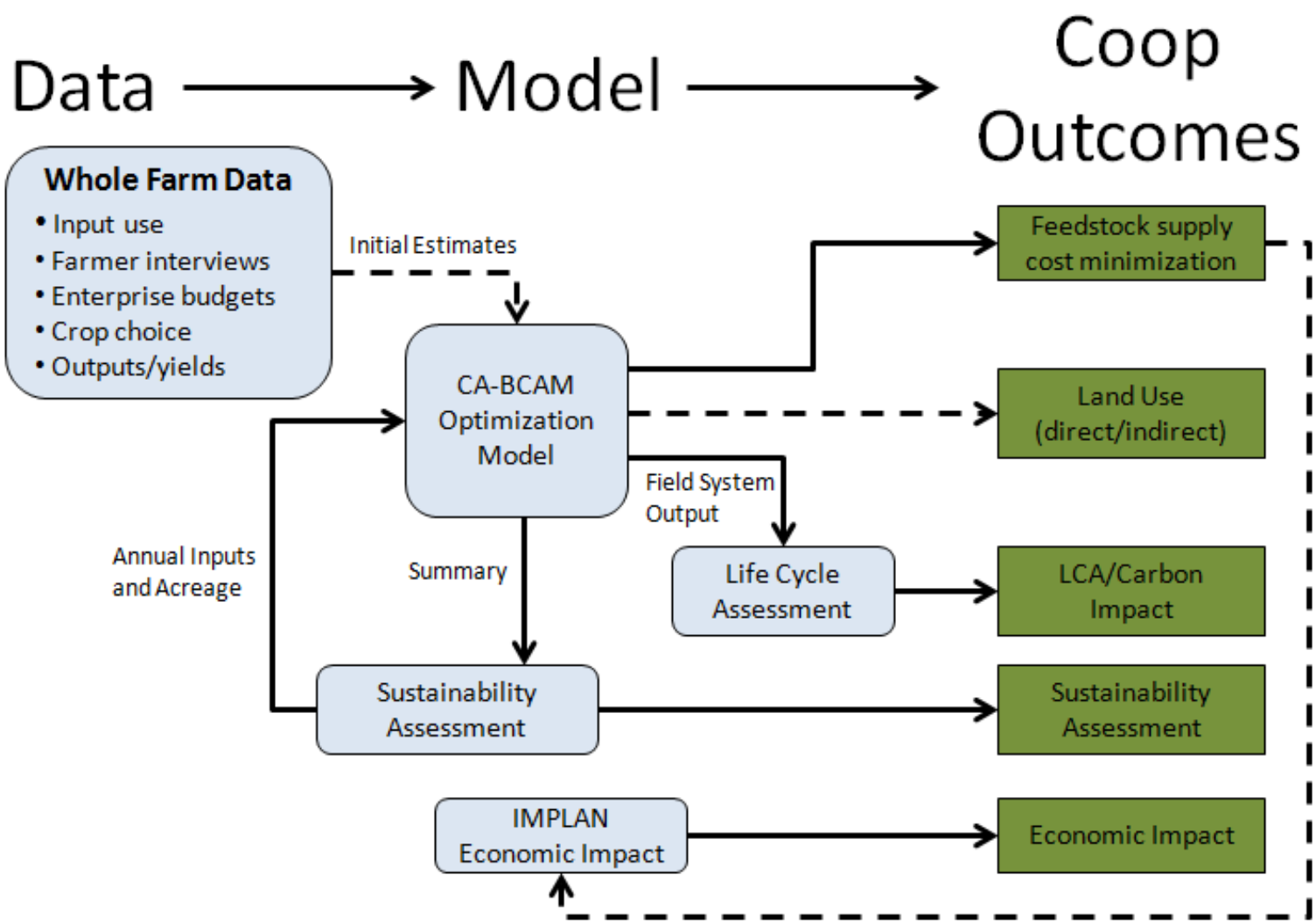
1. To provide an adequate food supply for a growing human population at a reasonable price.
2. To provide an increasingly high quality diet for all the world's people. (Diet diversity, more animal protein)
3. To maintain the income of farmers at levels comparable to that of the urban population
4. To maintain the natural resource base of agriculture. (soil erosion, soil quality?)
5. To use non-renewable resources prudently.
6. To maintain and provide habitat and resources for other species, and to maintain the function of supporting natural ecosystems.

What we call sustainable depends on the boundary conditions



Kruseman et al., 1996

Information transfer/ systems analysis /LCA/ and sustainability, Jan. 2012



Sustainability and Best Management Practices: Policy implications

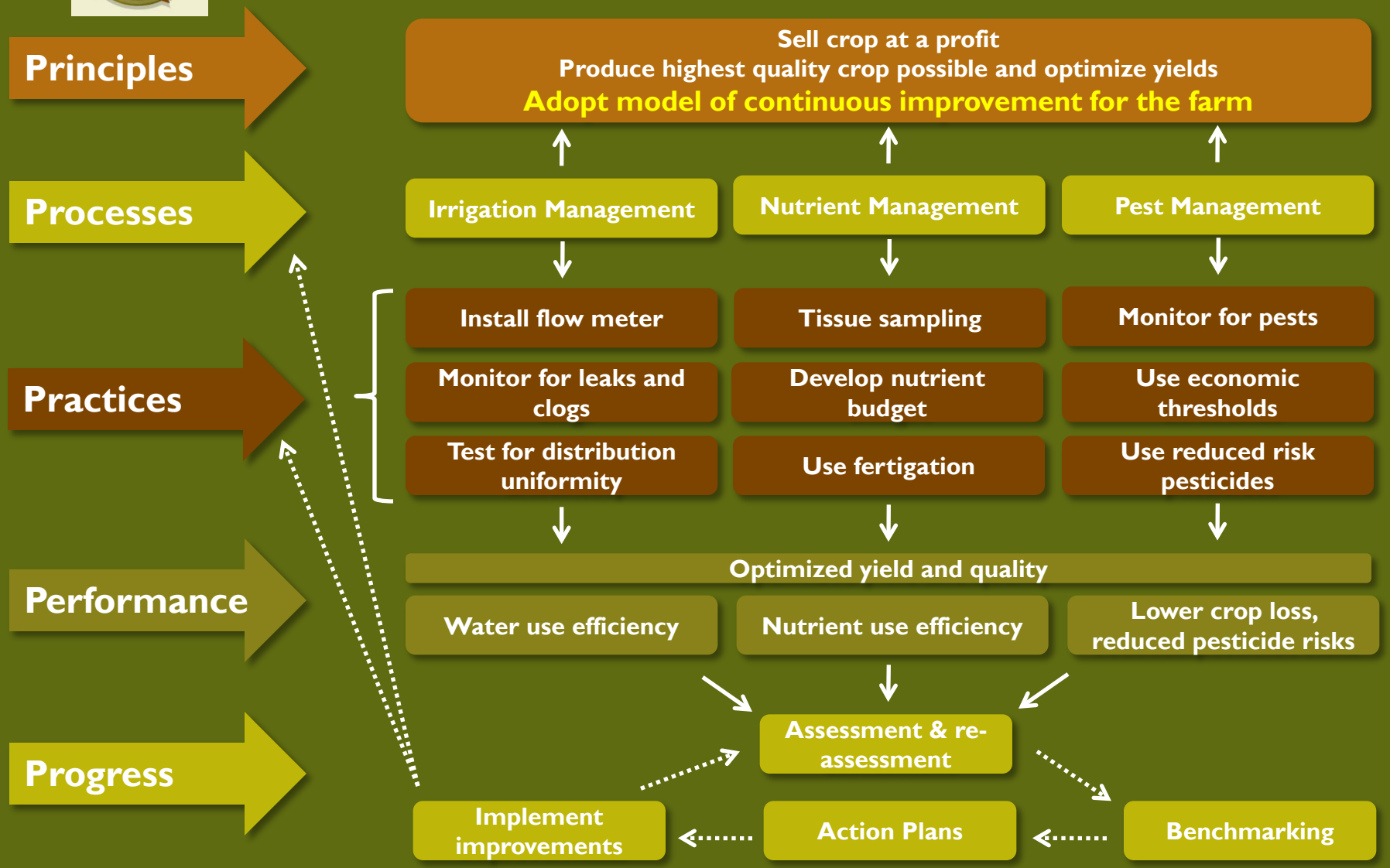
To define sustainable farming practices well, and have an effective sustainability standard for biofuel production, a mechanism for frequent evaluation is needed. Learning must be embedded in any standard. The use of standards must be inseparable from a constant evaluation process, in order not to inhibit positive change.

A flexible standard?

SureHarvest's Continuous Improvement Framework

1. **Principles**: The values that define your strategy
2. **Processes**: The set of managed activities that create internal and external value (e.g. production, sales, etc.)
3. **Practices**: The methods used to accomplish the desired operational results (e.g., irrigation management best practices)
4. **Performance**: The metrics and measurements used to evaluate practice and process results
5. **Progress**: The approach used to document, communicate and drive continuous improvement over time (e.g. assessment, benchmarking, action plans, training, reporting, etc.)

5P's in Action: Winegrape Example



Outline

- Are there opportunities for biofuel production from crops and residues in CA? (the role of LCFS and RFS2)
- Mendota Advanced Beet Energy Coop and an example_using a cropping system optimization model for multiple purposes
- Sustainability Considerations
- Generalizing

Sustainability and Best Management Practices: Policy implications

In CA, there are many statutes, rules and regulatory activities that in effect are sustainability standards. Adopting additional 3rd party standards in areas where these function well is largely unnecessary or duplicative and undermines many current state processes.

But the LCFS provides an additional positive mechanism that incentivizes gains in efficiency for feedstock producers.

Improving efficiency spares natural resources

On-going regulatory processes in California: CV-Salts CVRWQCB

- In 2006, the Central Valley Water Board, the State Water Board, and stakeholders began a joint effort to address salinity and nitrate problems in California's Central Valley and adopt long-term solutions that will lead to enhanced water quality and economic sustainability. **Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) is a collaborative basin planning effort aimed at developing and implementing a comprehensive salinity and nitrate management program.**

- In July 2008, the **Central Valley Salinity Coalition (CVSC) was formed**. CVSC **represents stakeholder groups working with the Board** in the CV-SALTS effort. Its purpose is to organize, facilitate and fund efforts needed to fulfill the goals of CV-SALTS. CVSC coordinates the meetings of the CV-SALTS committees, maintains an independent web site, and manages the projects originating from this effort. Their website: www.cvsalinity.org.

On-going regulatory processes in California: IRRIGATED LANDS REGULATORY PROGRAM

The Irrigated Lands Regulatory Program (ILRP) regulates discharges from irrigated agricultural lands. Its purpose is to prevent agricultural discharges from impairing the waters that receive the discharges. To protect these waters, **Regional Water Boards have issued conditional waivers of waste discharge requirements to growers that contain conditions requiring water quality monitoring of receiving waters and corrective actions when impairments are found**.

http://www.swrcb.ca.gov/water_issues/programs/agriculture/

On-going regulatory processes in California: Pest Management Alliance Grants

SACRAMENTO -- The California Department of Pesticide Regulation awards grants to …to reduce pesticide risks in neighborhoods, schools, and farm fields across the state...DPR's Pest Management Alliance program…encourages industry-wide innovations that benefit workers, consumers, and the environment. IPM works with nature to minimize pests, nurture beneficial organisms, and promote least-toxic pest control. The program focuses on reduced risk pest management strategies. Since 1996, more than 200 projects have received support.

Recent Alliance grants:

- **The Almond Board of California**, to reduce the use of high-toxicity pesticides, with field demonstration orchards in Butte, Kern, and Stanislaus counties.
- **The California Association of Winegrape Growers**, to prevent sulfur drift and seek herbicide alternatives with vineyards in Alameda, Mendocino, Monterey, Napa, Riverside, San Joaquin, San Luis Obispo, Santa Barbara, Sonoma, and Stanislaus counties.
- **The California Citrus Research Board**, to encourage biological controls on key citrus pests, with demonstration groves in Kern and Tulare counties
- **The California Dried Plum Board**, to reduce the use of high-toxicity insecticides and pesticide runoff into surface and ground water, with field work in Butte, Fresno, Glenn, Madera, Merced, Sutter, Tehama, Tulare, Yolo, and Yuba counties.
- **The California Tree Fruit Agreement**, to develop an IPM system for controlling major stone fruit pests in Fresno, Kings, Sutter, Tulare, and Yuba counties.
- **The University of California**, in cooperation with California's nursery industry, to seek more environmentally friendly pest control

These programs are only some of many in which CA leads the world in trying to regulate and improve the total outcome of natural resource use within the state. Sustainability standards provide a filter with which to evaluate existing regulations for their usefulness.

Conclusions/Recommendations

The LCFS provides a strong incentive to minimize resource per unit of biofuel produced. This incentive is congruent with farmers' interests and with many characteristics associated with sustainability.

How to do assessment:

- A project-based (or ground-up) approach should be used for all California based biofuel production businesses when in-state agricultural biomass is used for feedstocks.
- Adopt the use of whole farm and representative farm models defined for well-chosen regions. Use these to account for crop resource use, farm resource use, and crop displacement in diverse cropping systems. This data can be used in LCA models to estimate carbon intensity related to feedstock production.
- Use actual data or locally adjusted representative farm models to create fuel CI estimates (CARB's 2A/2B pathway). This includes actual crop displacement to be used for estimation of market-mediated effects.

Conclusions/Recommendations

Certification:

- Third party sustainability standards applied within California may be largely redundant and incompatible with state regulatory processes. They cannot be used to displace, undermine or make more complex the process of compliance with the state's already intensive and dynamic regulatory structure and processes.
- Sustainability standards within the LCFS should not become a fugitive pathway to impose additional regulations on agriculture outside of the regulatory pathways and processes currently functioning, unless a significant omission can be identified, that is unlikely to be rectified in the future. In-state mechanisms should be preferred.
- **ACTION: The state should create something like a programmatic standard or EIR for in-state biomass production that identifies and accounts for existing regulations, certification and compliance measures.** This will substitute for other certifications. An objective of all recent governors is to harmonize the state's diverse policies and regulations. Sustainability standards provide an opportunity for doing so.

Conclusions/Recommendations

Certification:

- For fuels imported into California, there are many third party standards that have been developed. All are likely to provide assurance that a set of guidelines have been followed, with few substantive differences likely to result among them. In that case, several should be allowed, letting the fuel providers decide among a range of acceptable standards.
- **The cost of compliance** should be the primary distinguishing characteristic among the standards.
- **Standards that presumptively discriminate against irrigated systems or the use of modern crop varieties should not be considered**.

Conclusions/Recommendations

Requirements

Learning must be the defining characteristic of sustainability standards, because **the key characteristic of sustainability is flexibility:** the capacity to respond to changing factors.

- Encourage process focused methods. These are superior to adopting arbitrary thresholds. The goal is to **provide additional incentives that encourage improvement over time in all critical areas of farm management.**
- **The LCFS can help pay for the cost of public goods difficult to fund otherwise.**

Can we have a prudent bioenergy policy that increases sustainability?

"…legal systems embody the rule of law to the extent that their rules are:

1. Prospective rather than retroactive,
2. **Not impossible to comply with,**
3. Are promulgated (made known)
4. **Are clear**
5. **Are coherent with respect to each other**
6. **Are stable enough to be guidelines for longer-term conduct**
7. **Are administered consistently and uniformly.**

(Natural Law and Natural Rights _ J. Finnis, 1980)

Do the rules and regulations discussed here comply with this overview of just and effective law?