Can we link improved nutrient management with alternative energy production and green house gas reduction?

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California Bioresources Alliance_7th Annual Forum
What could work for the Future?

California's greenhouse gas reduction targets

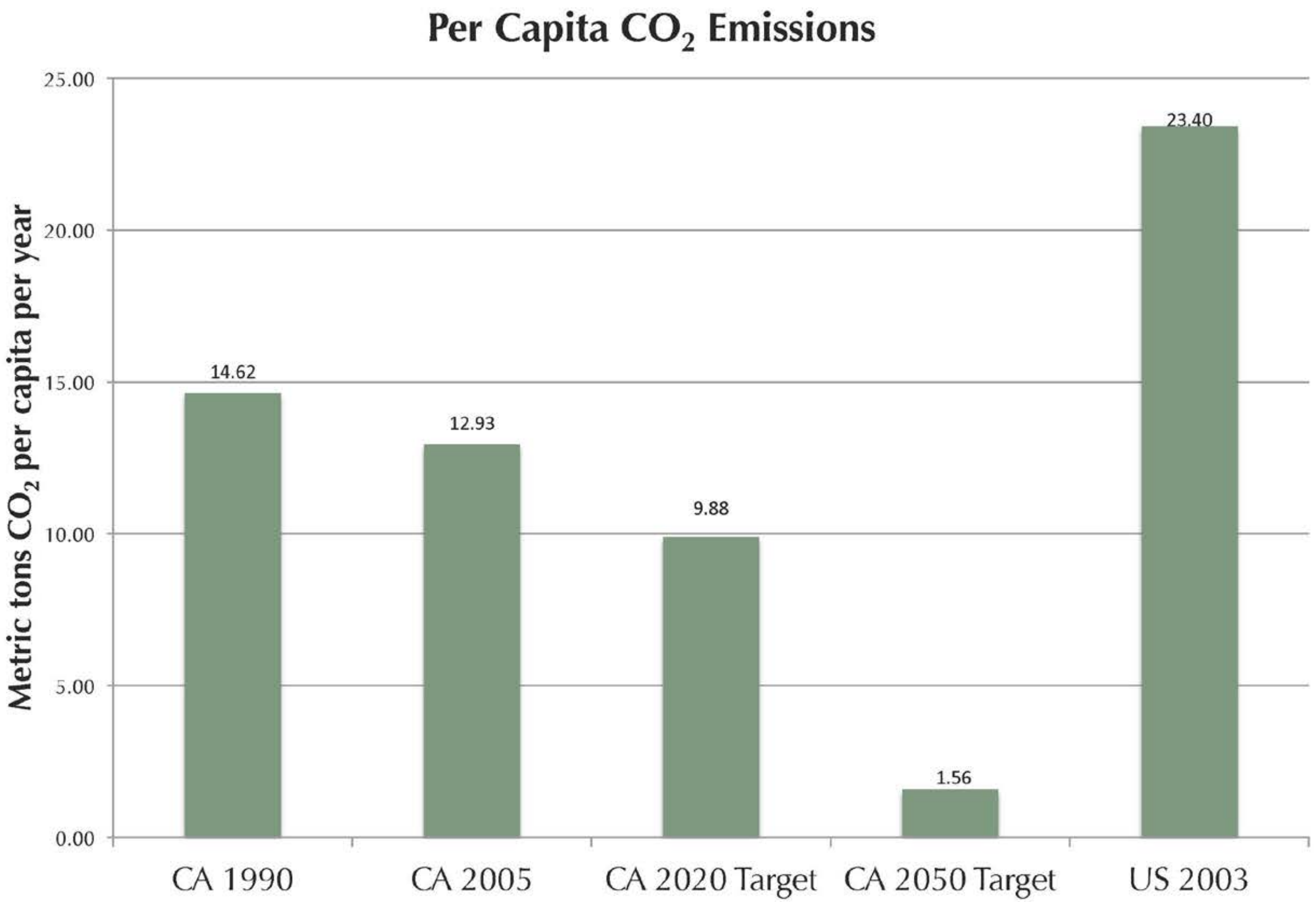
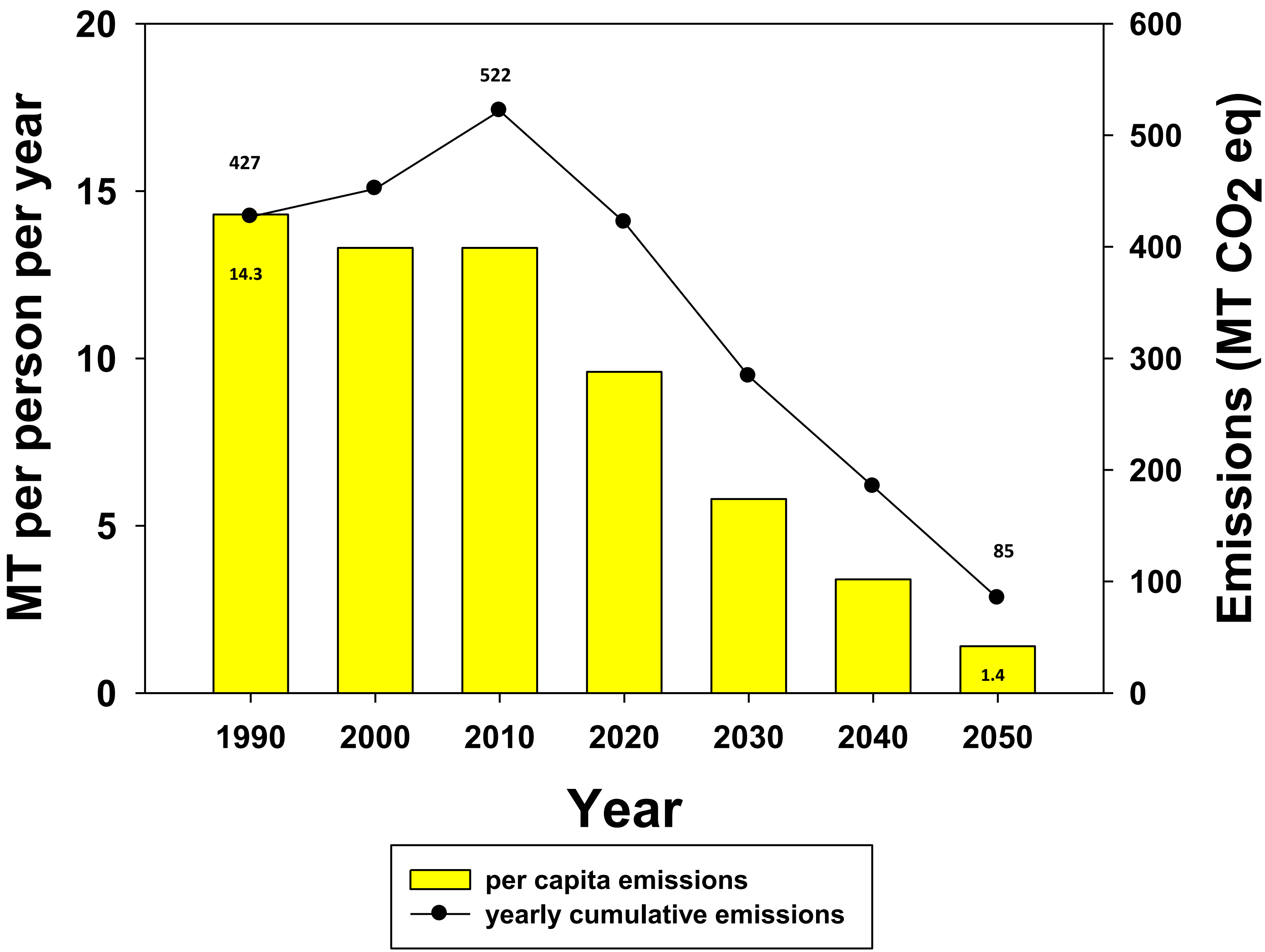


Fig . 6: Emission Trajectory Towards 2050



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- **Surplus N in the Tulare Lake Basin and elsewhere in CA**
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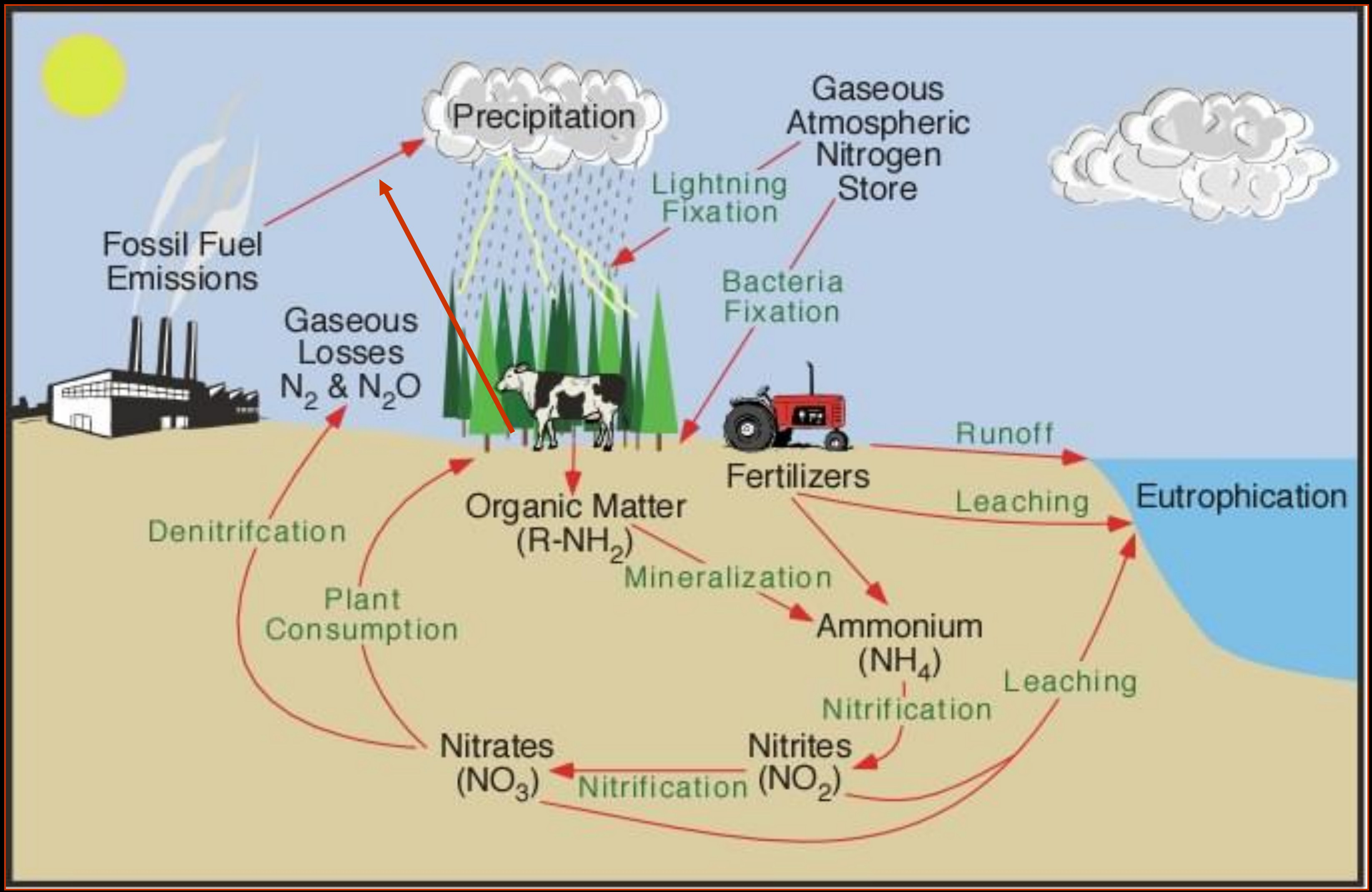
Simplified N cycle

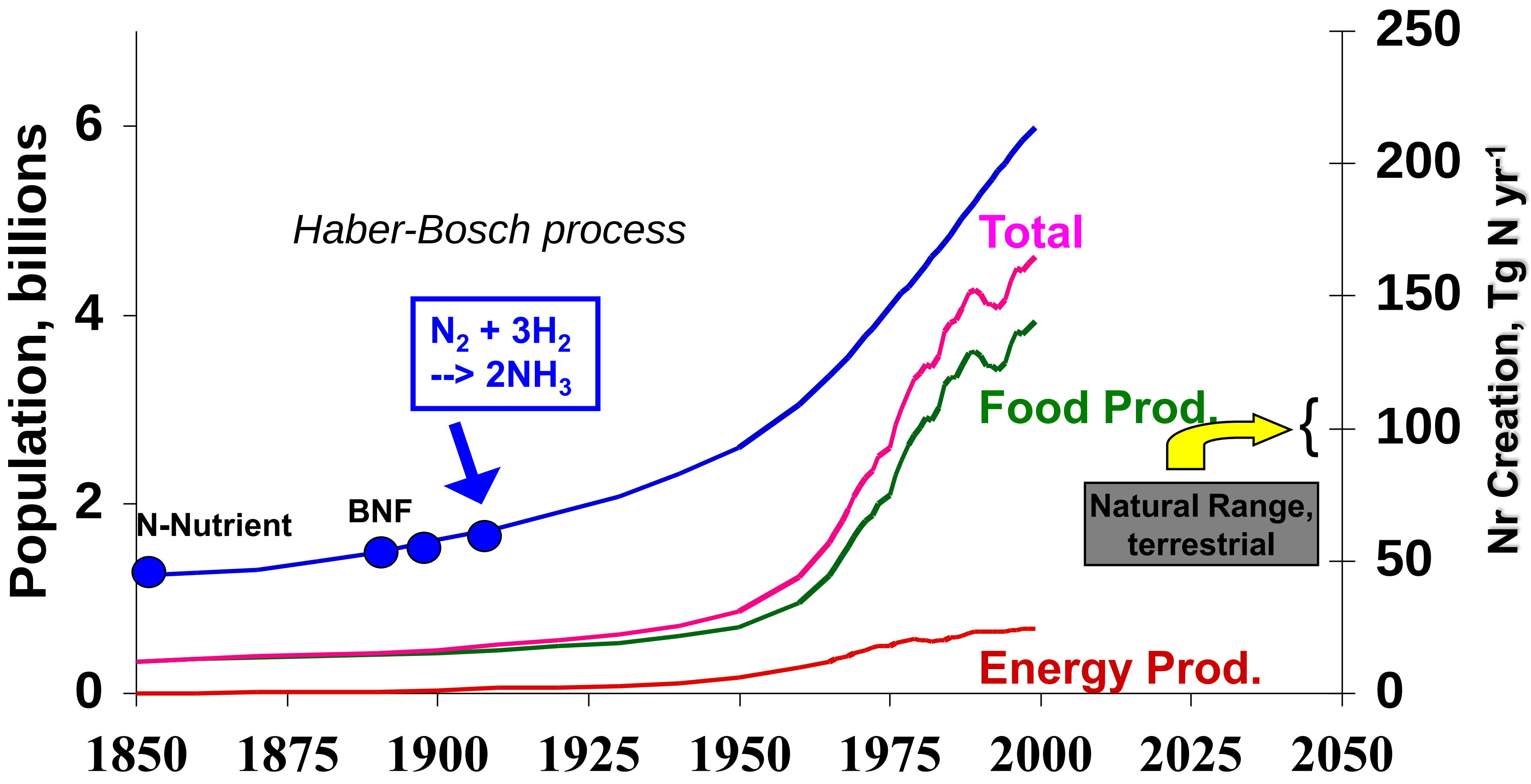


N is limiting in most natural systems, but there is too much reactive N (Nr) in the San Joaquin Valley

- Unreactive N is N_2, and equals 78% of earth's atmosphere
- Reactive N (Nr): is all biologically, chemically and physically active N compounds in the atmosphere and biosphere of the Earth
- N_2 is naturally converted to Nr, primarily by biological nitrogen fixation (BNF), principally be legumes.
- <1% of organisms are able to convert N_2 to Nr. All the rest are dependent on those organisms.
- N is in short supply. N is the limiting nutrient to most temperate terrestrial ecosystems

Galloway, U. Virginia

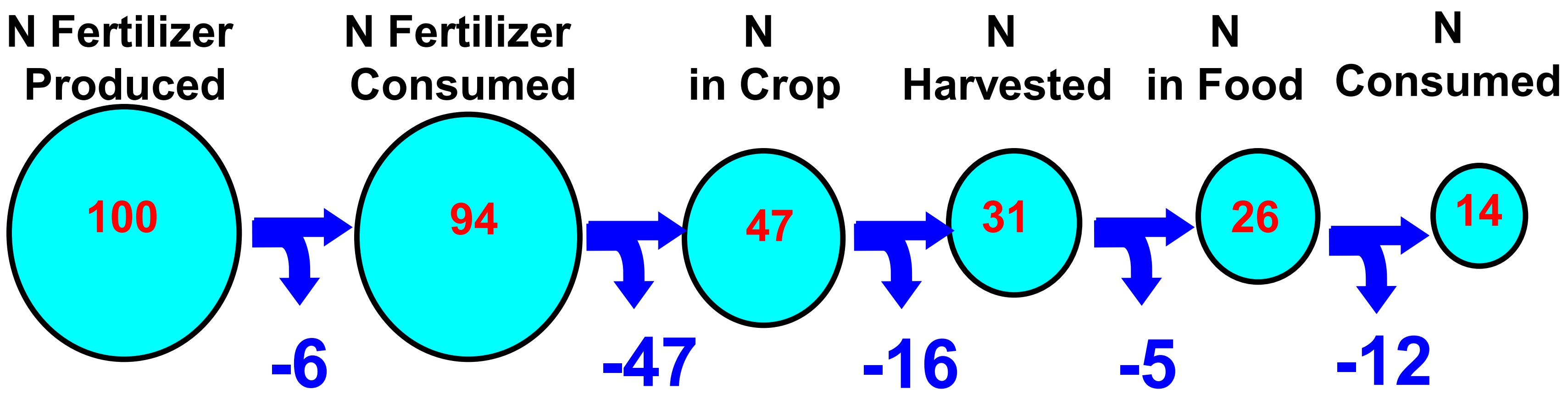
Timeline of Global Reactive N Creation by Human Activity 1850 to 2000



12 Tg N does not equal 130 Tg N

Galloway et al., 2003

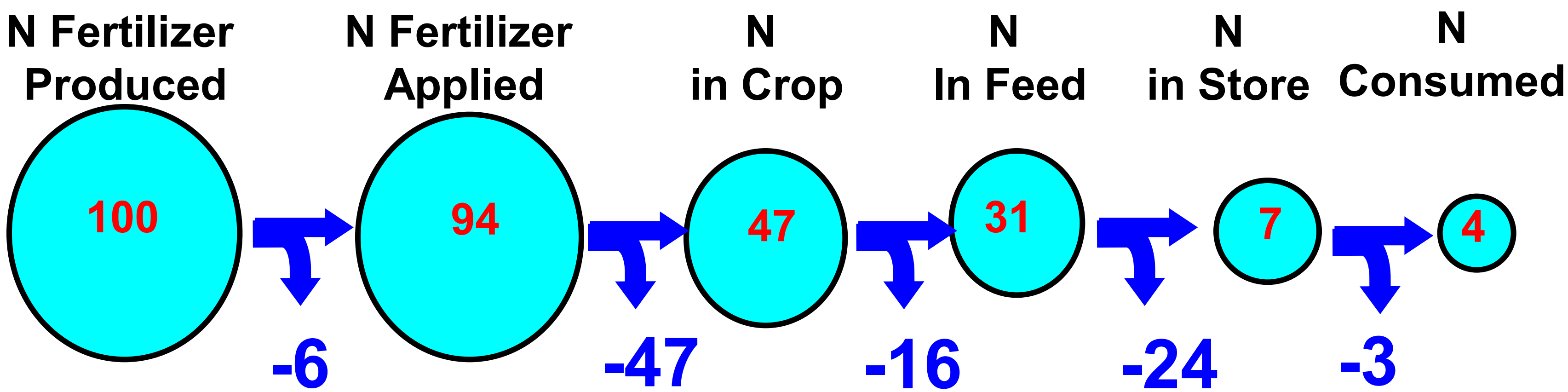
The Fate of Haber-Bosch Nitrogen



14% of the N produced in the Haber-Bosch process enters the human mouth……….if you consume plant-based foods

Galloway et al., 2003

The Fate of Haber-Bosch Nitrogen

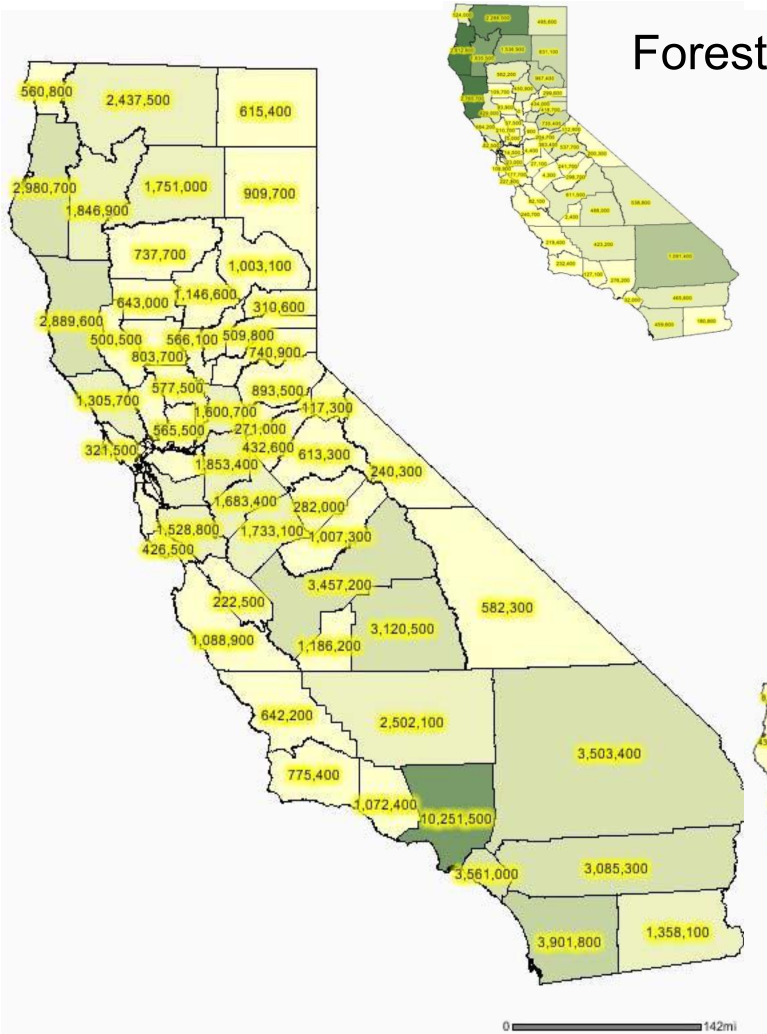


4% of the N produced in the Haber-Bosch process and used for animal production enters the human mouth.

Galloway et al., 2003

Assessing Nitrate in California's Drinking Water, With a Focus on Tulare Lake Basin and Salinas Valley Groundwater

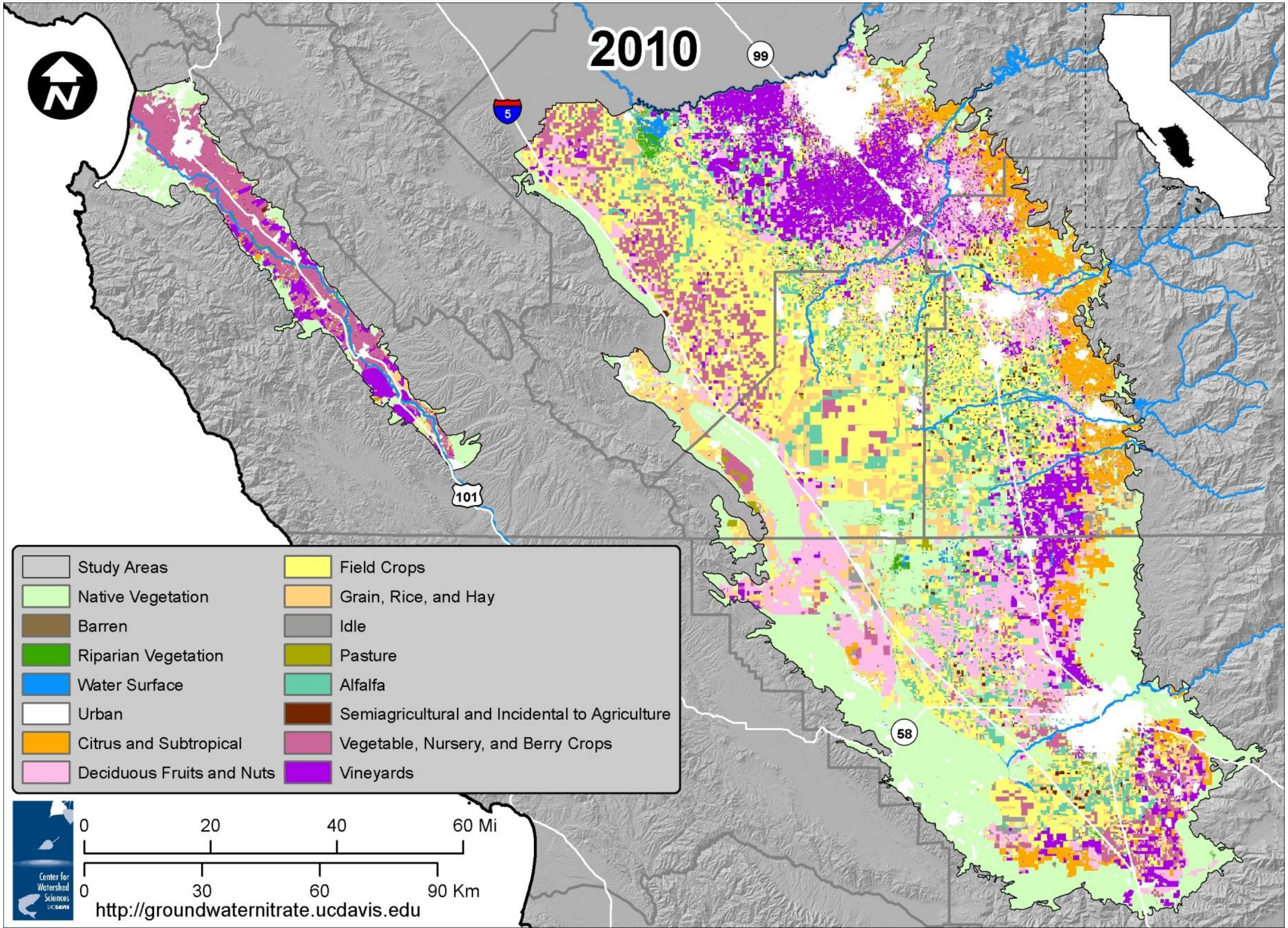
T. Harter and J. Lund, et al., 2012.
Center for Watershed Sciences, UC Davis
http://groundwaternitrate.ucdavis.edu



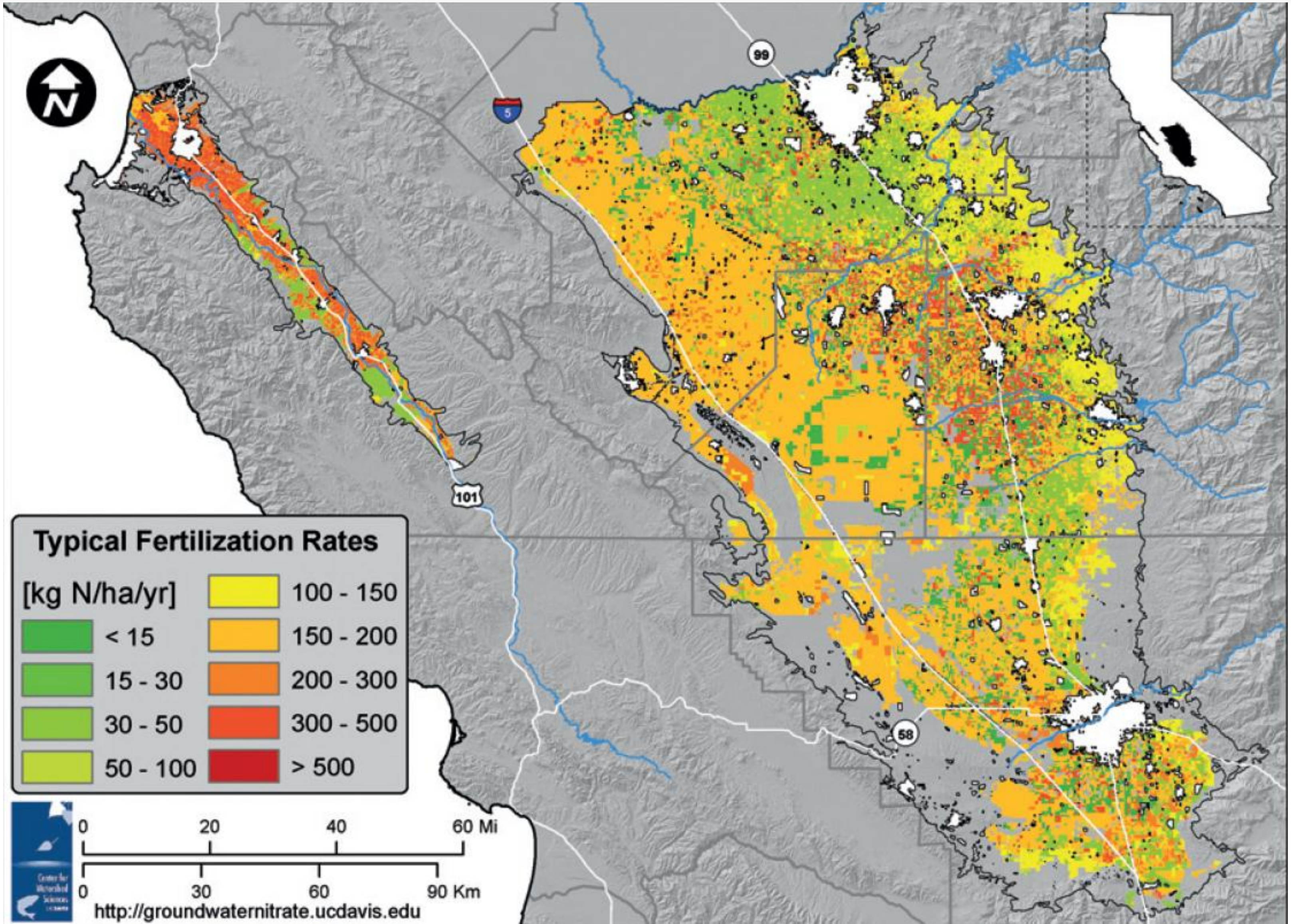
Estimated total biomass resources gross bdt, 2007. Williams et al, 2008

CALIFORNIA
BIOMASS COLLABORATIVE

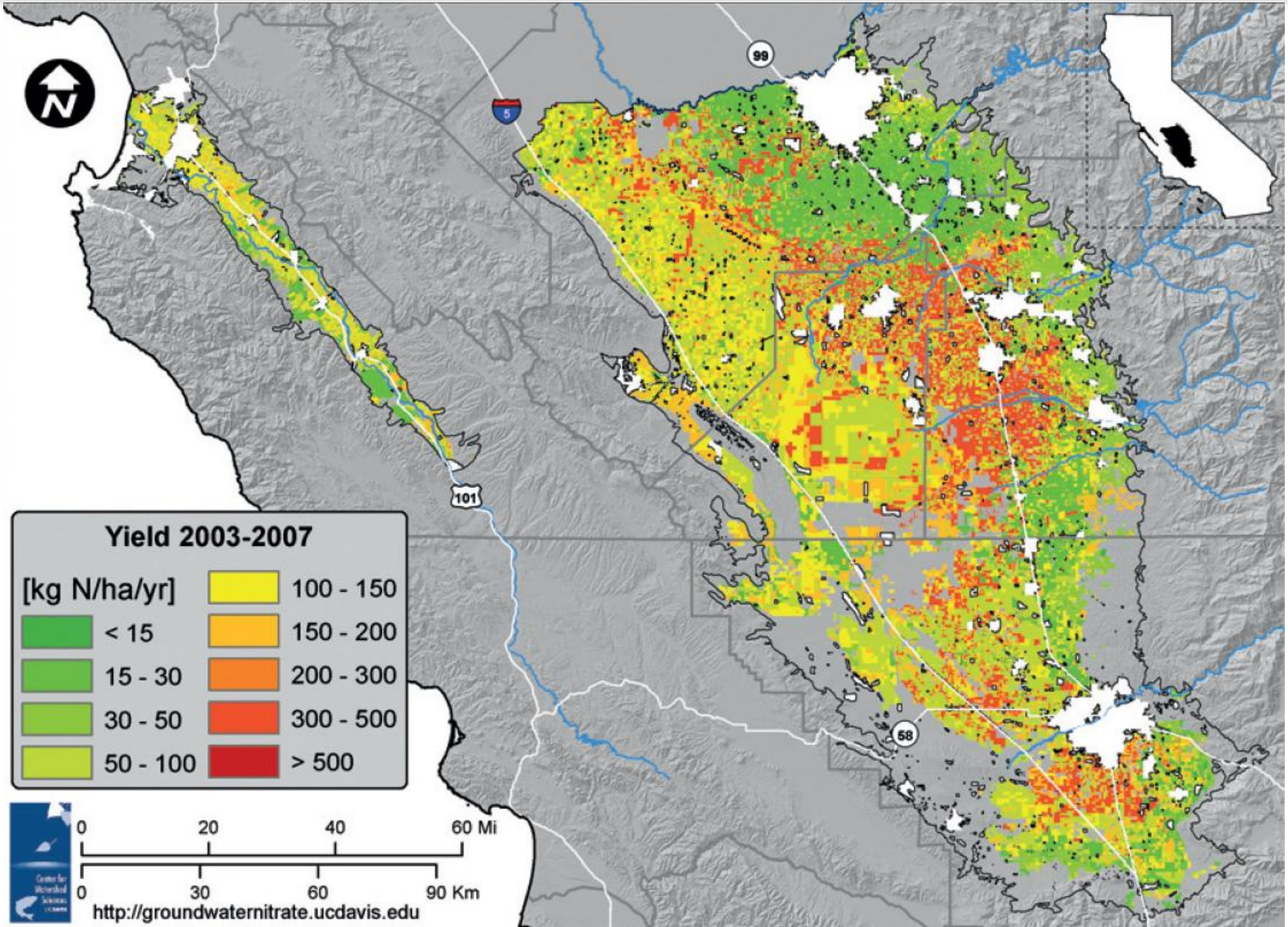
Agricultural Sources



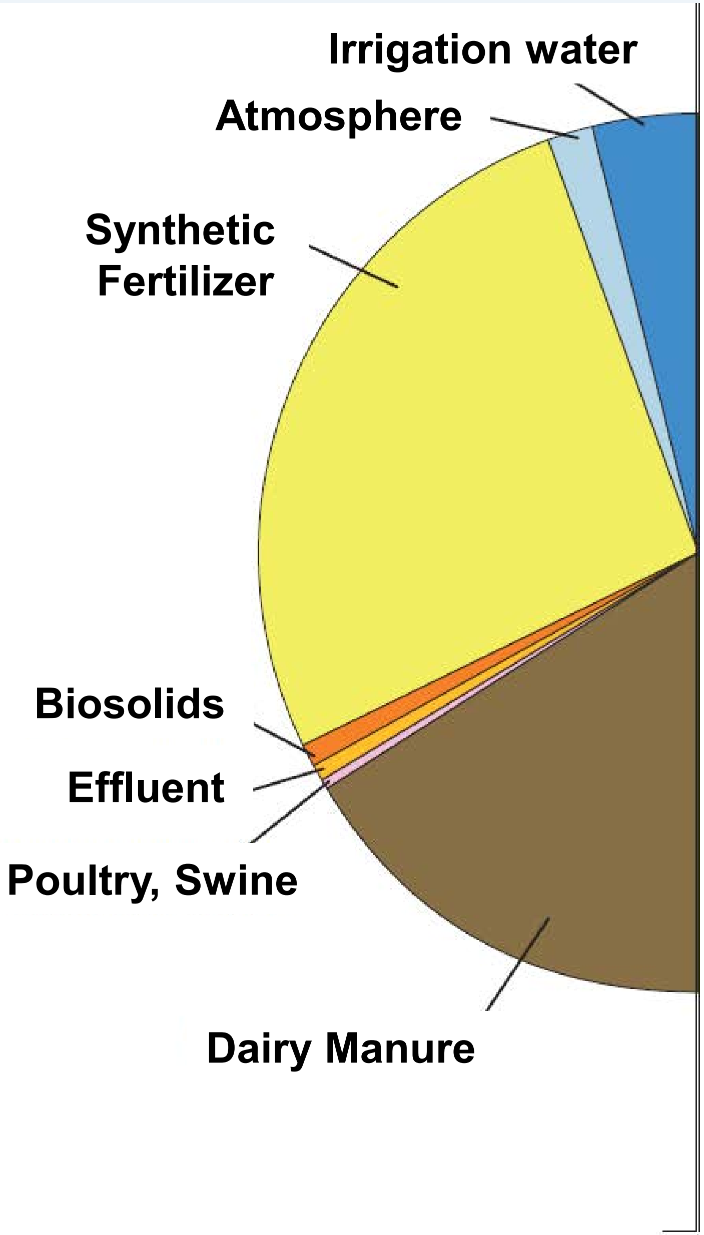
Estimated Fertilizer N Applied

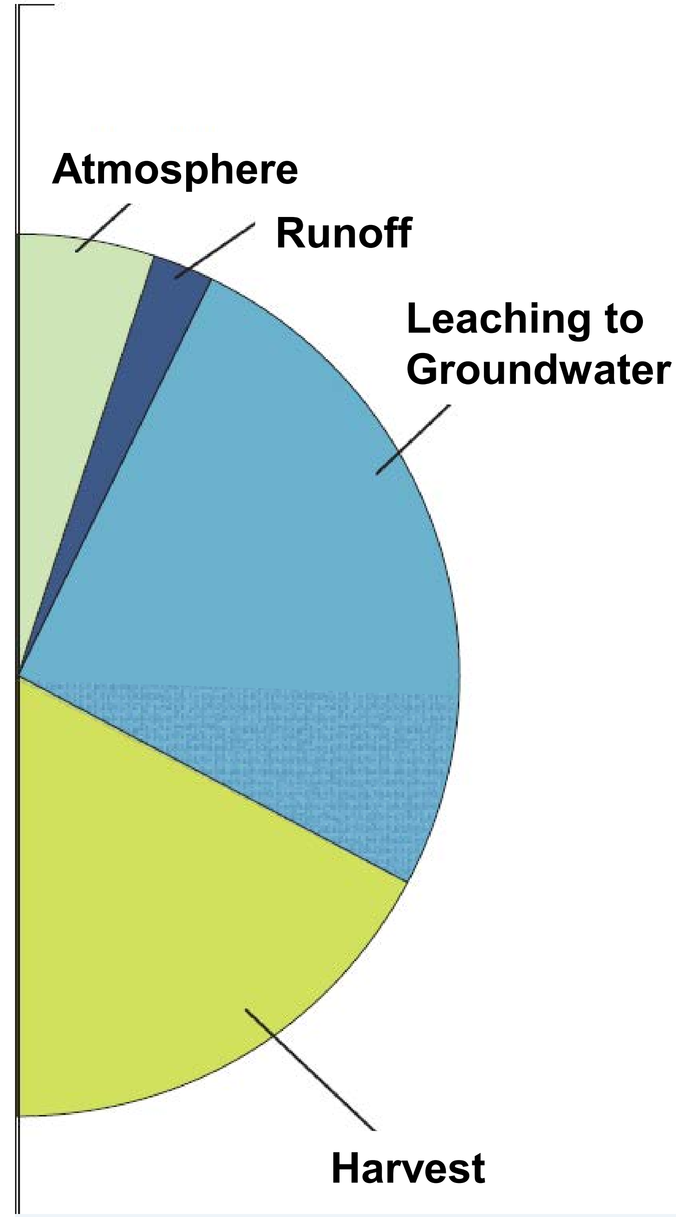


Estimated Harvested Nitrogen



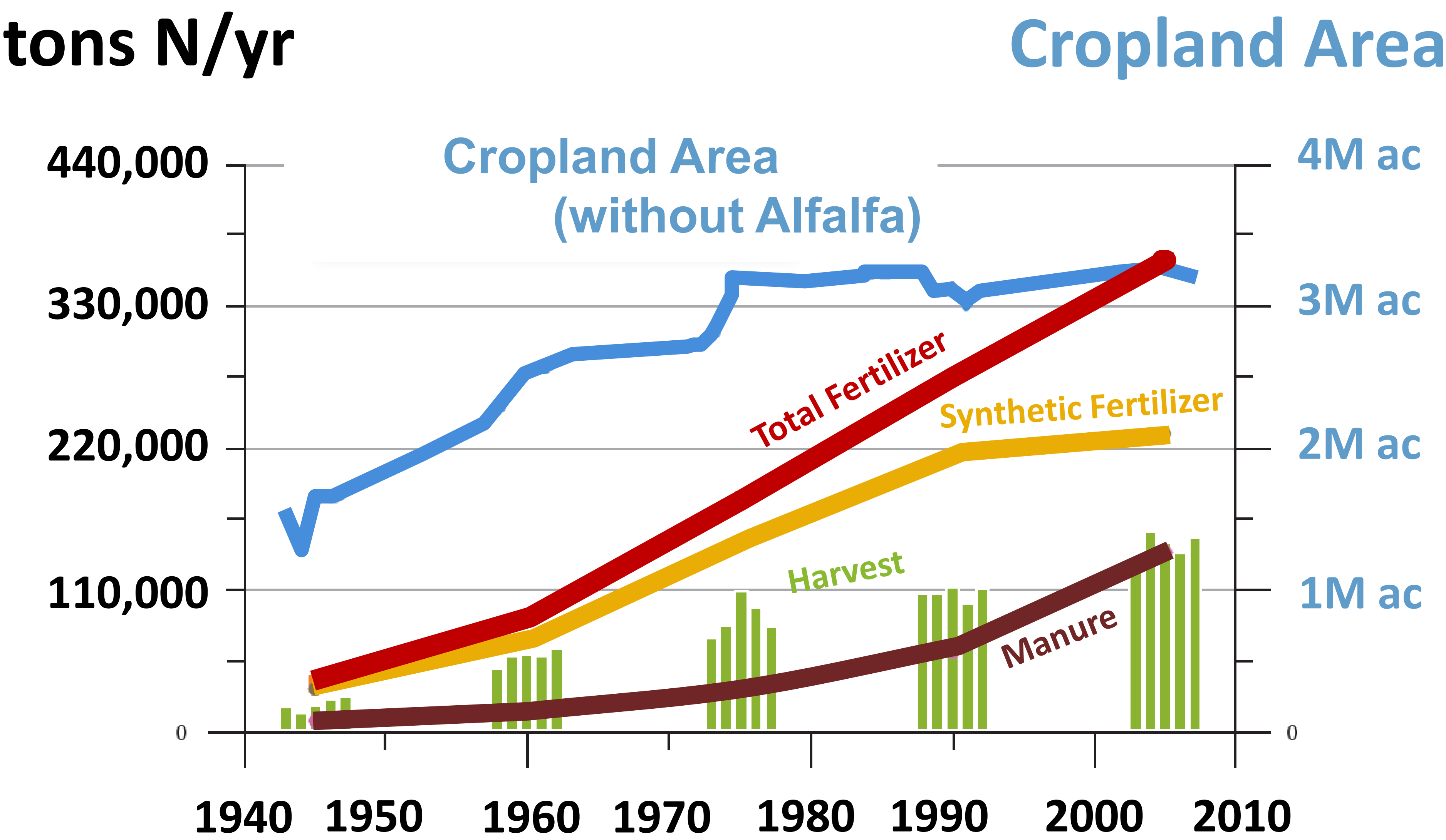
Total Nitrogen Inputs:
420,000 tons N/yr

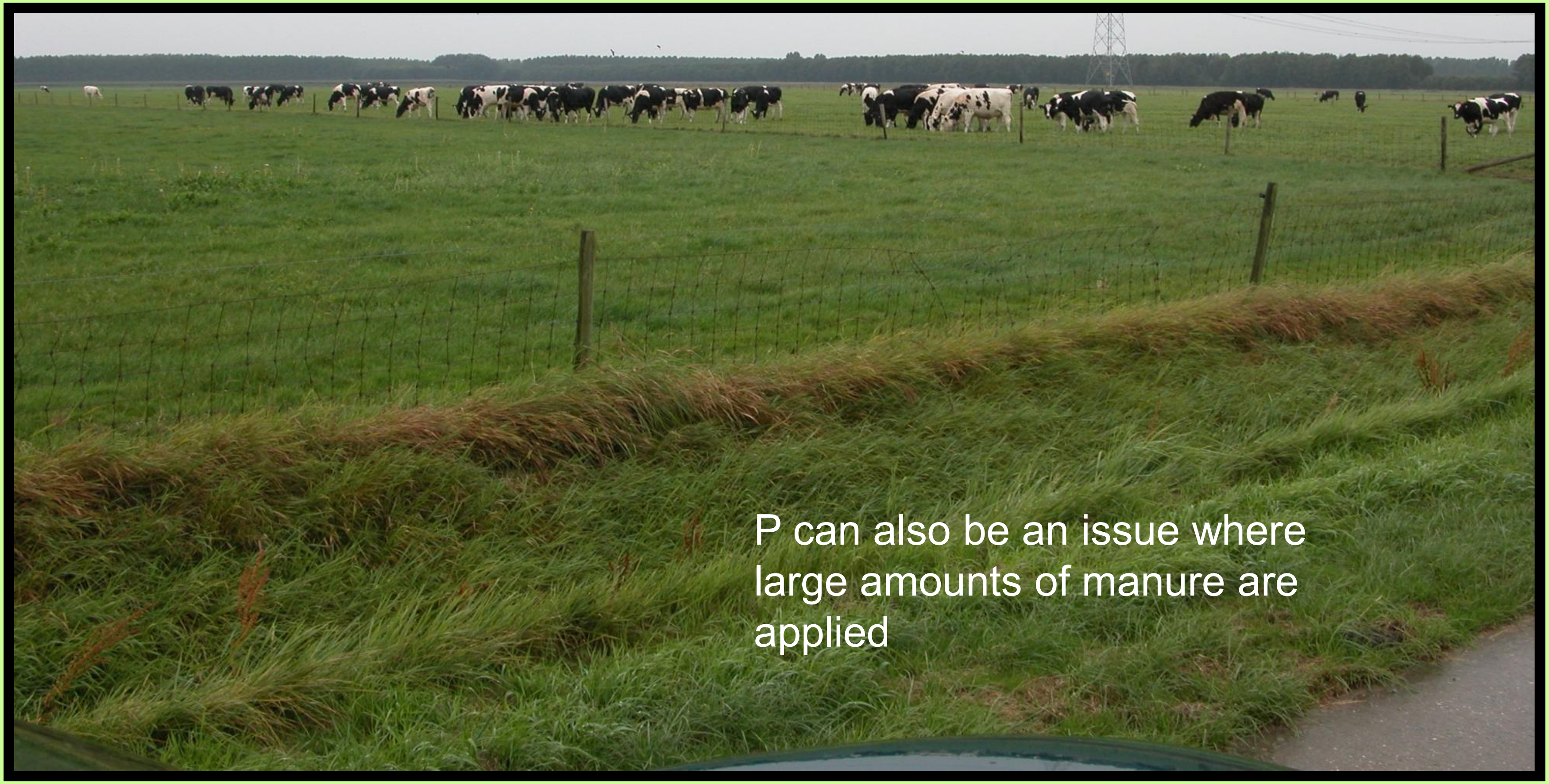




Total Nitrogen Outputs:
420,000 tons N/yr

Historic Nitrogen Fluxes





Cattle grazing at the Dairy Research and Extension Center near Lelysted in the The Netherlands.

“… diffuse phosphorus pollution from the historical burden of agricultural fields (manure and fertilizer) will continue for many decades whatever manure policy The Netherlands will carry out.”

--- National Institute for Public Health and Environment, 2004

Chardon, 2004; Schoumans et al., 2004 Aarts et al., 2000

- In The Netherlands, farms intensified from the 1960s until 1984, when the European milk quota system was introduced.
- Mainly because of inappropriate manure and fertilizer use, ground water NO3 content exceeds the 50 mg/L standard. Nitrate leaching is also associated with declining water quality in streams and lakes.
- The P nutrient surplus on farm land on a national scale is 36 kg/ha/yr (17.5 to 74). About 50 % of all farm soils are above P saturated levels. There is no way to significantly reduce P loading to the environment over the short to mid-term.

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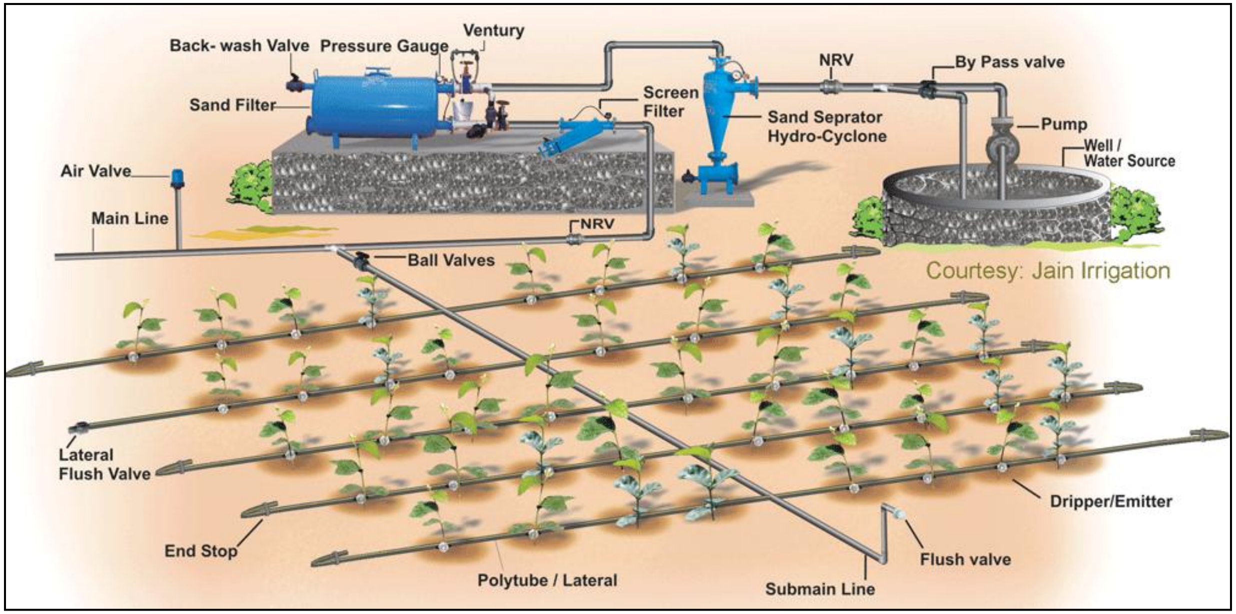
De Wit (1992): Resource use efficiency in agriculture, Agri
Systems, 40:125ff

“… a feature of (agricultural) intensification is that it is not the improvement of one growing factor that is decisive, but the improvement of a number of them.”

This leads to positive interactions that result in the total effect of all these improvements being larger than the sum of the effects adopted separately.

Drip irrigation



Increasing returns to total factor productivity :

The need for nutrients and water, expressed per unit surface area, increases with the yield level,

but decreases when expressed per unit yield.

Corn's Impacts, 1987-2007

Land Use	Soil Loss	Irrigation	Energy	Climate
Amount of land to produce one bushel of corn	Soil loss per bushel, above a tolerable level	Irrigation water use per bushel	Energy used to produce one bushel	Emissions per bushel
↓	↓	↓	↓	↓
37%	**69%**	**27%**	**37%**	**30%**

NCGA
www.ncga.com

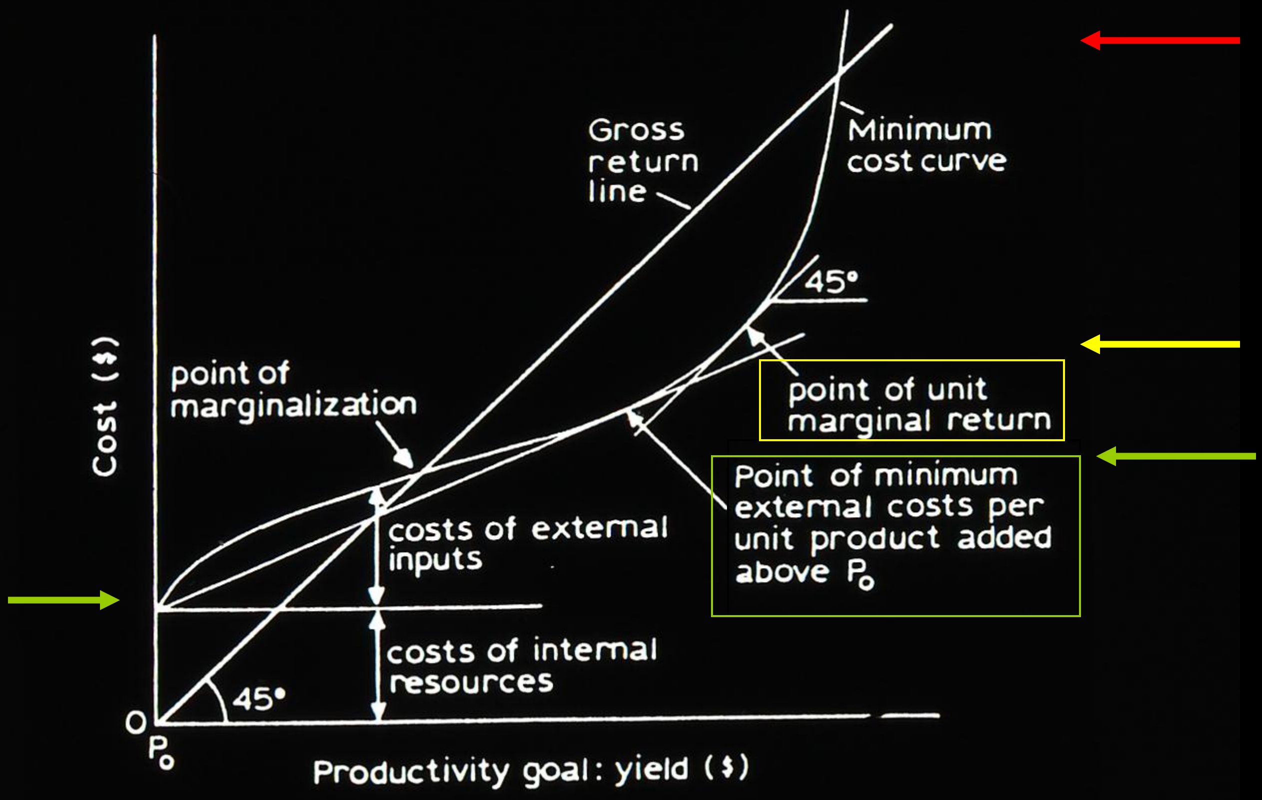
“…We estimate the net effect on GHG emissions of …agricultural intensification between 1961 and 2005...

While emissions from factors such as fertilizer…have increased, the net effect of higher yields has avoided emissions of up to 161 GtC (590 GtCO2eq) since 1961.

(Investments in)… yield improvements should be prominent among efforts to reduce future GHG emissions.”

Greenhouse gas mitigation by agricultural intensification. Burney, J.A., et al., 2010. PNAS. On-line

Cost of land and family labor



Minimum production costs as a function of productivity (or profitablity) goals of farming systems. (de Wit, 1992 adapted from Holt, 1988).

CA Bioresources Alliance: overview

- We have always relied on livestock
- The role of livestock has changed, but has also remained the same
- We have new needs and opportunities for research on the integration of livestock and crops in California, and with alternative energy production.

Human Ecology 101:

Livestock have always been essential for food production:

Ruminants (cattle and sheep) eat low quality plant material and convert it into high quality proteins and fats. Manure was a valuable and limited fertilizer for grain crops.

Monogastric species (pigs and chickens) consume left-overs and residues from the human food chain, and forage for additional foods unfit for humans. These are then eaten.

Animals were a banking system for grain surpluses. When grain was in surplus, animals were fattened. When grain became scare, animals were slaughtered. This is how it still works, but at a different scale.

In California, animals are fed a wide array of crop residues and by-products, making the entire agricultural system more efficient, less wasteful, and food generally less expensive.

Intensive dairy, near Merced

How to calculate GHG values for the LCFS?

- **By-product feeding is based on least-cost, ration balancing (optimization) models which integrate the use of diverse feeds based on species-specific nutritional objectives and price. Optimum solutions change constantly due to price, learning (formal research and industry trial and error) and other non-obvious localized constraints. Most rations for ruminants are optimized for energy density targets, secondarily for protein and other critical components.**

- **This issue is especially complicated in CA, where numerous by-products are available and fed (> 15 commonly in dairy rations). Currently, for example, a large amount of canola meal is being used in CA.**

As-fed Rations on California Dairies: High Groups

P.H. Robinson (An. Feed Sci. & Tech., in press)

Dairy #	3	5	7	9	Range
			% of Total Mixed Ration		
Alfalfa	24	18	0	23.8	0 to 24.1
Almond hulls	2.8	13.4	4.9	0	0 to 15.3
Corn silage	23.1	18.4	12	39.8	0 to 25
Corn grain	20.0	0	18.7	8.4	8.5 to 26.5
Canola Meal	0	0	7.4	0	0 to 8.3
Cotton seed	8.5	6.3	11.4	6.7	0 to 12.1
Soybean meal	7.7	0	0	0 (7.8)**	0 to7.1
Wheat midds	0	8.2	7.6/13.3*	0	0 to 8.2
DDGS	3.5	6.8	7.1	6.6	0 to 10.3

*beet pulp + barley / ** linseed meal

As-fed Rations on California Dairies: High Groups

P.H. Robinson (An. Feed Sci. Tech., in press)

Dairy #	3	5	7	9	Range (1 to 16)
# of Cows in milk	3000	1890	825	1200	825 to 5000
Milk yield (lb/cow/d)	89.6	91.6	92.7	96	72.9 to 114
DM intake (lb/cow/d)	59.6	63.3	63.1	55.6	47.6 to 66.9
CP (%)	17.47	16	17.13	17.98	15.9 to 18.9
NE_L (MJ/lb DM)	3.18	3.14	3.42	3.2	3.06 to 3.42
NDF	44.3	44.1	53.8	46.9	41.2 to 53.8

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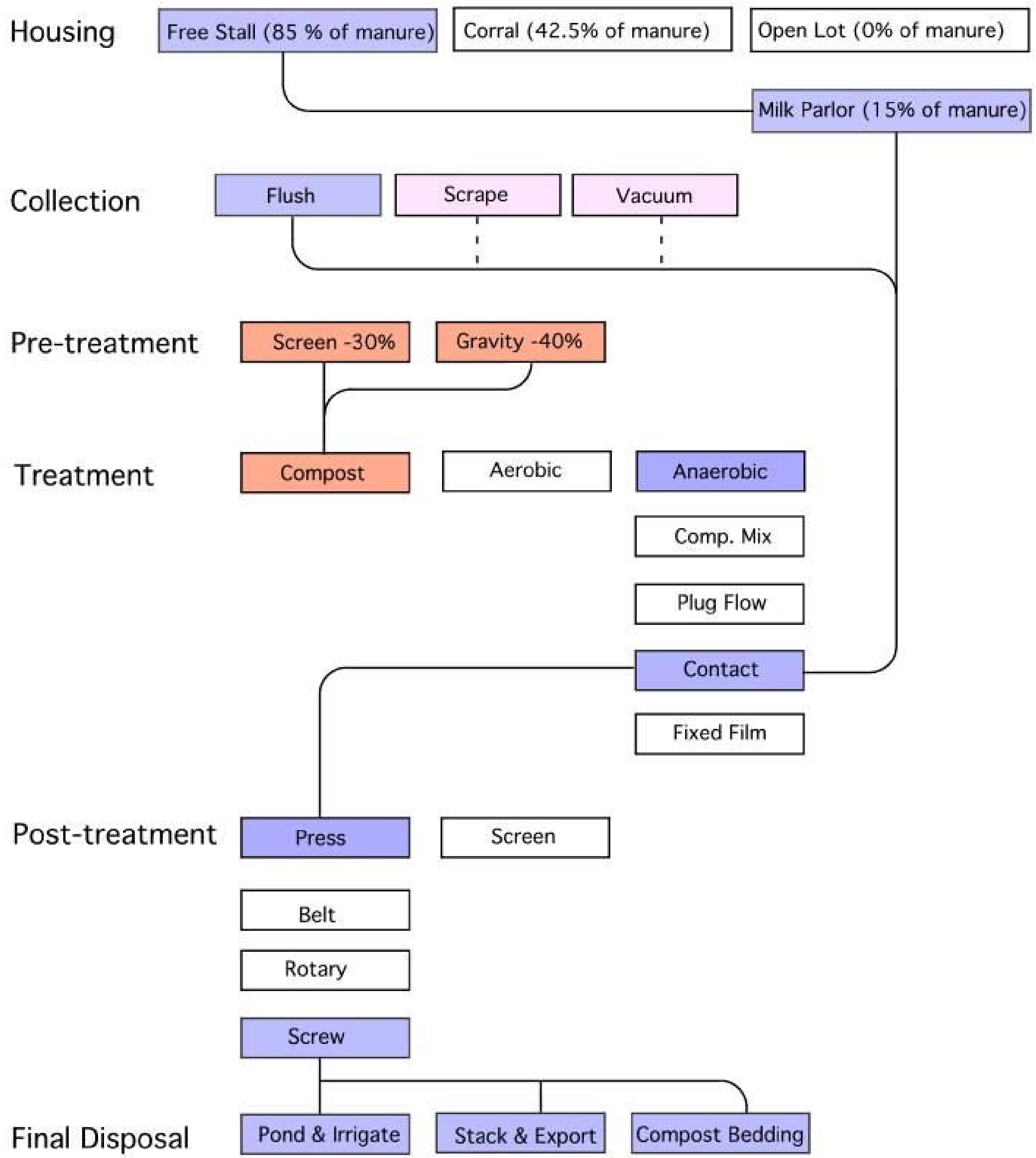
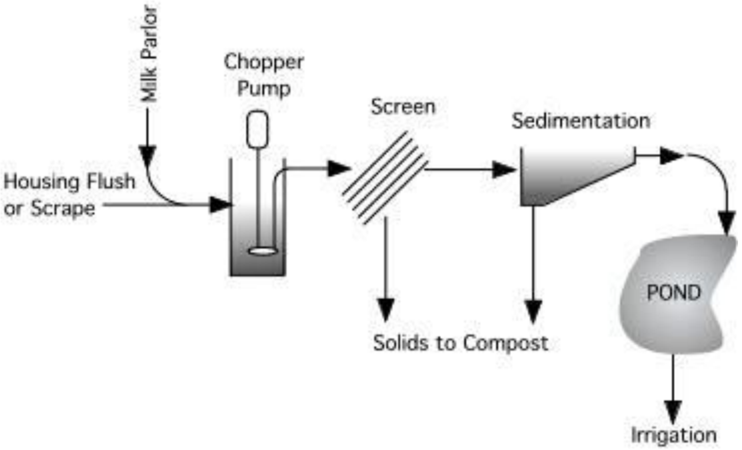
Manure Processing Options

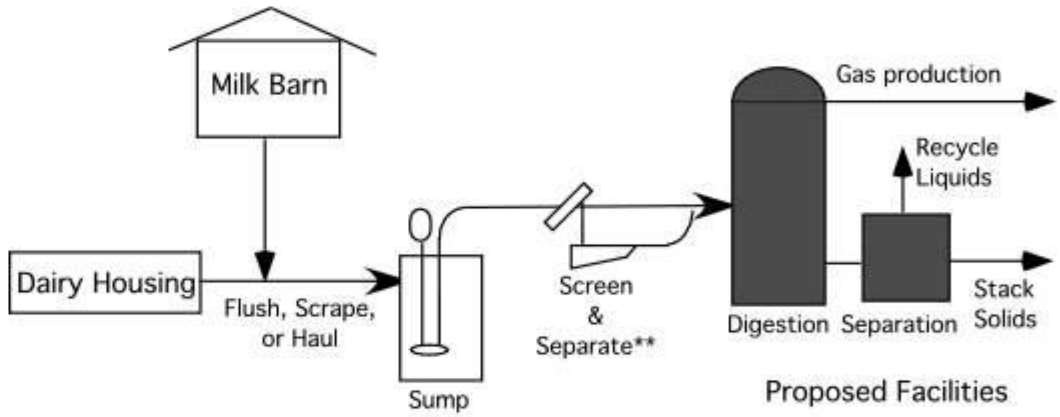


Feed lot near Coalinga

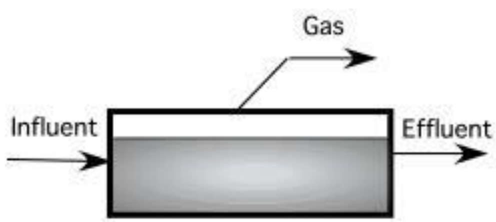

9470
4374
4374
3455
3455
4256


Milk Parlor
Chopper
Pump
Screen
Sedimentation
Housing Flush
or Scrape
POND
Solids to Compost
Irrigation

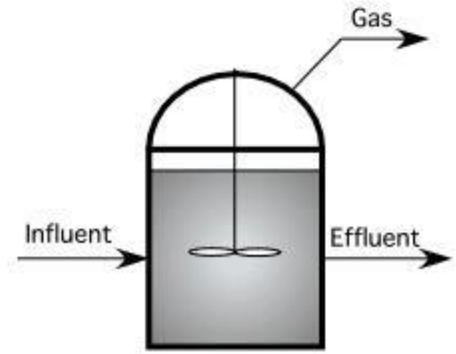
Anaerobic Digesters



** Screen & separate may be by-passed



Plug Flow Reactor



Completely Mixed Reactor

Different manure handling systems, and digester designs, result in different effluent characteristics and lend themselves to different post-digester effluent processing systems. **But AD systems do not affect the amount of nutrients that must be managed**.

NO3 losses (lb/ac) following a single irrigation in diverse sandy loam soils in the SJV

Soils	NO3 –N top foot				NO3-N top 3 feet			
	Before lb/ac	*After lb/ac*	*lost lb/ac*	*%*	*Before lb/ac*	*After lb/ac*	*lost lb/ac*	*%*
Hanford sl	**209**	**36**	**173**	**83**	**281**	**113**	**169**	**60**
Dinuba sl	**143**	**56**	**87**	**61**	**255**	**147**	**107**	**42**
Coplan l	**804**	**346**	**458**	**57**	**959**	**514**	**445**	**46**
Delhi s	**81**	**23**	**58**	**72**	**127**	**108**	**19**	**15**

Ist or 2nd irrigation applied to corn (Campbell-Matthews et al., 2004)

Long term research on agricultural sustainability at UCD’s Russell Ranch

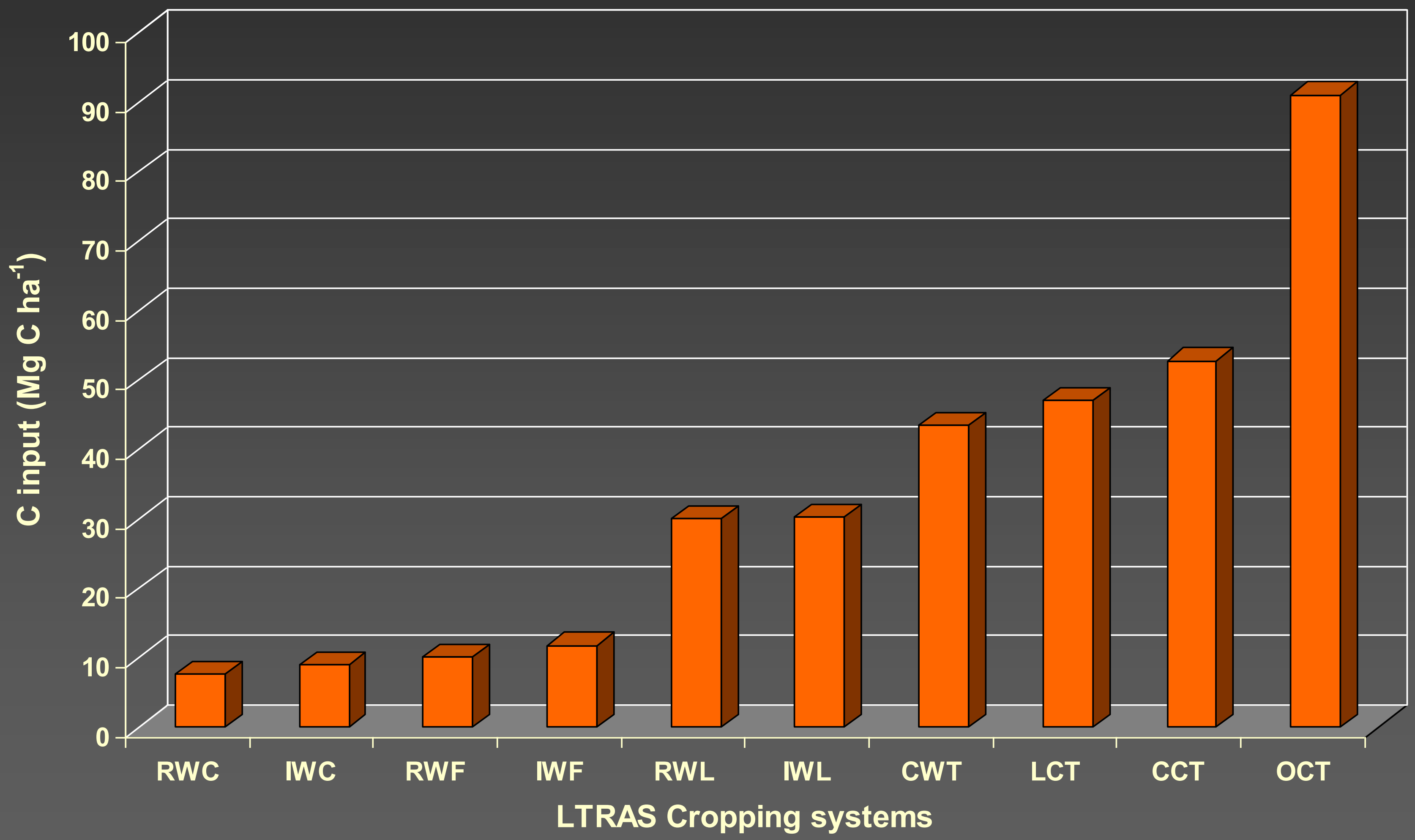
Where does LTRAS fit into the context of sustainable agriculture?

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

D.S. Powlson, 1996


Conventional
Organic

Total C input over 10 years of cropping



Kong et al. 2004

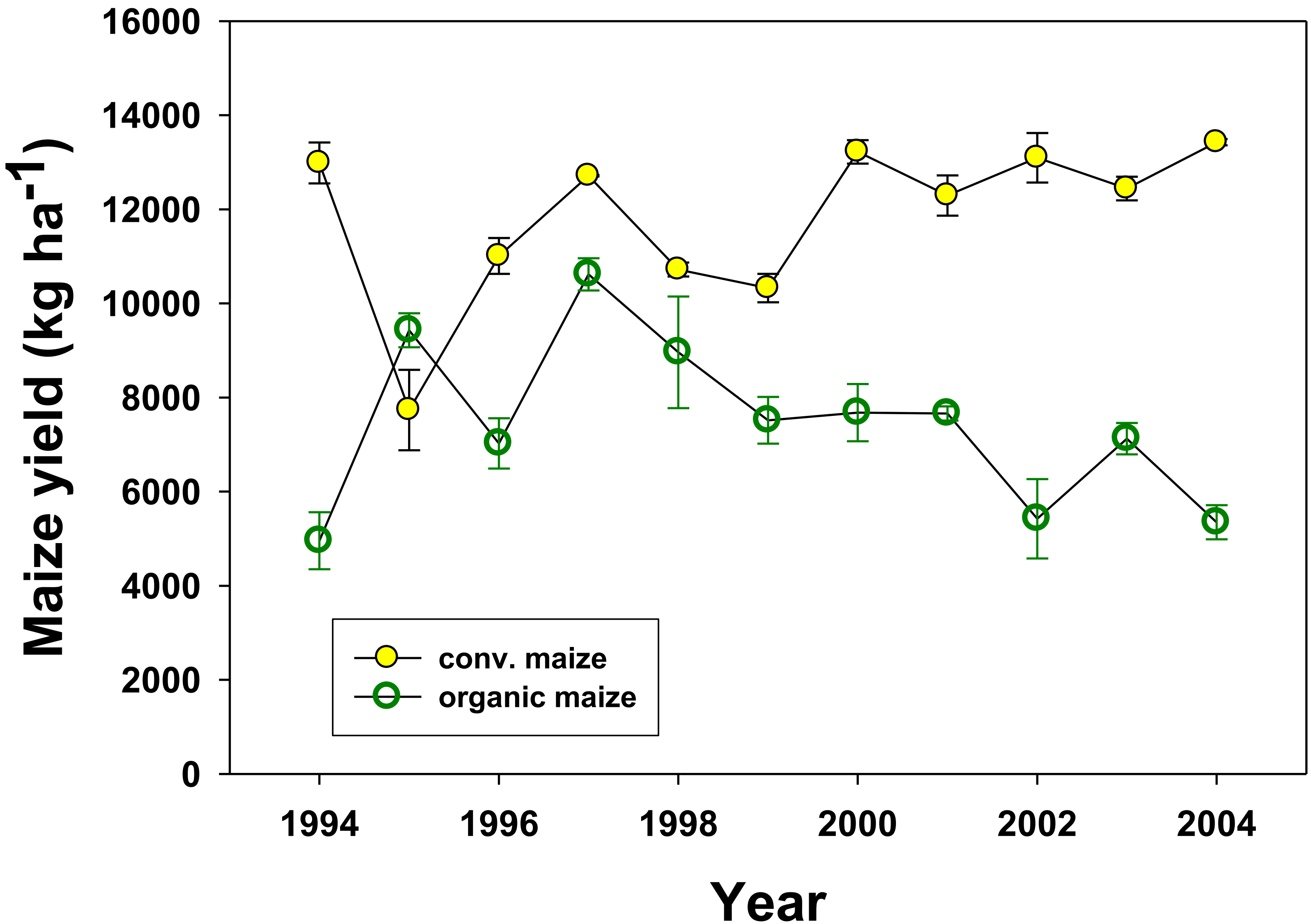
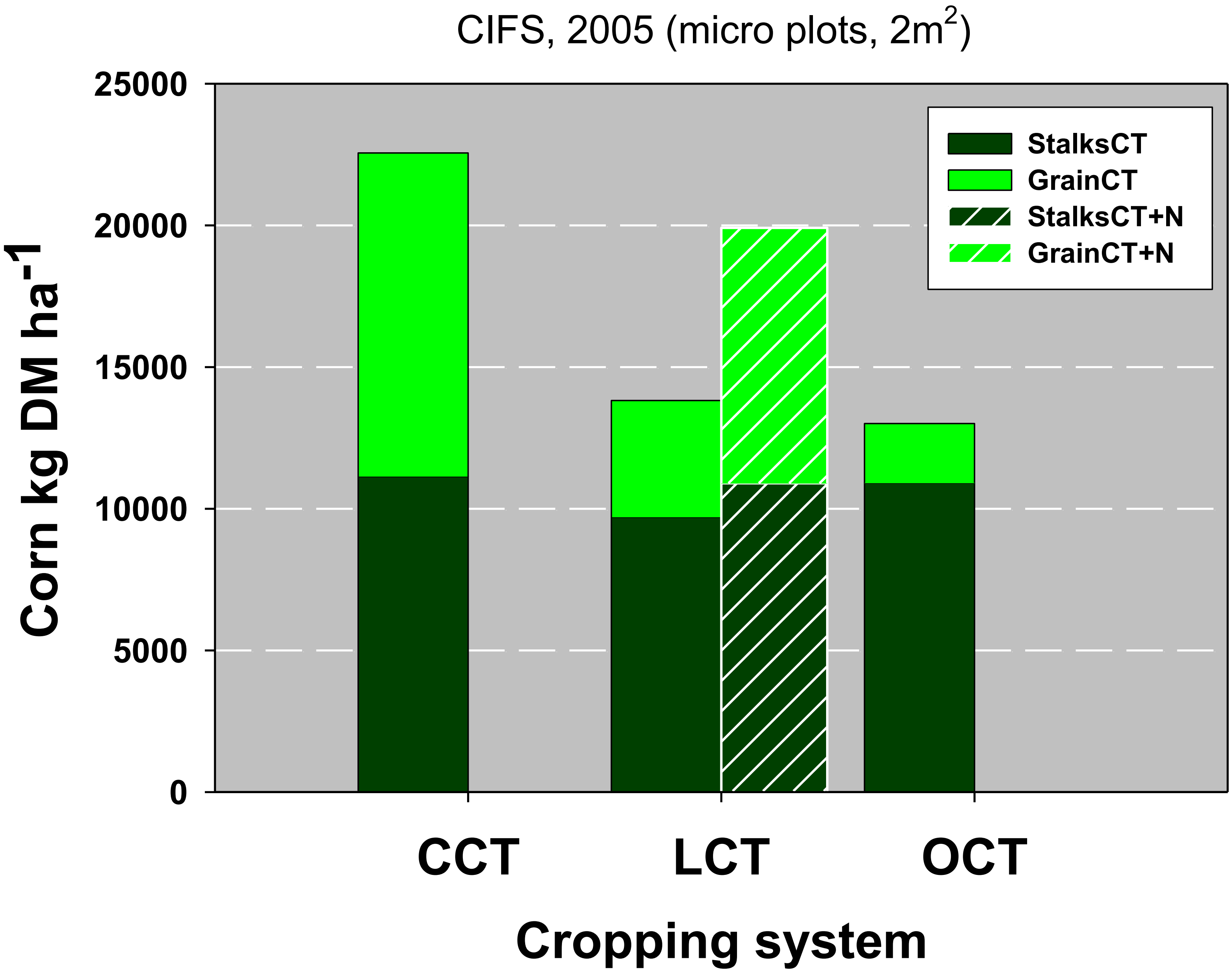
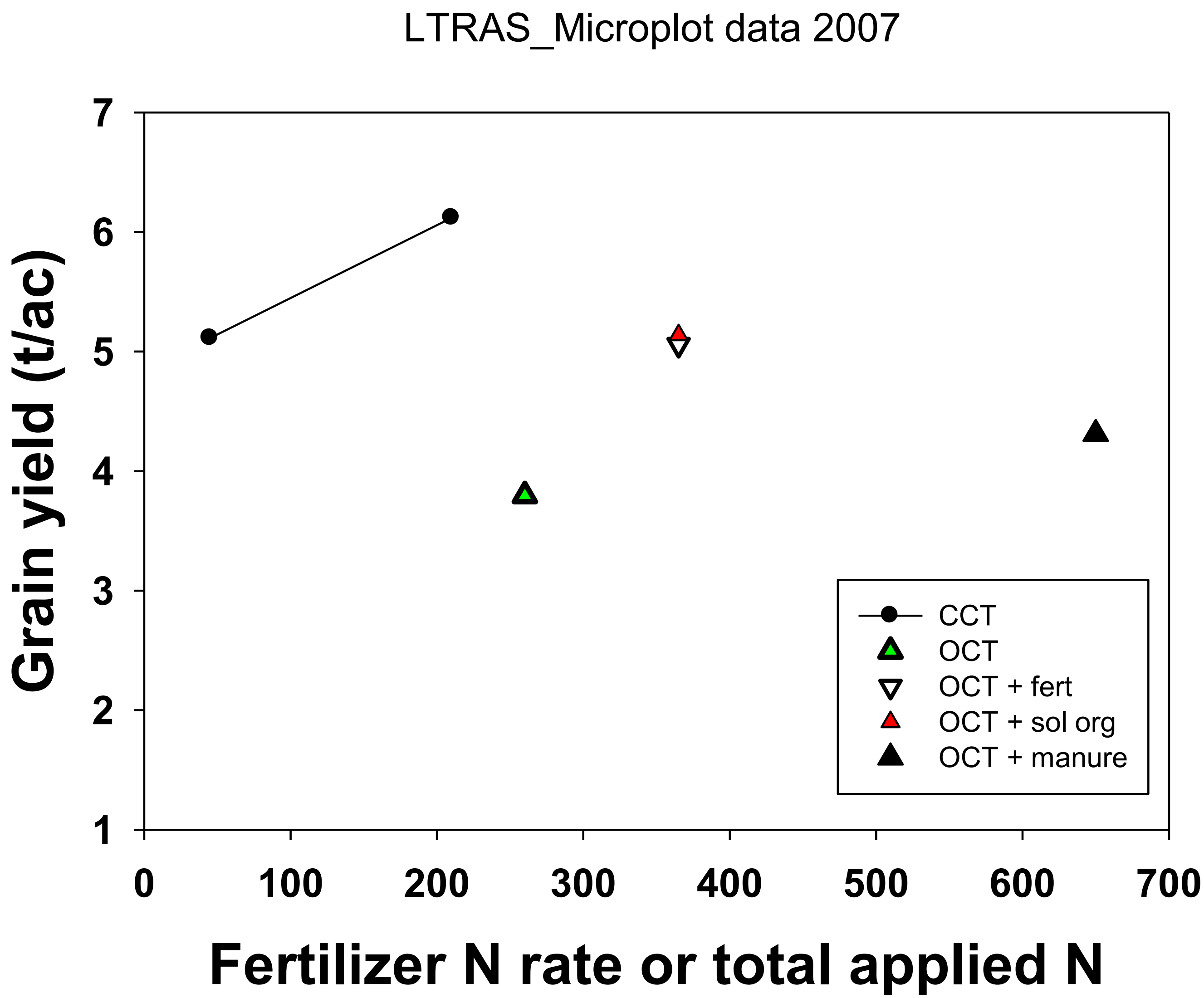


Fig. 1. Maize yields, 1994-2004, LTRAS


CIFS, 2005 (micro plots, 2m2)
Corn kg DM ha-1
25000
20000
15000
10000
5000
0
StalksCT
GrainCT
StalksCT+N
GrainCT+N
CCT
LCT
OCT
Cropping system

High analysis, soluble N organic fertilizers can be used to enhance the yields of some crops in organic or conventional systems.



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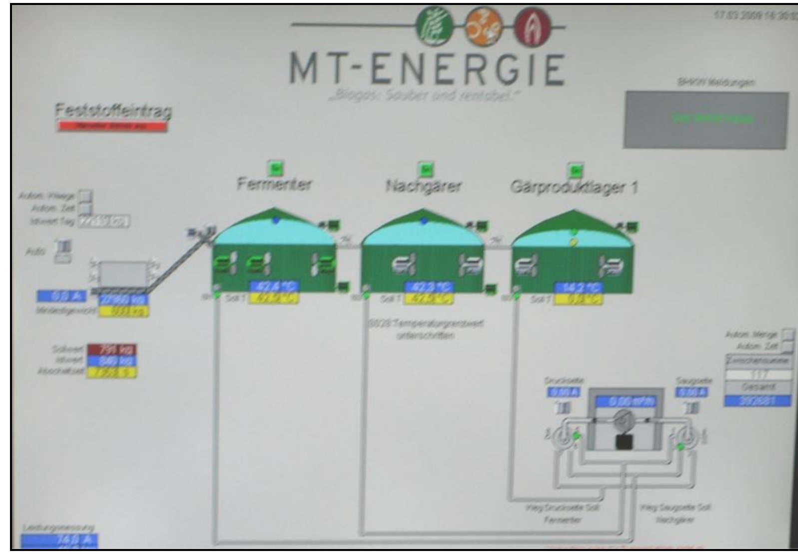
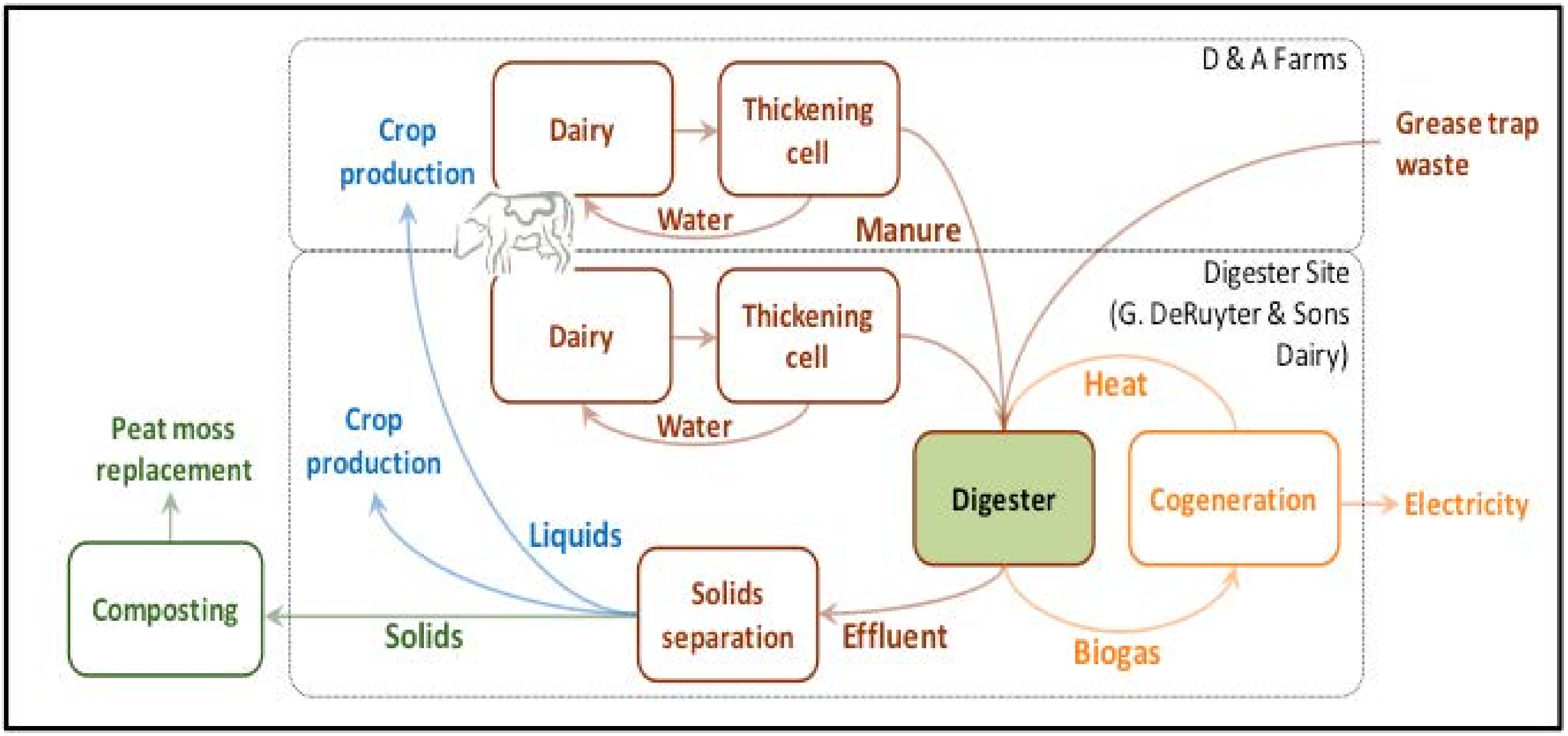


Biogas to electricity facility in Germany, 2009

Effluent is removed daily [7%DM (summer)-8.5 % DM (winter)]. NO3: 5.6%/m3; P: 2.4%/m3; K: 5.6%/m3. It is field spread. They sell it for 12-13 euros/m3.

Schematic of one possible set of pathways for nutrient removal from a Washington State Dairy (Nutrient recovery targets: 70% NH_3, 80% P, 20% K).



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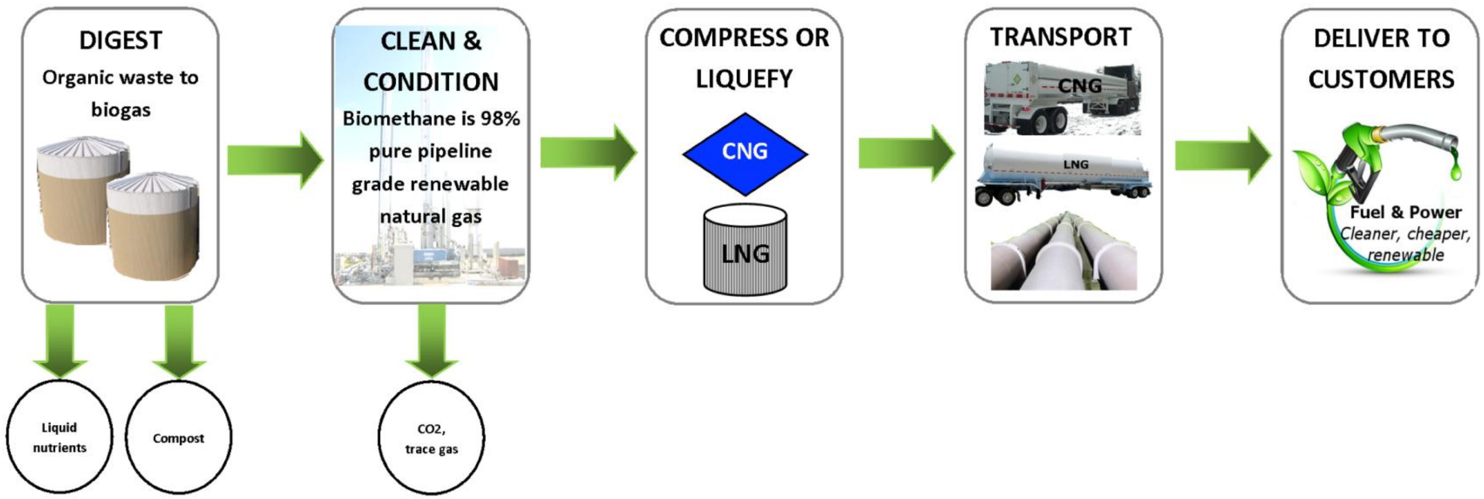
C. Frear (Washington State University); EPA Technology Market Summit, Washington DC, May 14, 2012

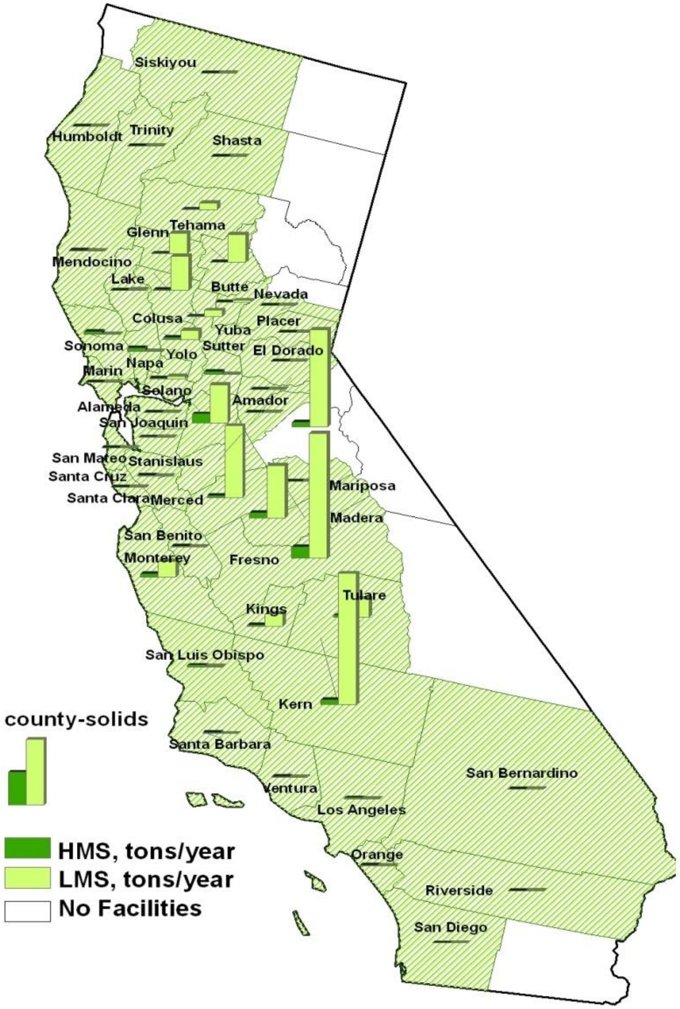
Instead of electricity production, biogas might be cleaned, compressed and used for fuel. Currently done at the Fiscalini Dairy in California.

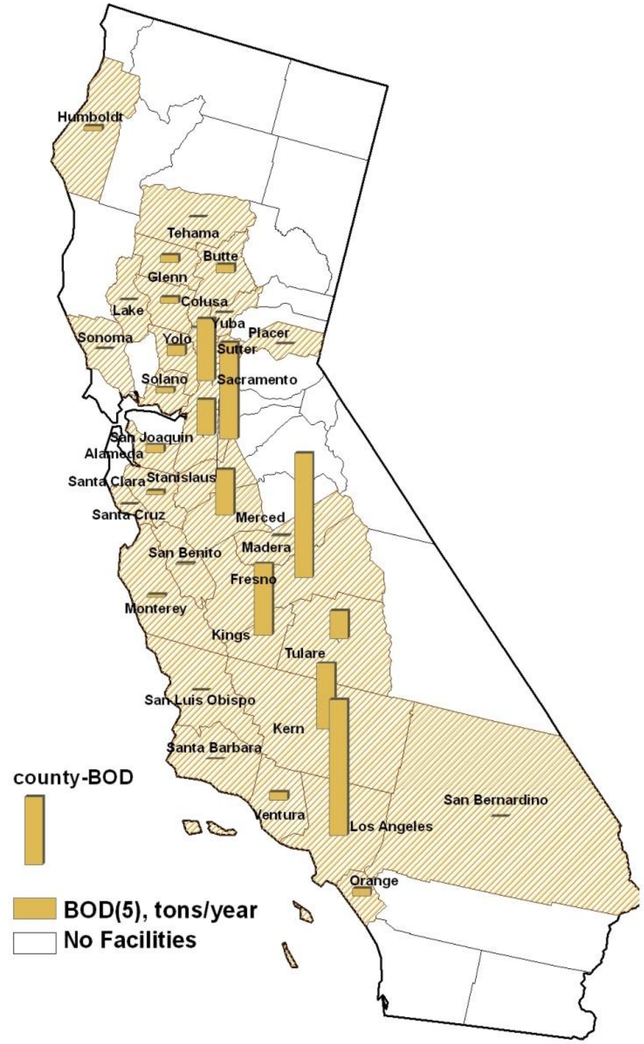


C. Frear (Washington State University); EPA Technology Market Summit, Washington DC, May 14, 2012

California Food Processing Industry Organic Residue Assessment

Amon et al., 2011

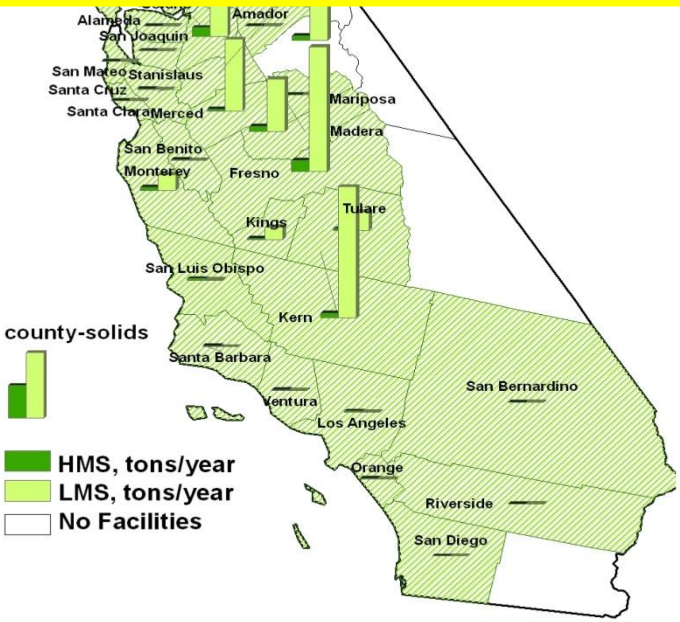


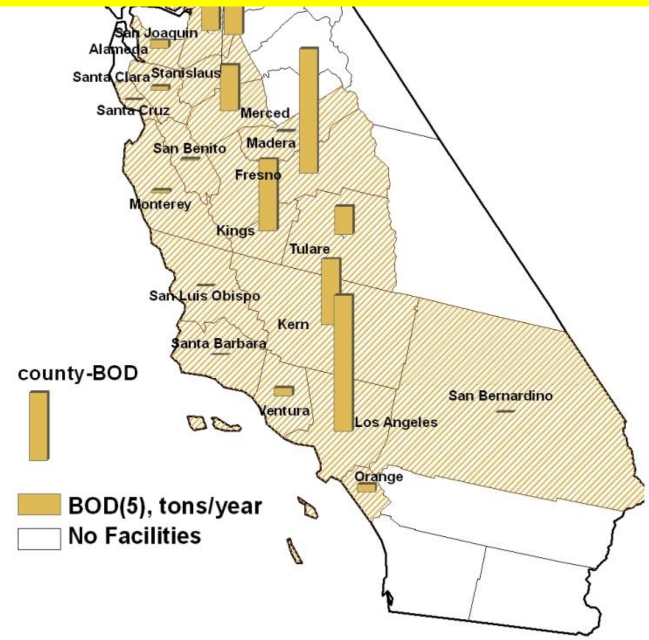


California Food Processing Industry Organic Residue Assessment

Amon et al., 2011

Co-digesting dairy manure with other, higher energy materials will increase biogas yields and may improve economic performance of the dairy-based AD systems. But this can only happen if the additional nutrients introduced can be removed cost-effectively from the dairies and used efficiently elsewhere in agriculture.





The accumulation of surplus nutrients in confined animal feeding operations like dairy farms in California, is characteristic of modern, intensive animal agriculture. There are many benefits that derive from such systems, but also some costs.

To address nutrient surpluses associated with dairy operations in the San Joaquin Valley and elsewhere, economic ways must be found to concentrate nutrients in manure and remove them from the livestock farms for use on other farms without livestock. Policies should facilitate this.

An active nutrient recovery process is needed from AD effluent, leaving residual water on the farm. These processes currently are expensive relative to the value of the nutrients recovered.

In the San Joaquin Valley, salts in manure, particularly sodium (Na), must also be managed. This makes the problem of nutrient concentration much more difficult and expensive.

Some of the costs of nutrient concentration from digester effluent may be offset from on-farm energy production using anaerobic digestion systems, with the digester effluent then being treated for nutrient recovery.

Other portions of the total cost may be reduced through a combination of fertilizer sales, carbon credits and direct public subsidies. A combination of creative research and policy construction is needed. Policy must account for net benefits.

Reducing N and P losses from CAFOs, (and reducing N losses from agriculture in general) will involve costs, either directly for interventions, or indirectly through higher food prices, or loss of farm businesses.

Integrating nutrient management with energy production and green house gas reduction offers promising opportunities to address several environmental and economic problems in an integrated manner. This may be one way to minimize public costs generally for the environmental improvements desired.

What is sustainabilty?

The debate over sustainability means discussing the implications of human choices when looking for compromise solutions between two pressures:

1. Economic pressure driving further intensification (higher rates of throughputs per acre and per hour of labor)
2. Ecological limitations or pressure to reduce the rate of throughput (lower input systems have less environmental impact).

We must consider Net Benefits