Nitrogen Fertilizer Loading to Groundwater in the Central Valley

Thomas Harter
University of California Davis
ThHarter@ucdavis.edu

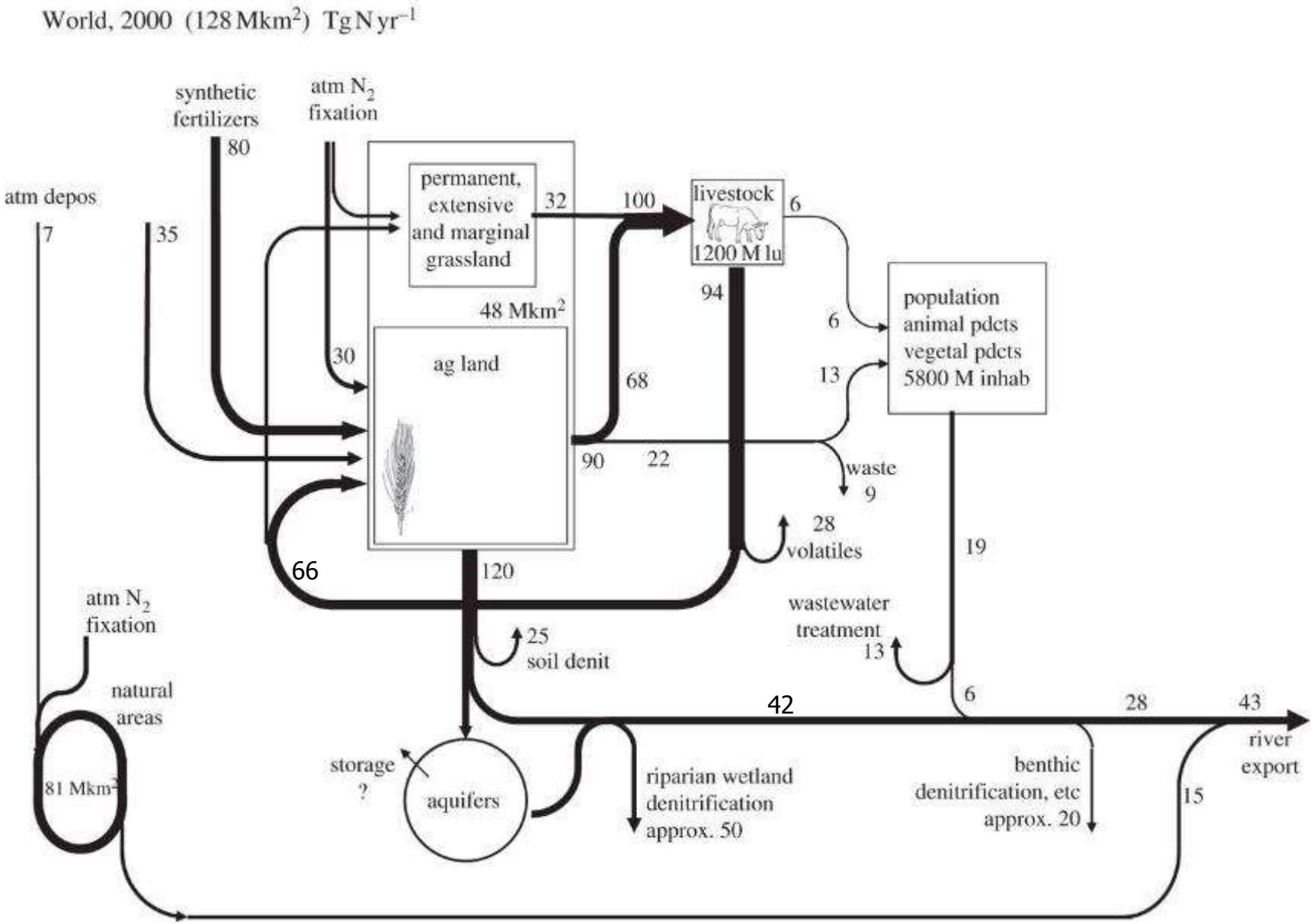
http://groundwater.ucdavis.edu

@wasserstille

UC Davis Team

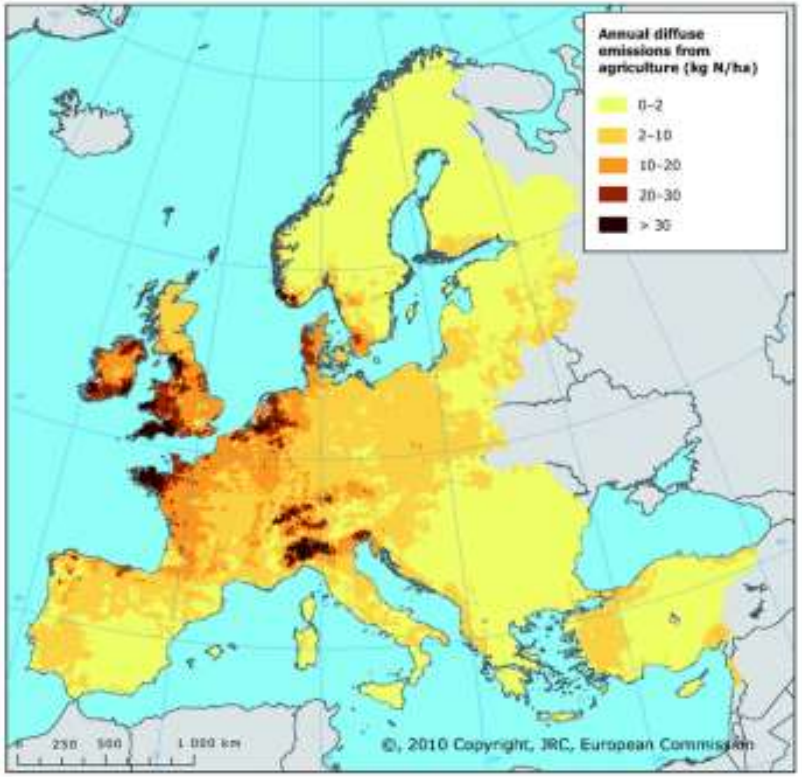
- Thomas Harter, PI
- Katherine Ransom, MS 2012, PhD 2017
- Giorgos Kourakos, Postdoc 2010-2015, Visiting Scientist 2015-2017
- Chris Henri, Postdoc 2016-current
- Mehrdad Bastani, PhD Student
- Shahar Baram, Postdoc, 2013-2016
- Matt Read, Field Technician
- Estathis Diamontopoulos, Project Scientist, 2016-2017
- Quinn Barber, Internship, Spring 2015
- Phillip Geier, Internship, Summer 2015
- Olin Applegate, BS 2011, MS Hydrology 2014
- Taryn Parson, MS Student
- Emily Kennedy, MS Student
- …..many undergraduate students for data entry jobs….

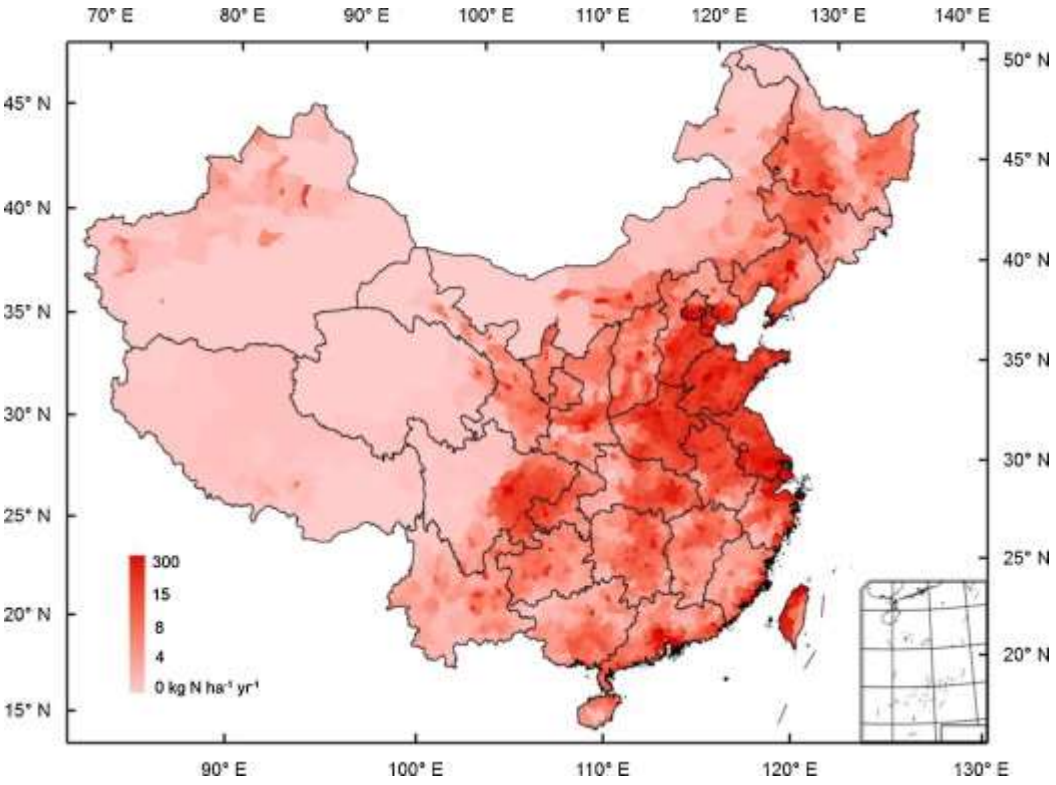
Global Perspectives on Nitrogen Cycling: Watershed N Cycle



Billen et al., Royal Society 2013

Nitrate Leaching to Groundwater: Europe & China

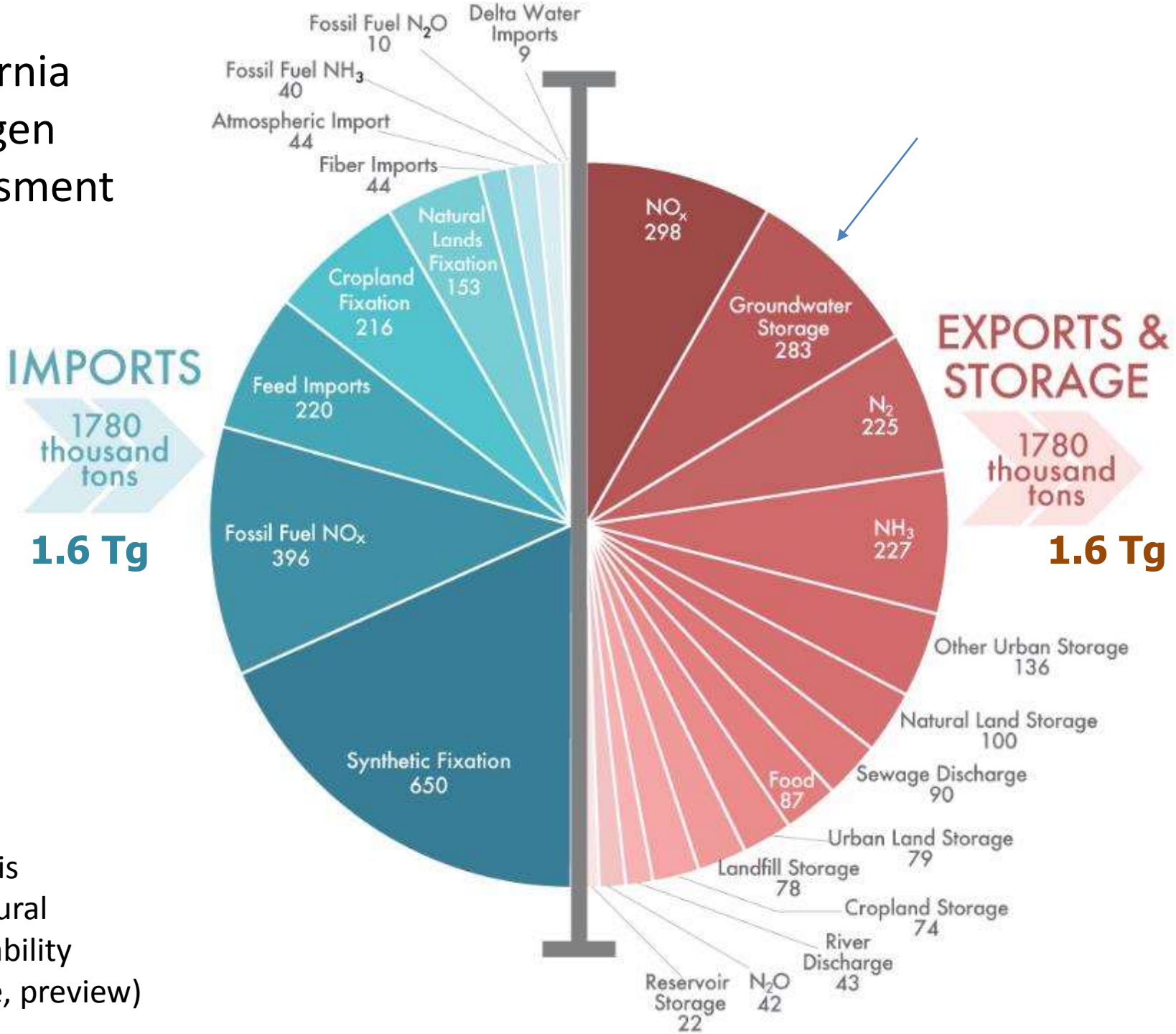




Gu et al, Glob Env Change 2013

http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_nitrate_pollution_of_water

California Nitrogen Assessment



(UC Davis Agricultural Sustainability Institute, preview)

Assessing Potential Nitrate-N Loading to Groundwater

Review of Literature & Scientific Reports

Method:
- Identify average loading rate
- Digitize applicable properties into GIS map

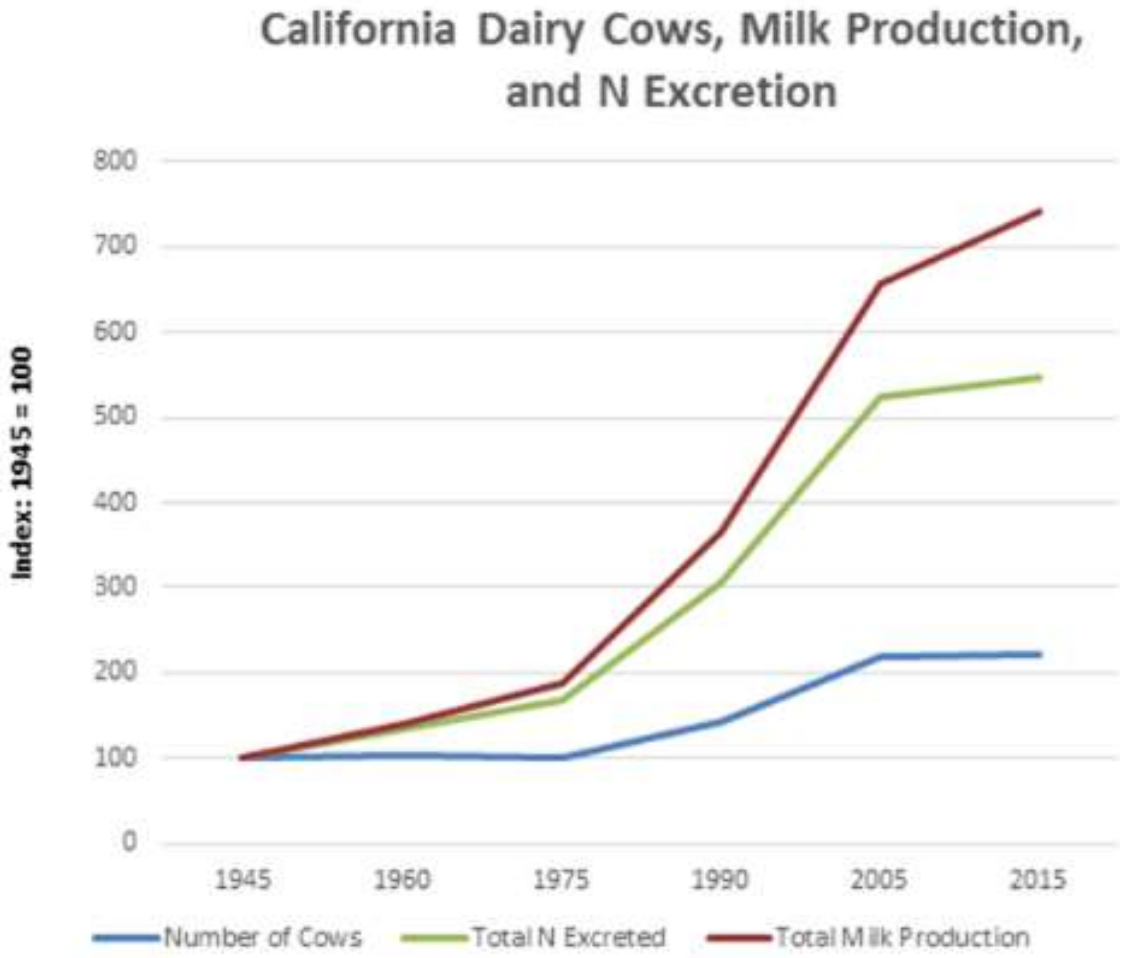
Landuses:
- Urban
- Golf courses
- Dairy corrals
- Dairy lagoons
- WWTP perolation basins
- FP percolation basins

Nitrogen Mass Balance
- County Level
- Field Scale (50 m x 50 m)

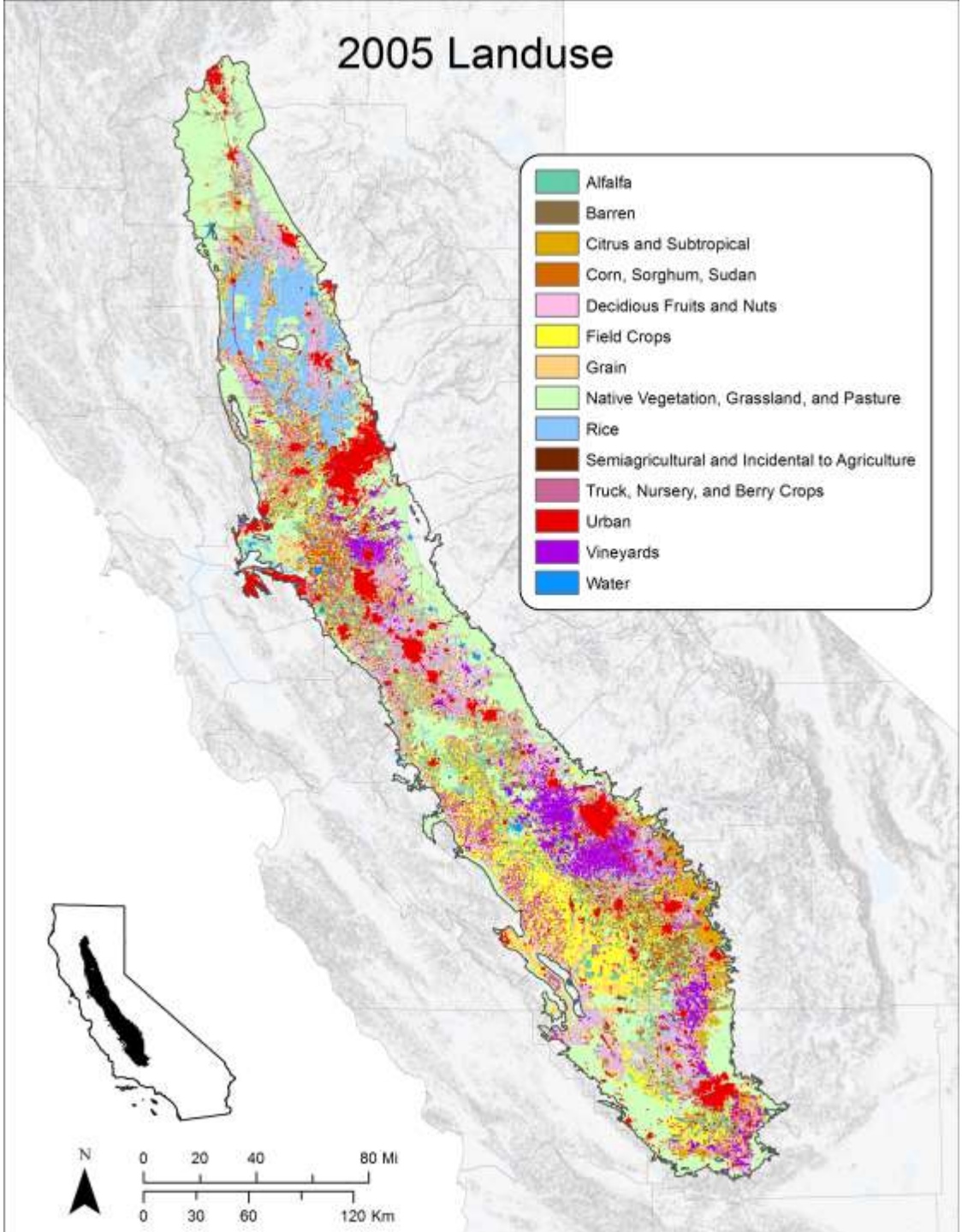
Method:
- Identify all nitrogen fluxes
- Potential N Loading to Groundwater = A-R
- Digitize/map properties/fields

Facilities/Landuses:
- WWTP effluent land application
- FP effluent land application
- Biosolids land application (TLB)
- Dairy land application
- 58 crops (DWR categories)

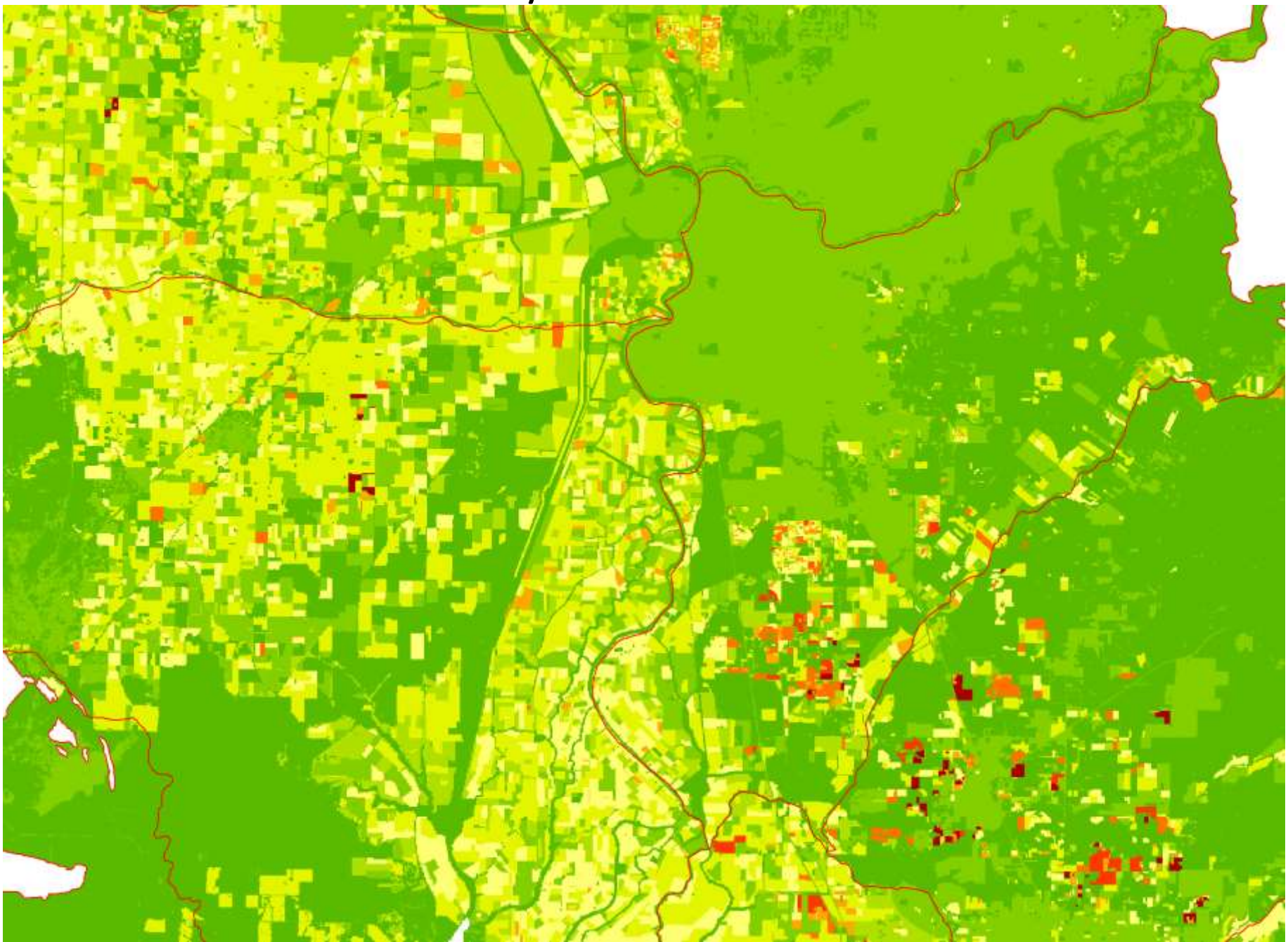
Animal Farming: Central Valley Trends



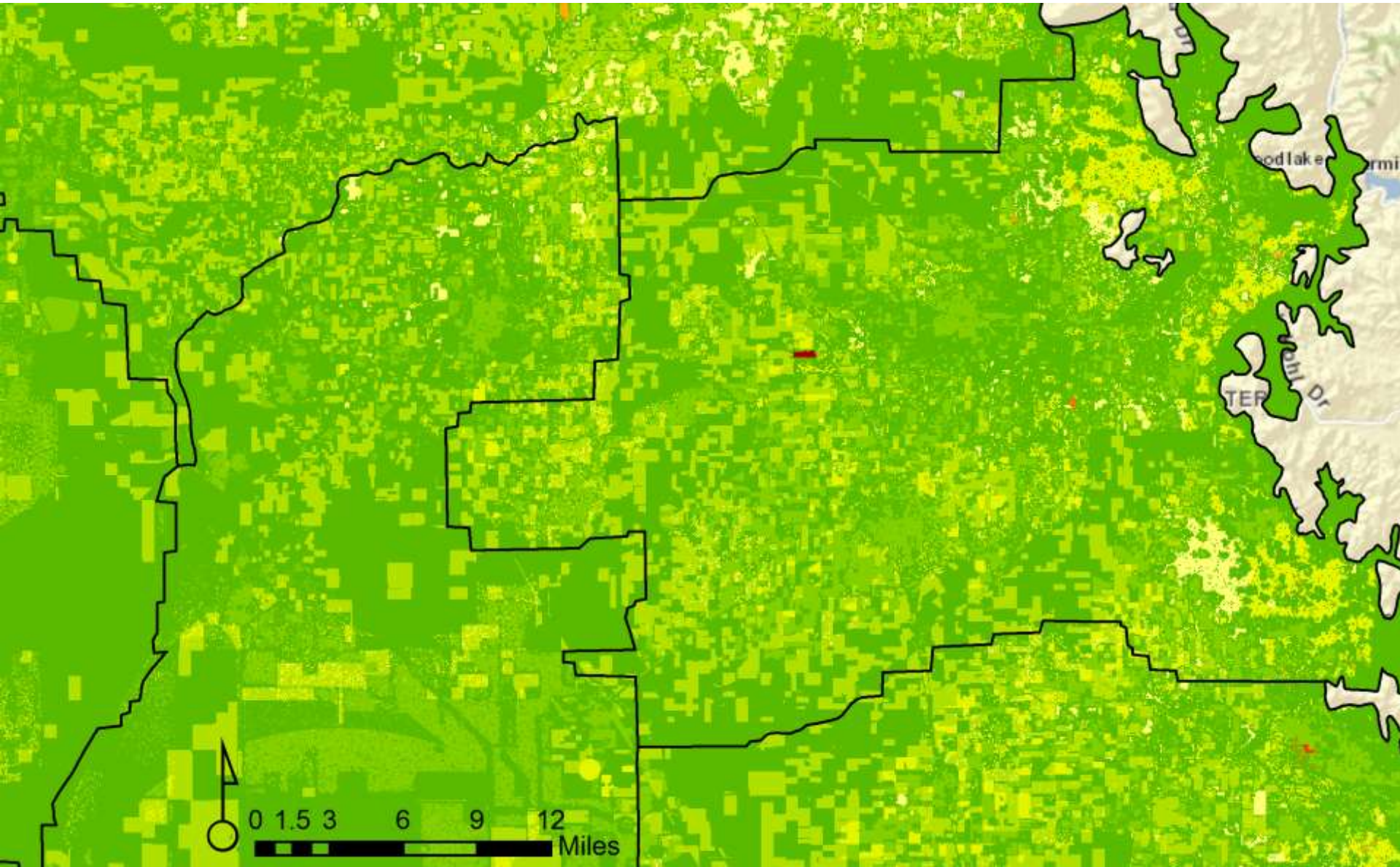
Landuse


2005 Landuse
Alfalfa
Barren
Citrus and Subtropical
Corn, Sorghum, Sudan
Decidious Fruits and Nuts
Field Crops
Grain
Native Vegetation, Grassland, and Pasture
Rice
Semiagricultural and Incidental to Agriculture
Truck, Nursery, and Berry Crops
Urban
Vineyards
Water
N
0 20 40 80 Mi
0 30 60 120 Km

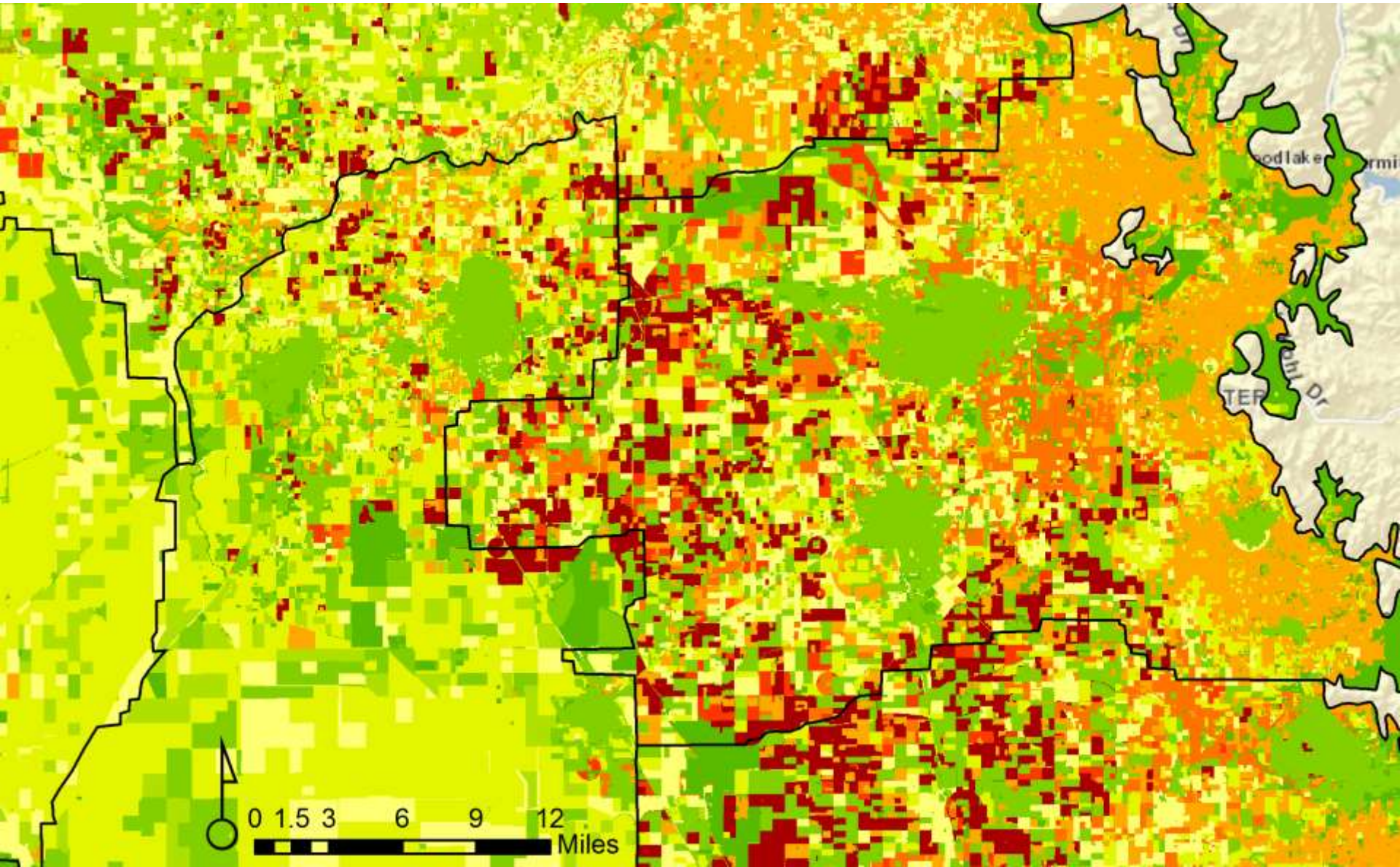
Detailed Scene – Davis/Sacramento 2005



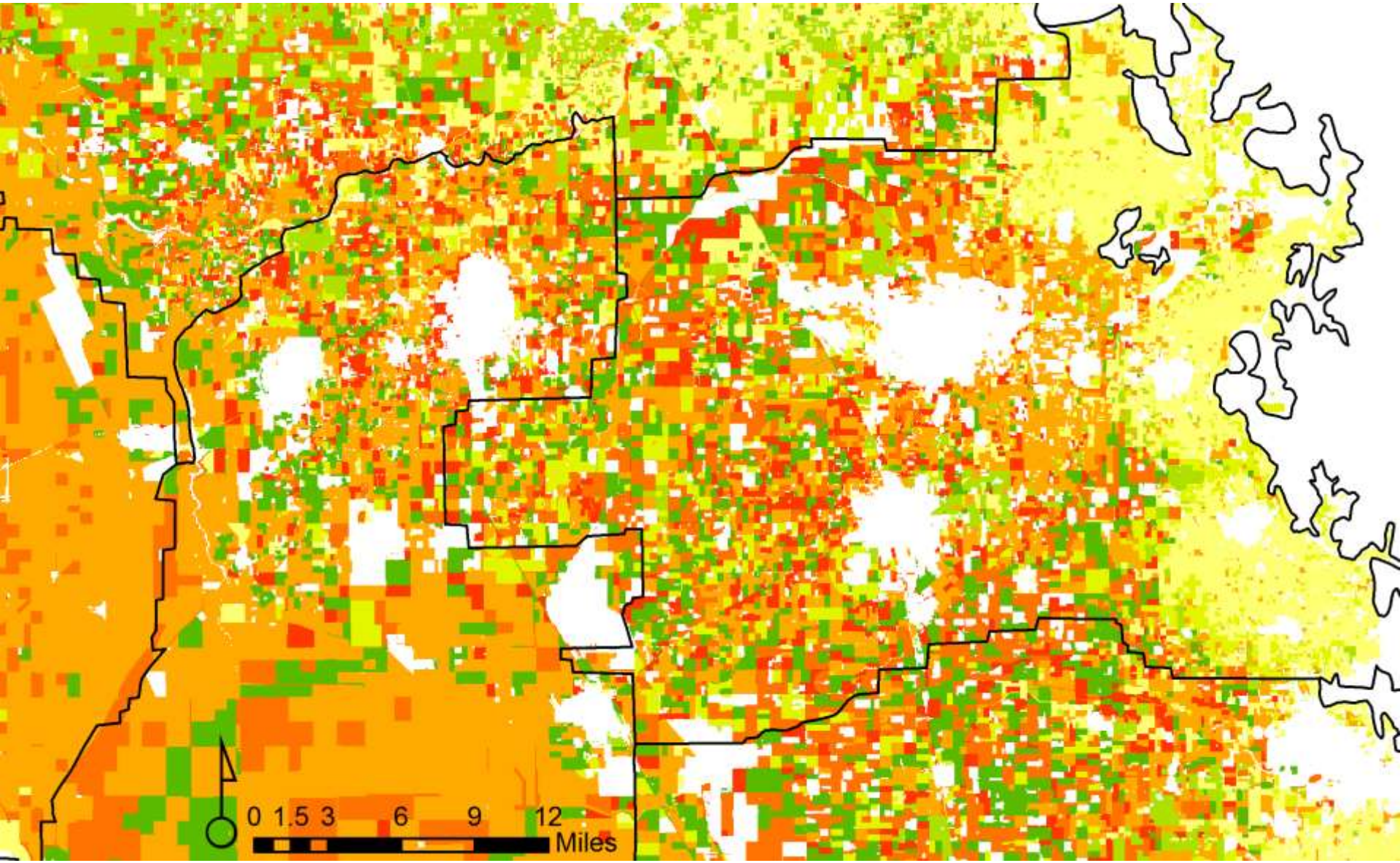
Detailed Scene Visalia/Tulare: 1945 N Loading (All)



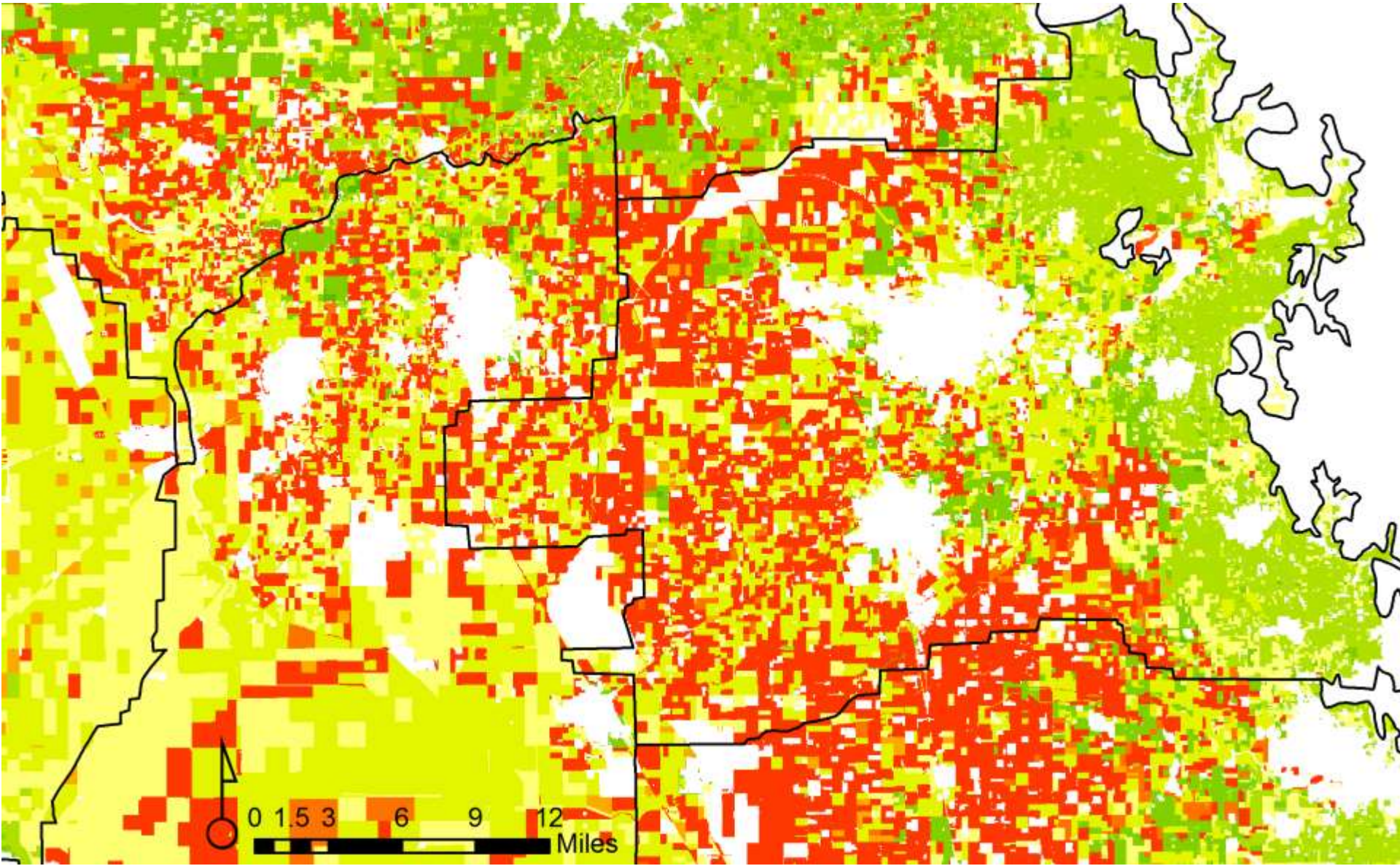
Detailed Scene Visalia/Tulare: 2005 N Loading (All)



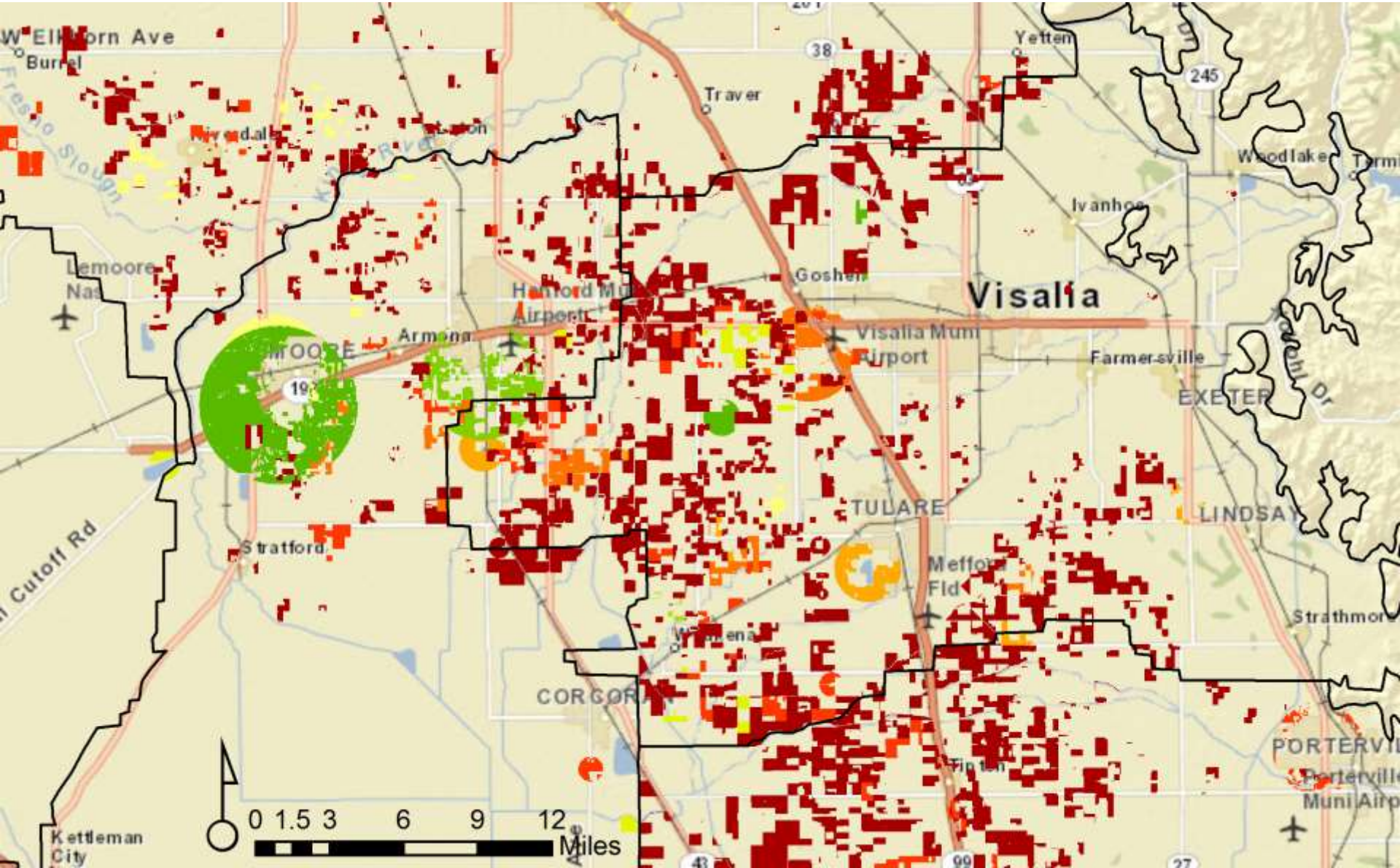
Detailed Scene Visalia/Tulare: 2005 Fertilizer N



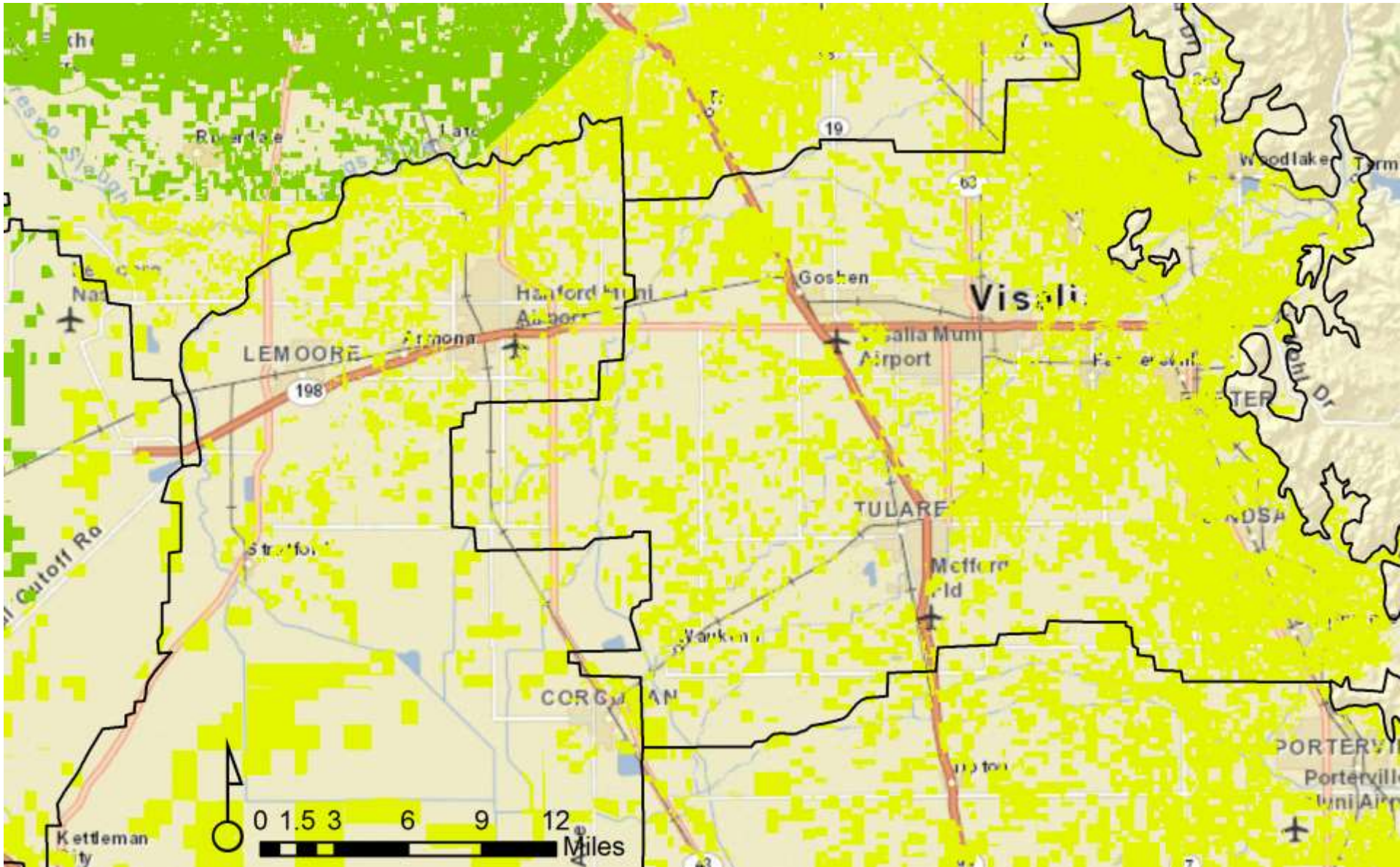
Detailed Scene Visalia/Tulare: 2005 Harvest N



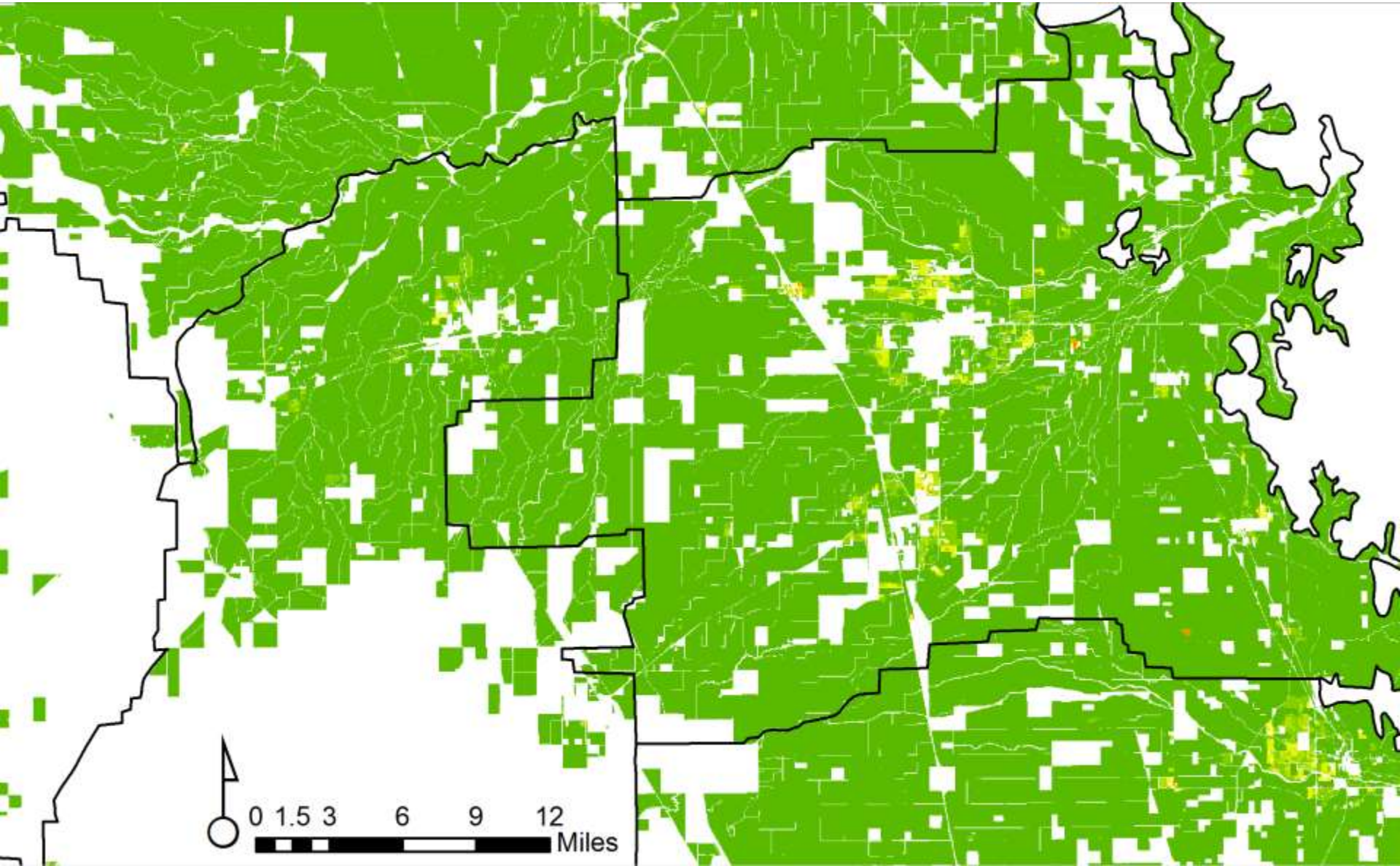
Detailed Scene Visalia/Tulare: 2005 Dairy Manure Applied N



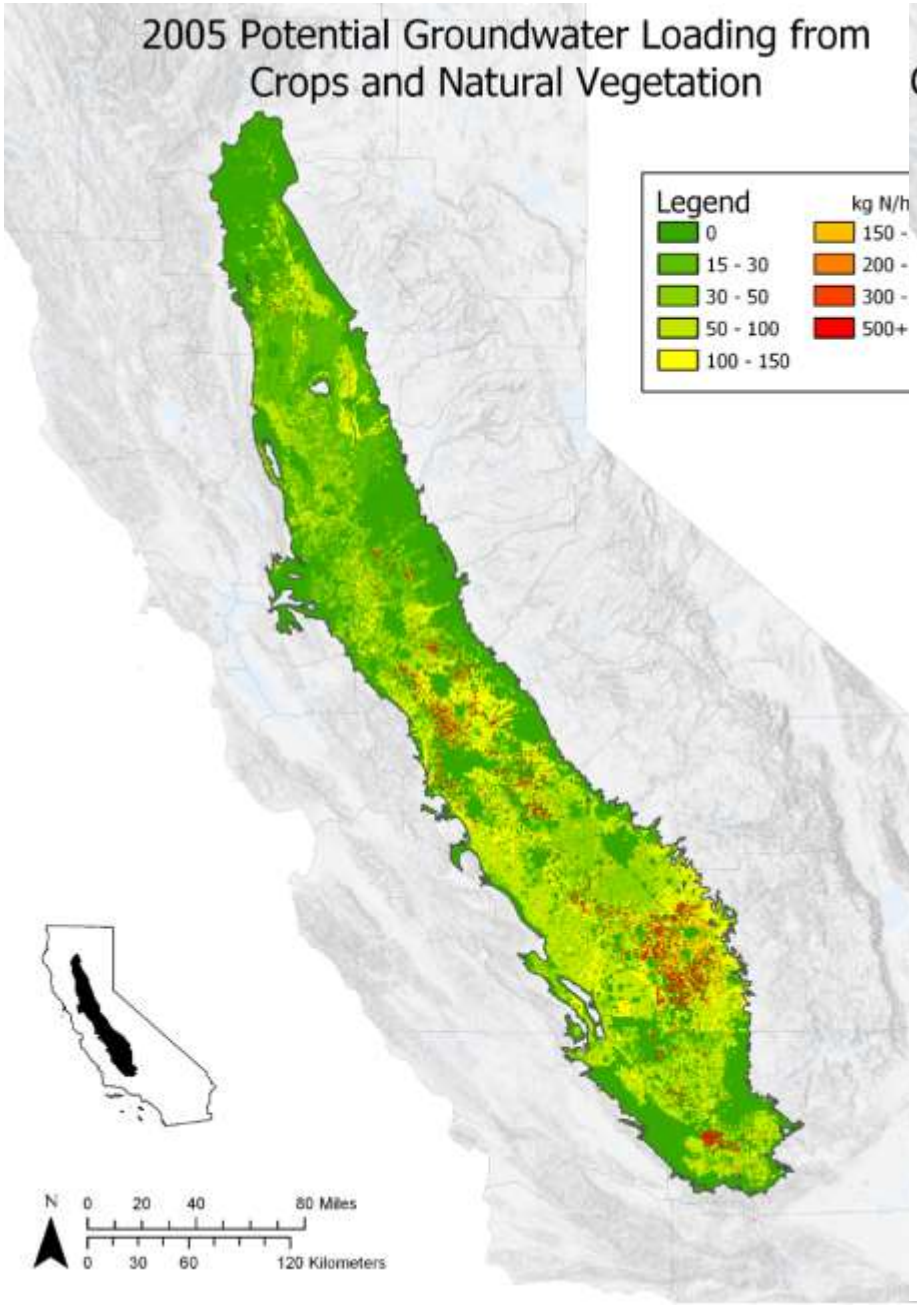
Detailed Scene Visalia/Tulare: 2005 Dairy Manure Export Applied N

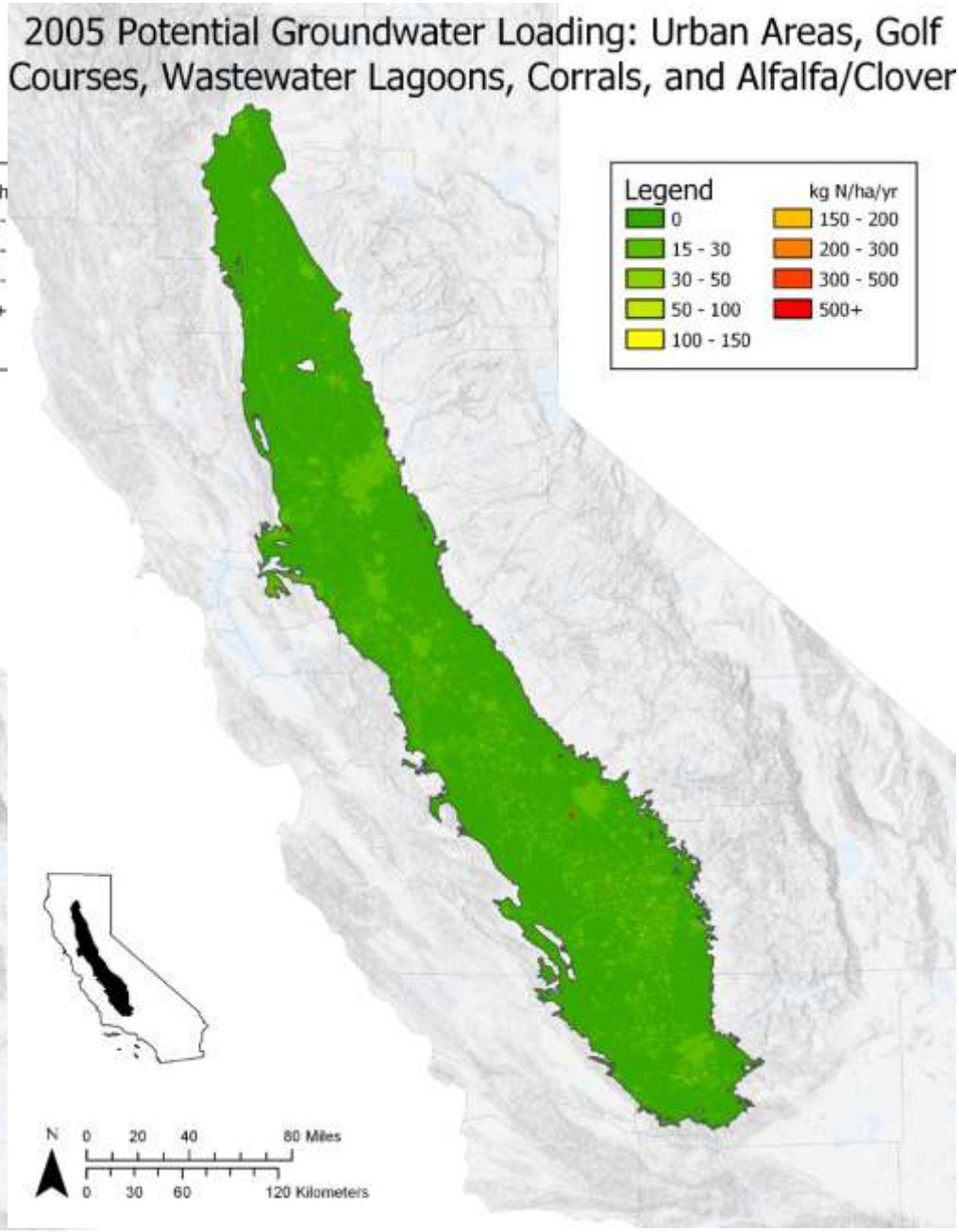


Detailed Scene Visalia/Tulare: 2005 Septic Leachate N

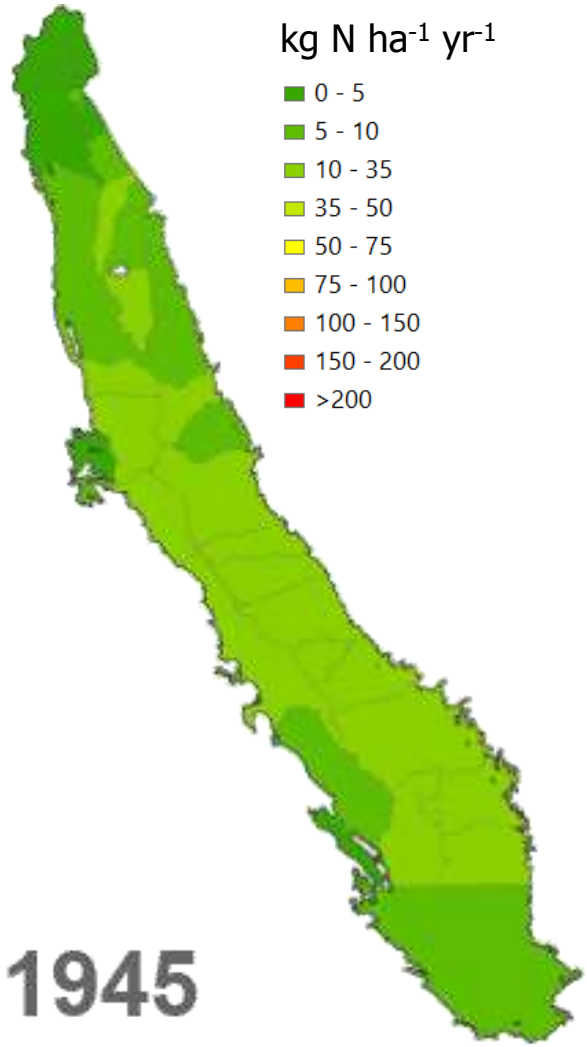


Potential Groundwater Nitrogen Loading, 2005

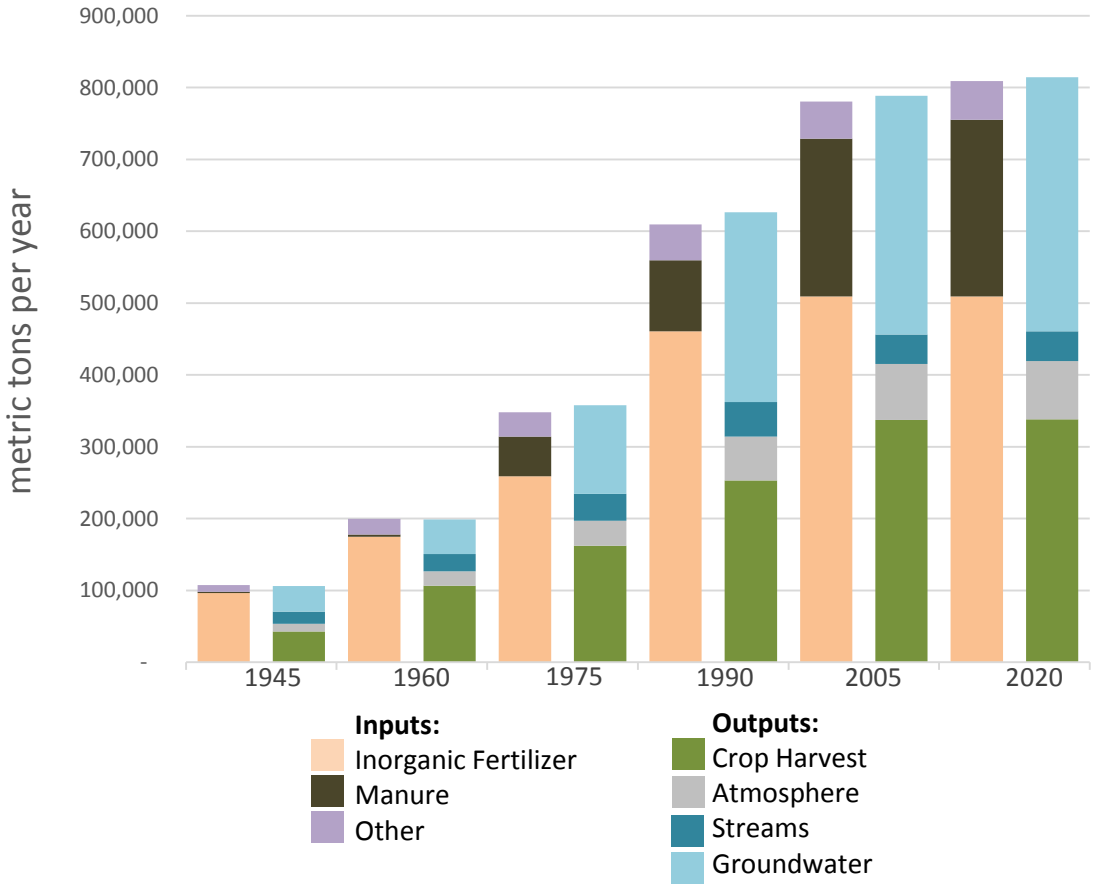




Identifying Risks:
Groundwater Nitrate Loading from Nitrogen Mass Balance

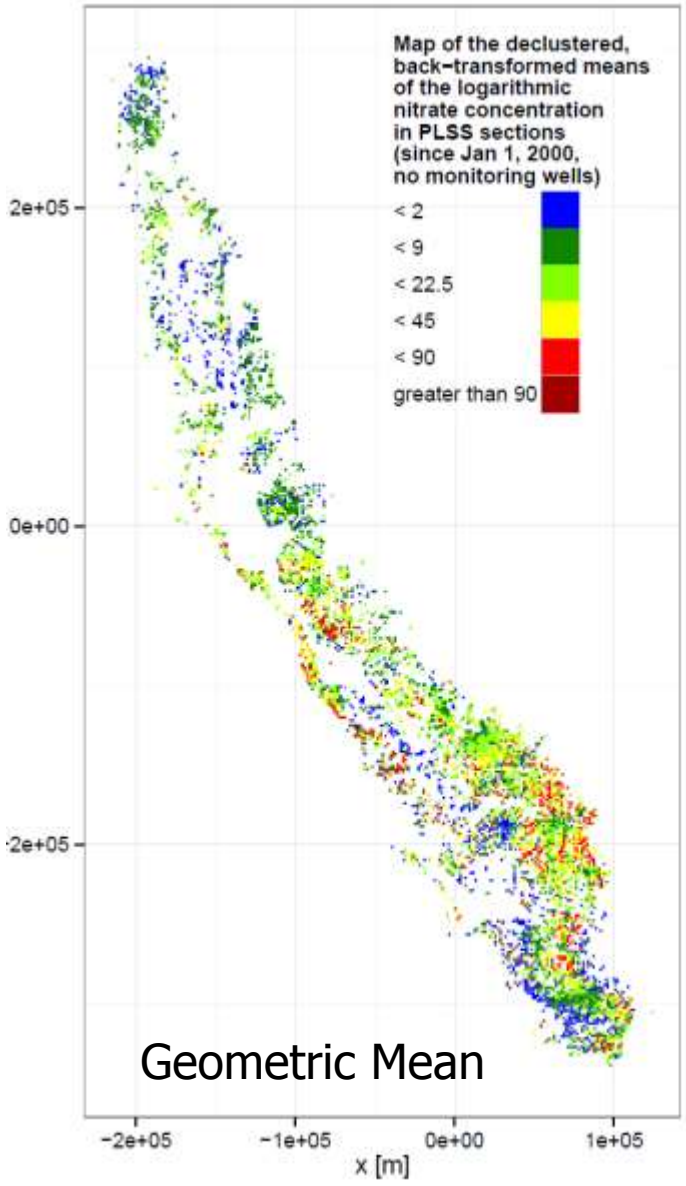


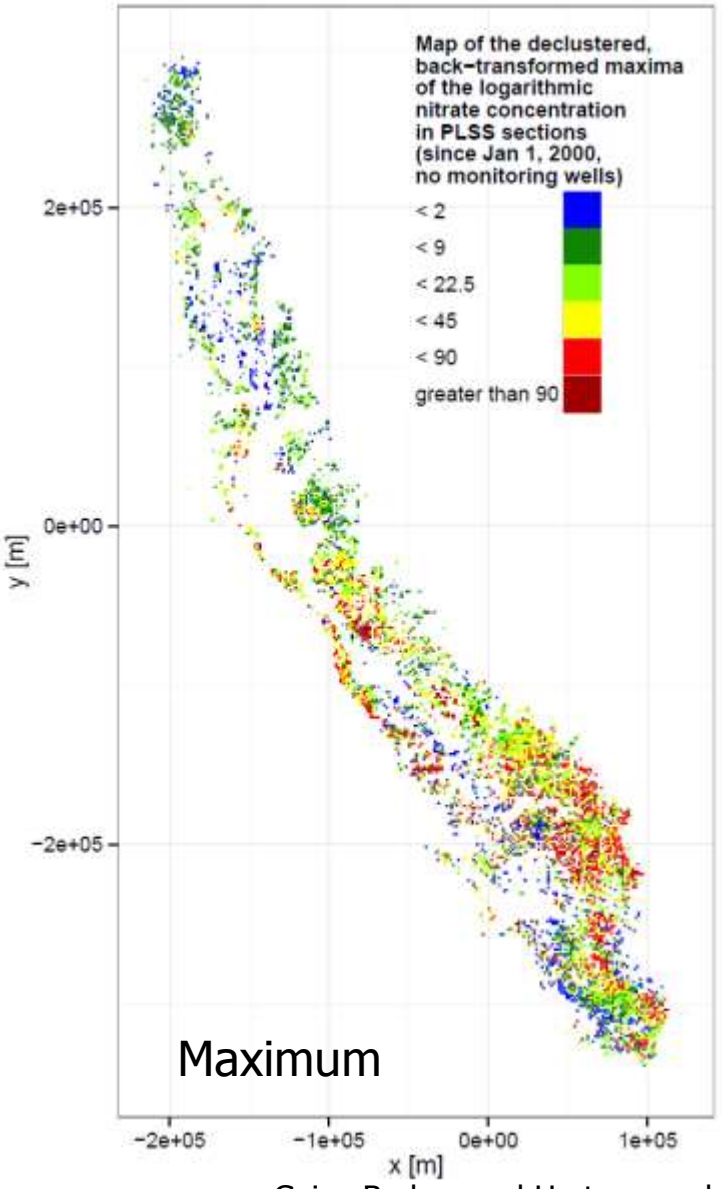
Meeting water quality standards would mean cutting groundwater loading by 2/3 – 3/4



Data from Harter & Lund, SBX2 1 Report, 2012 and ongoing research by Harter et al.

Groundwater Nitrate: Section (1 mi^2) Analysis

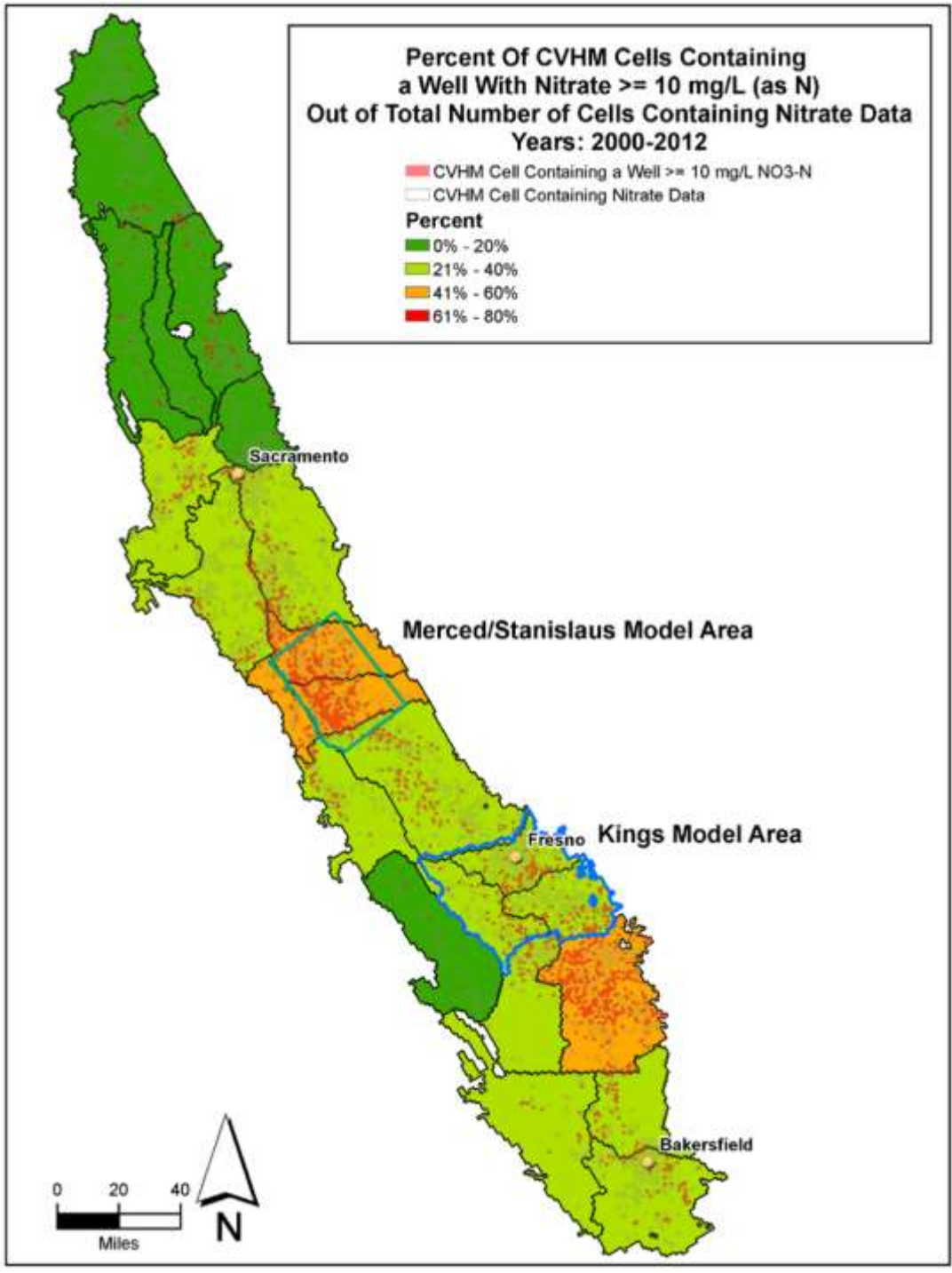




Geier, Barber, and Harter unpublished, 2015

Nitrate: Impacted regions within the Central Valley

red dots: wells above MCL for nitrate

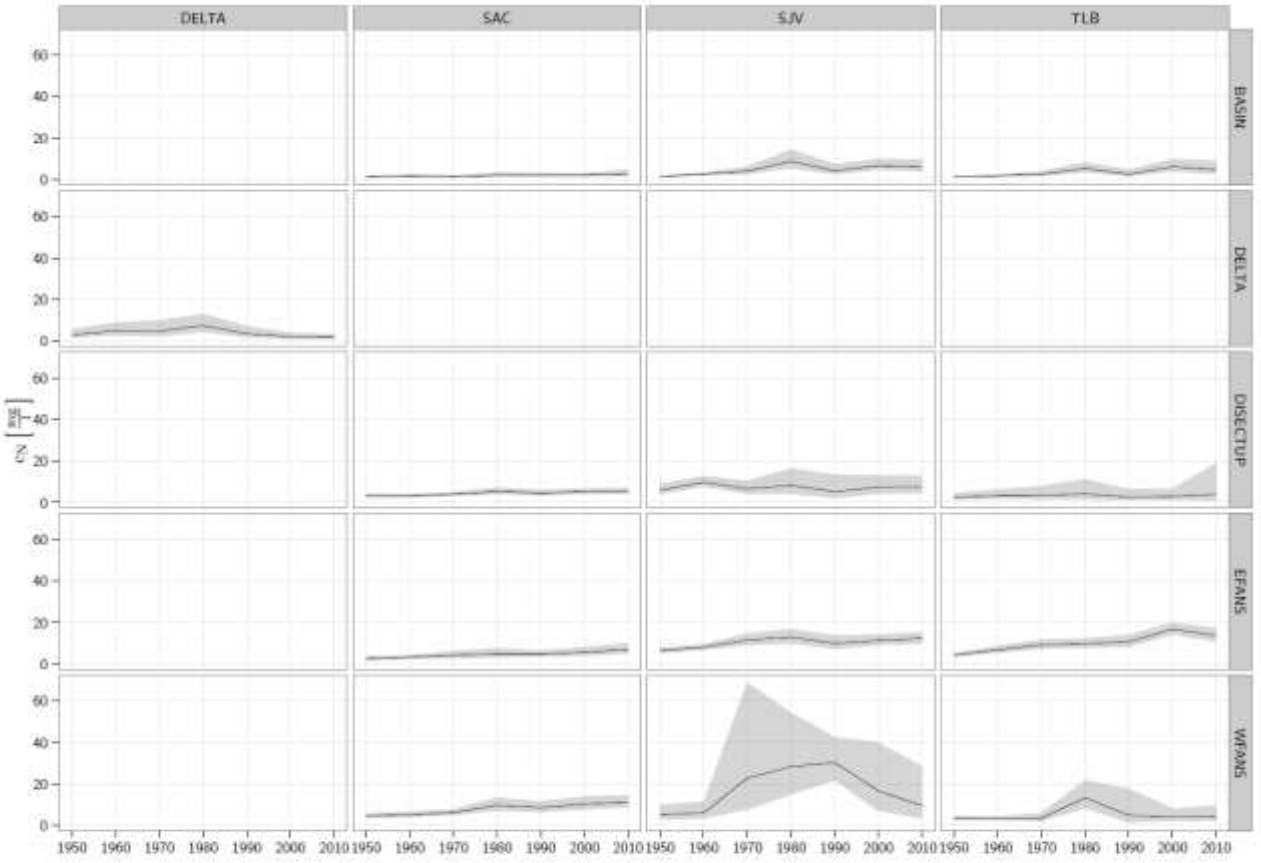


CVSALTS, Tasks 7 and 8 – Salt and Nitrate Analysis for the Central Valley Floor Final Report, December 2013

Figure 7-14

Regional Trend Monitoring:

Concentration,
1940s - current



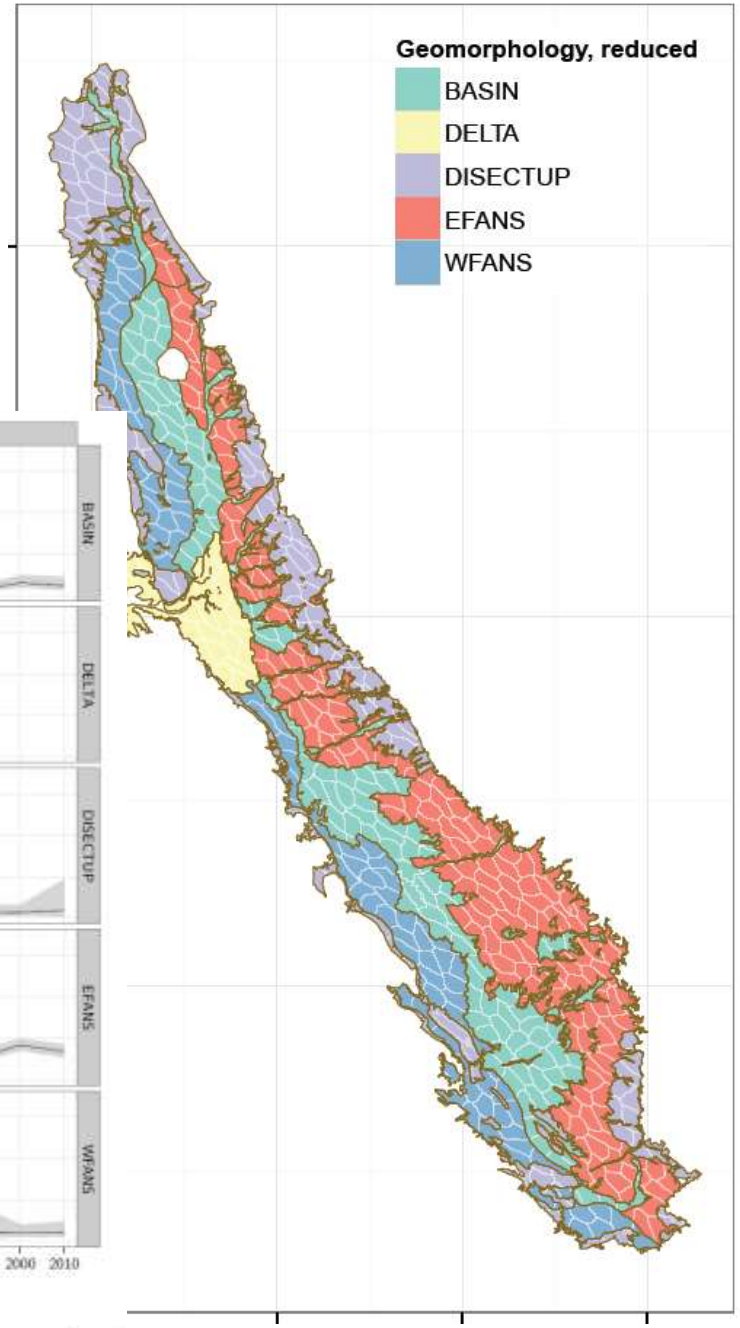


Figure 2.15: Decadal means and confidence intervals of c_N. c_N is the back-transformed median of the logarithmic annual well means in equal area cells.

Geier, Barber, Ransom, Harter, 2015

Regional Trend Analysis:
Exceedance Probabilities, 1940s - Current

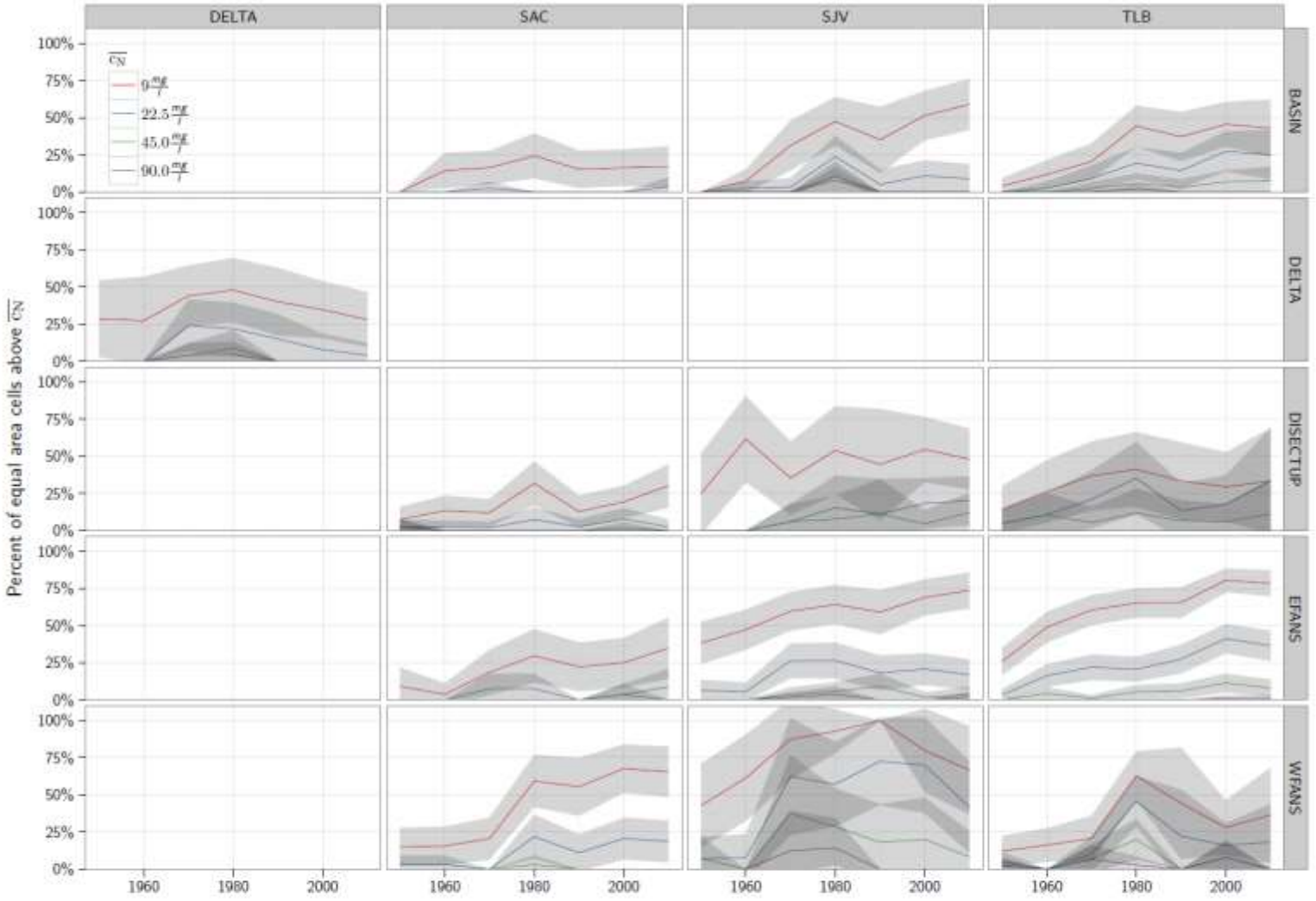


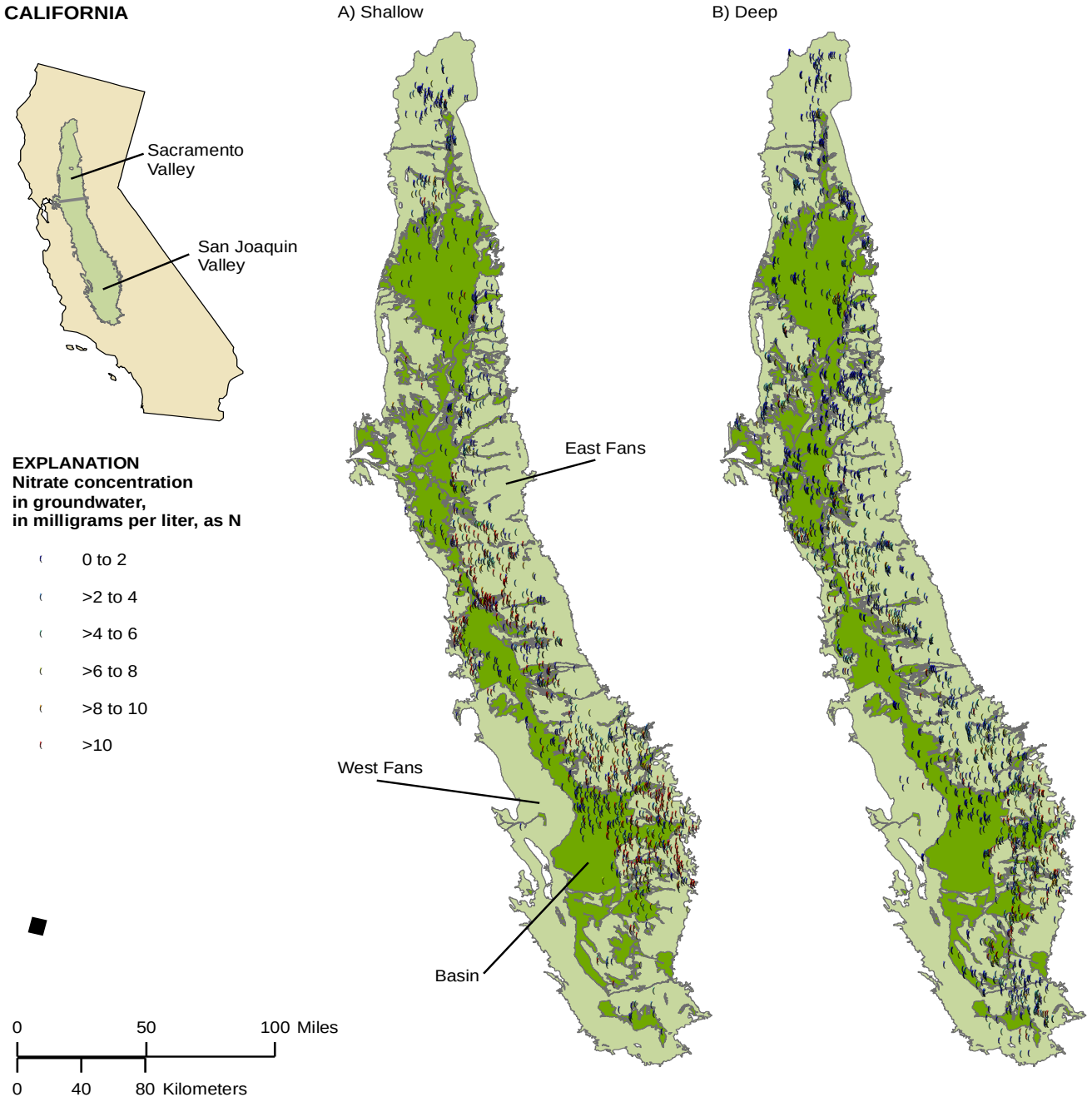
Figure 2.16: Decadal exceedance probability and confidence intervals for different values of $\overline{c_N}$. $\overline{c_N}$ is the back-transformed median of logarithmic annual well means in equal area cells.

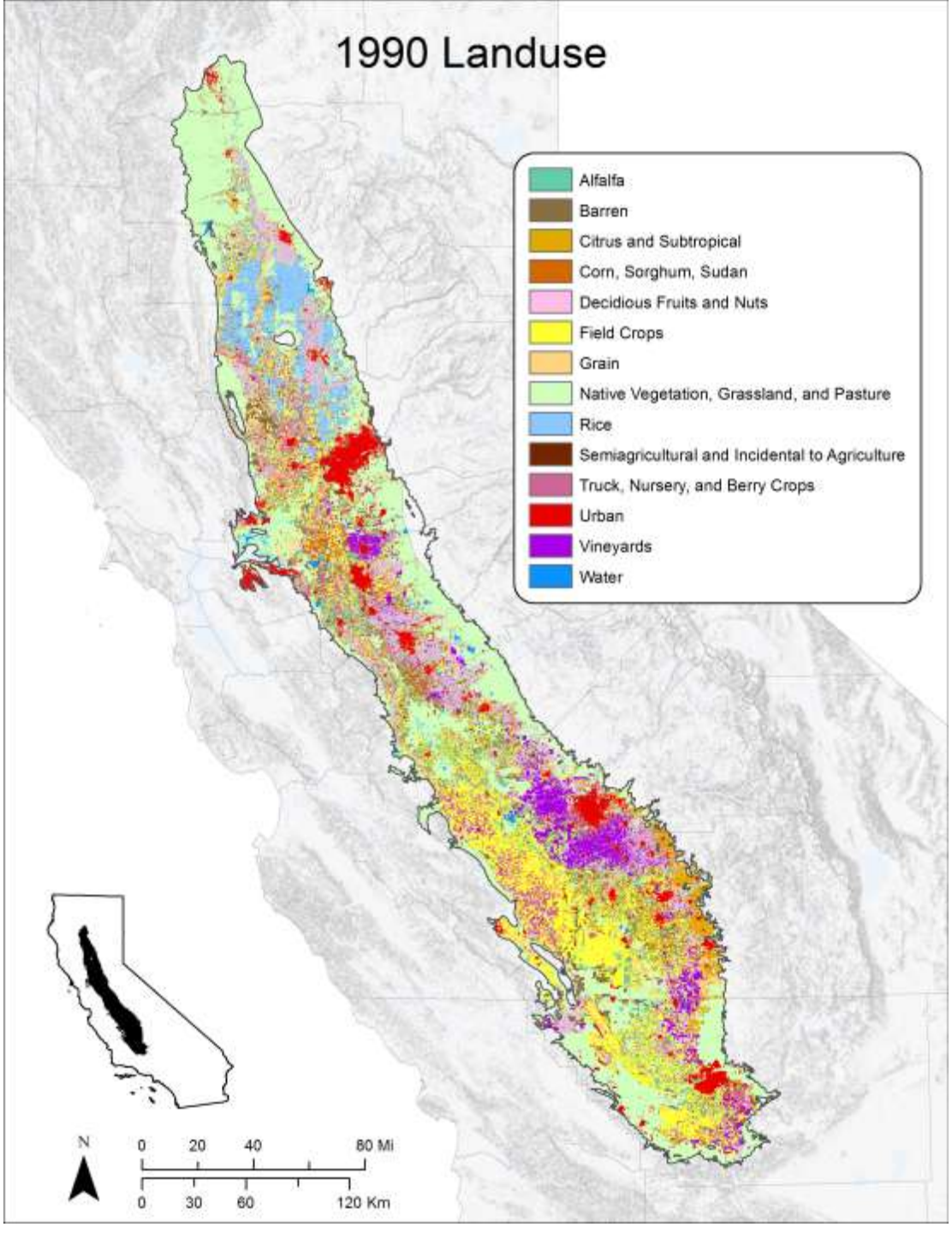
Groundwater Nitrate Data: Basic Statistical Analysis of Spatial and Temporal Patterns

Section	Region	Depth Cat.	#Wells	#EA	Mean $[\frac{mg}{l}]$	Med. $[\frac{mg}{l}]$	$>9\frac{mg}{l}$	$>22.5\frac{mg}{l}$	$>45.0\frac{mg}{l}$	$>90.0\frac{mg}{l}$
		< 200′, priv.	2	3	7.15	7.15	0%	0%	0%	0%
		< 200′, all	6	3	12.84	12.84	100%	0%	0%	0%
		all	1386	39	8.64	10	59.46%	8.11%	2.7%	2.7%
SJV	BASIN	Monitoring	304	16	18.06	16.73	71.43%	42.86%	28.57%	7.14%
		Domestic	128	30	11.15	16.74	64.29%	35.71%	7.14%	0%
		< 200′, priv.	432	17	6.71	6.7	46.67%	40%	13.33%	6.67%
		< 200′, all	518	17	6.74	11	53.33%	33.33%	13.33%	6.67%
		all	2143	55	5.01	5.87	35.85%	9.43%	3.77%	1.89%
	DISECTUP	Monitoring	44	7	23.75	28.86	80%	60%	40%	0%
		Domestic	36	11	14.42	9.16	66.67%	33.33%	11.11%	0%
		< 200′, priv.	1	3	8.84	8.84	0%	0%	0%	0%
		< 200′, all	2	4	19.52	19.52	50%	50%	0%	0%
		all	322	34	8.23	9.83	62.5%	12.5%	9.38%	0%
	EFANS	Monitoring	477	27	31.43	33.45	84%	60%	36%	24%
		Domestic	393	42	35.47	41.45	95%	70%	42.5%	10%
		< 200′, priv.	252	24	18.58	25.45	72.73%	54.55%	13.64%	4.55%
		< 200′, all	372	27	14.38	17.1	64%	48%	12%	4%
		all	3657	69	11.23	12.87	62.69%	13.43%	2.99%	1.49%
	WFANS	Monitoring	145	6	39.79	27.41	75%	50%	50%	25%
		Domestic	41	9	36.23	41.5	85.71%	85.71%	42.86%	0%
		< 200′, priv.	189	11	15.97	20	66.67%	44.44%	33.33%	33.33%
		< 200′, all	191	11	17.99	44.67	66.67%	55.56%	44.44%	33.33%
		all	1008	20	15.76	20.17	77.78%	44.44%	22.22%	5.56%

Geier, Barber, Ransom, Harter, 2015

What does this tell us about historic nitrogen loading from various landuses?

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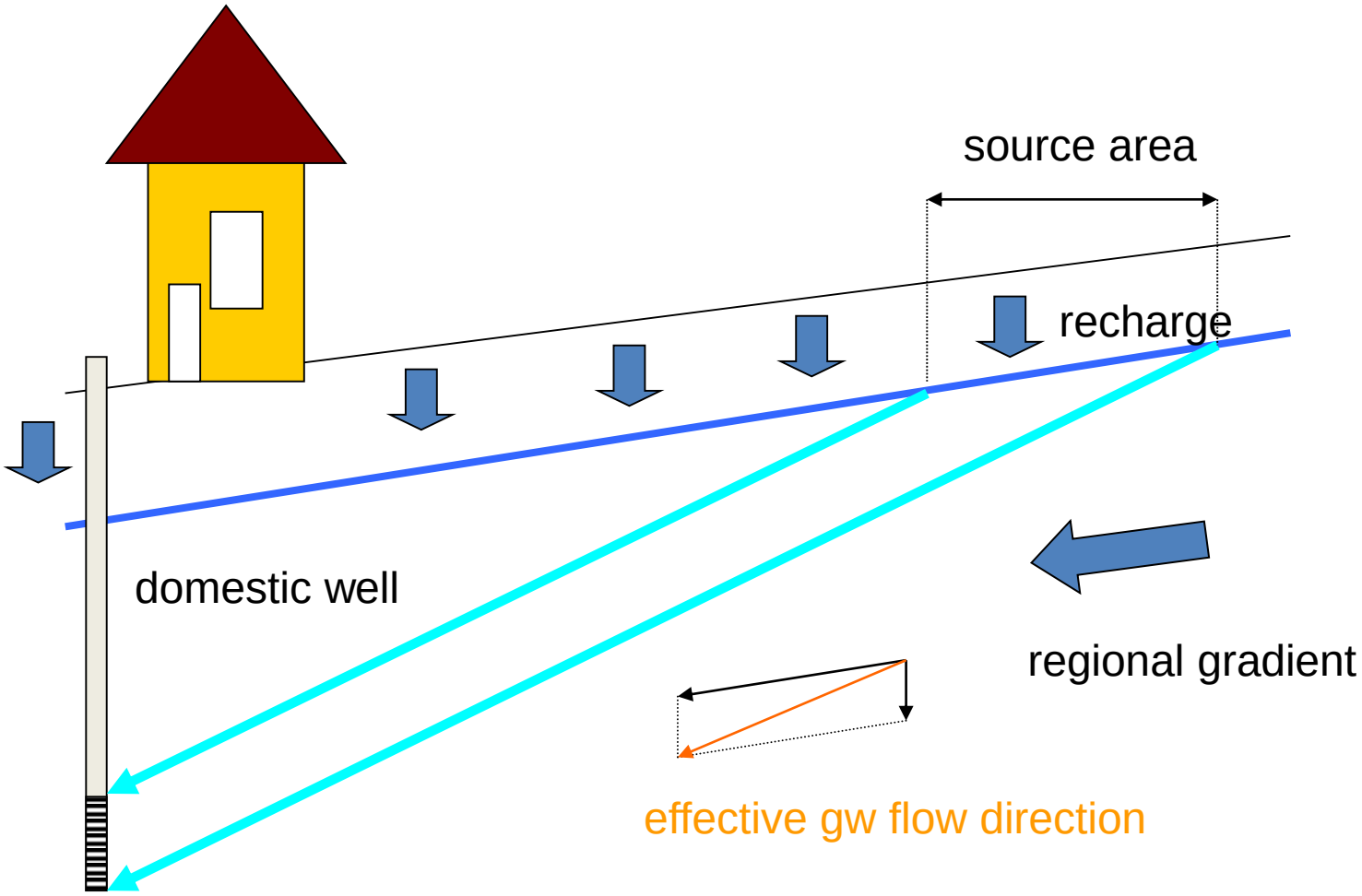
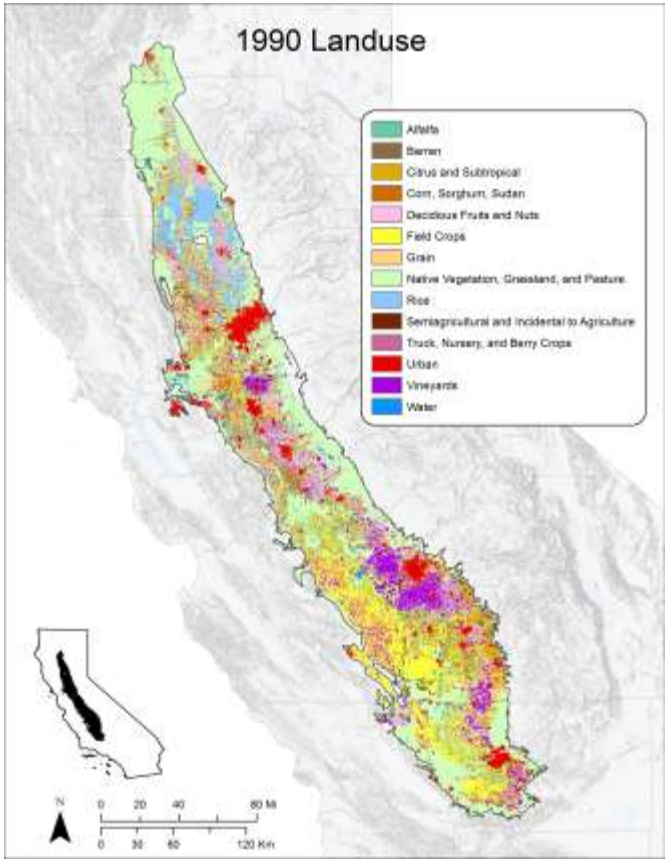
Monitoring in Domestic Wells





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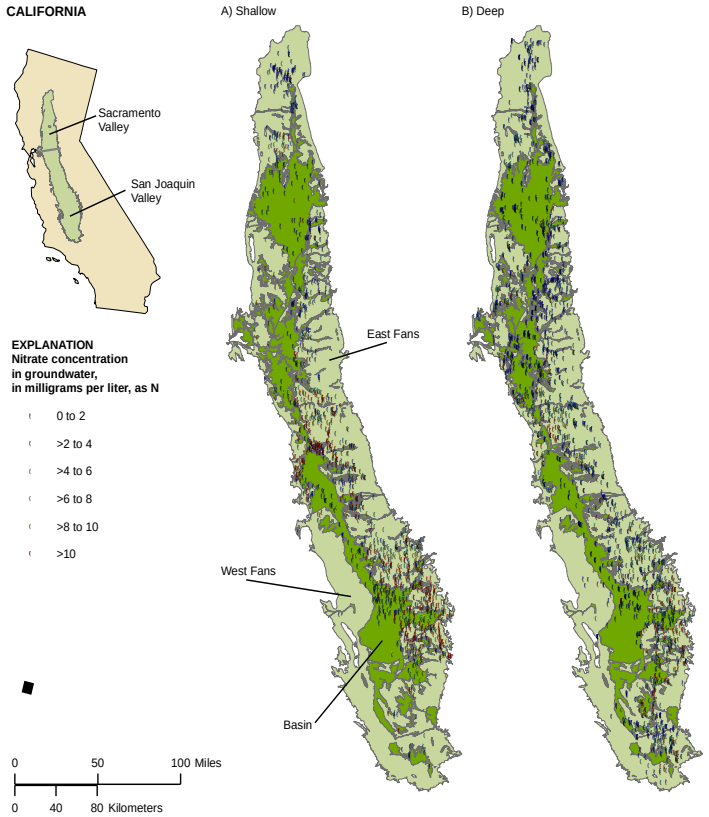
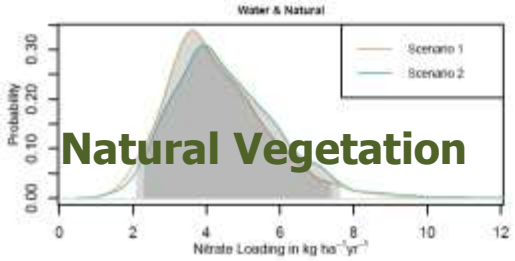


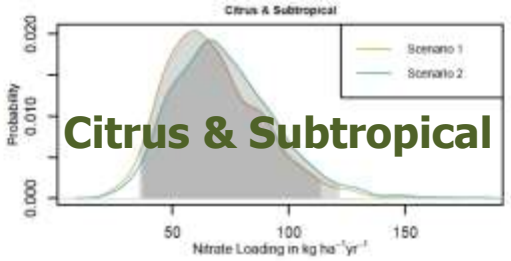
Bayesian (Statistical) Mixing Model to Estimate Crop/Landuse Type Specific N Loading

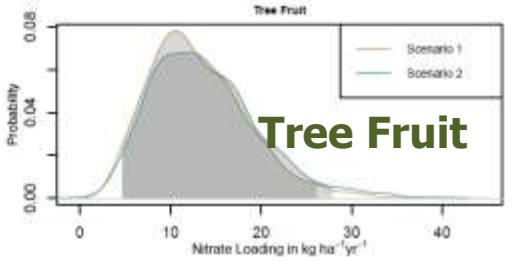
Estimated Nitrogen Loading at Time of Recharge [kg N/ha/yr]

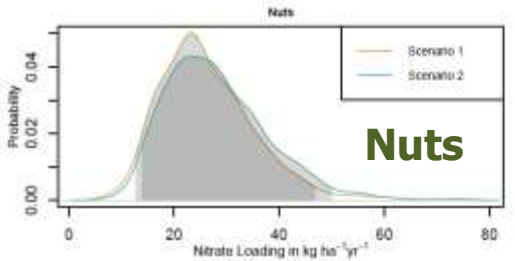
(1970s – 1990s)

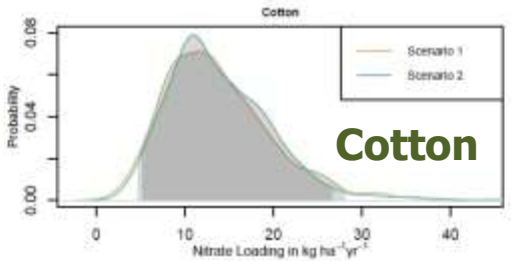
By Crop / Landuse Type

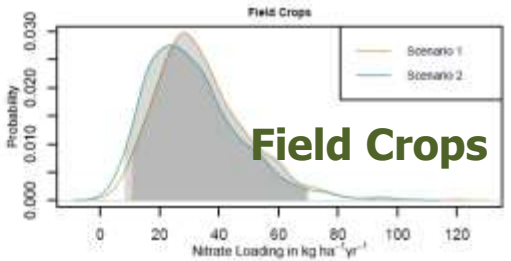


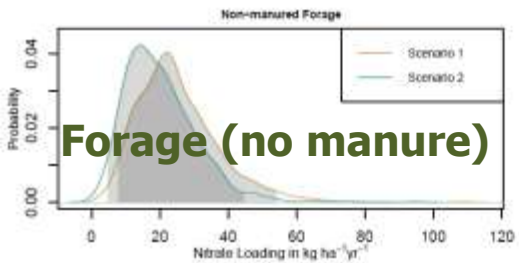


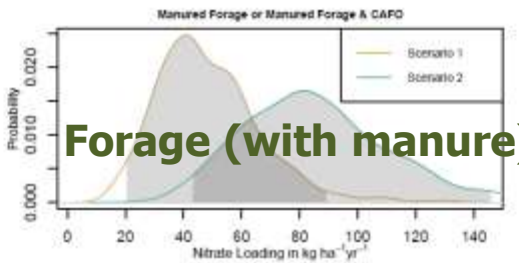


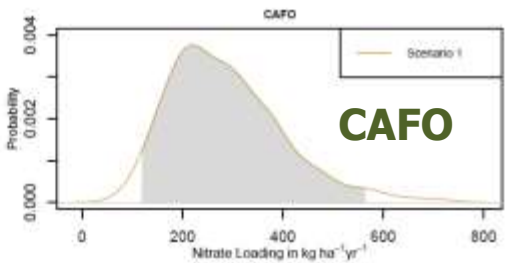


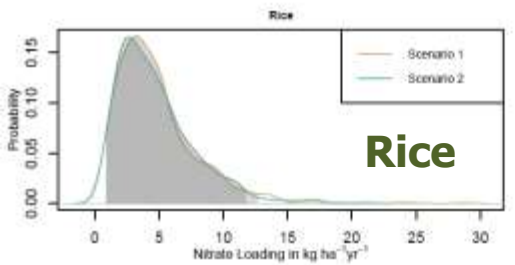


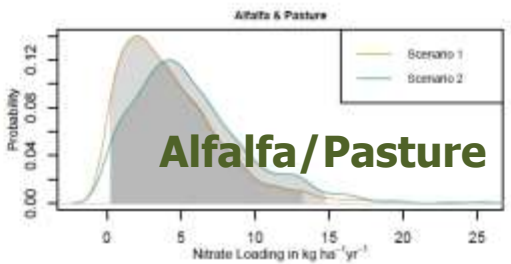


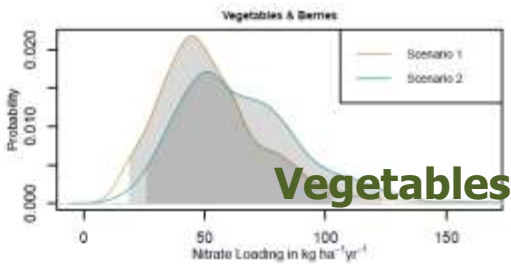


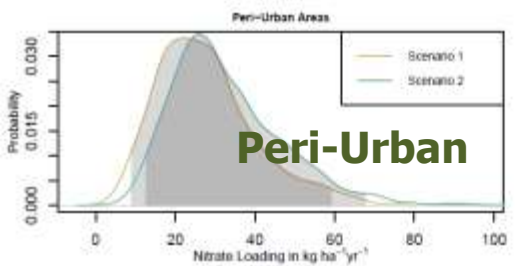


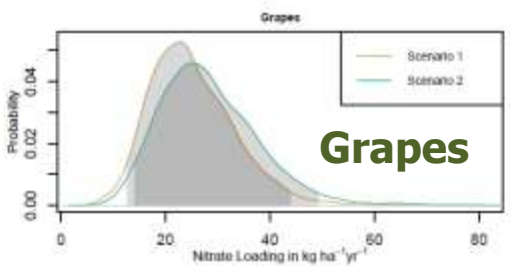


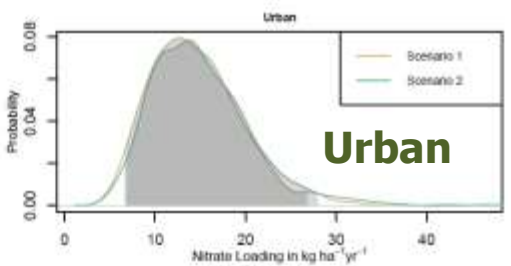










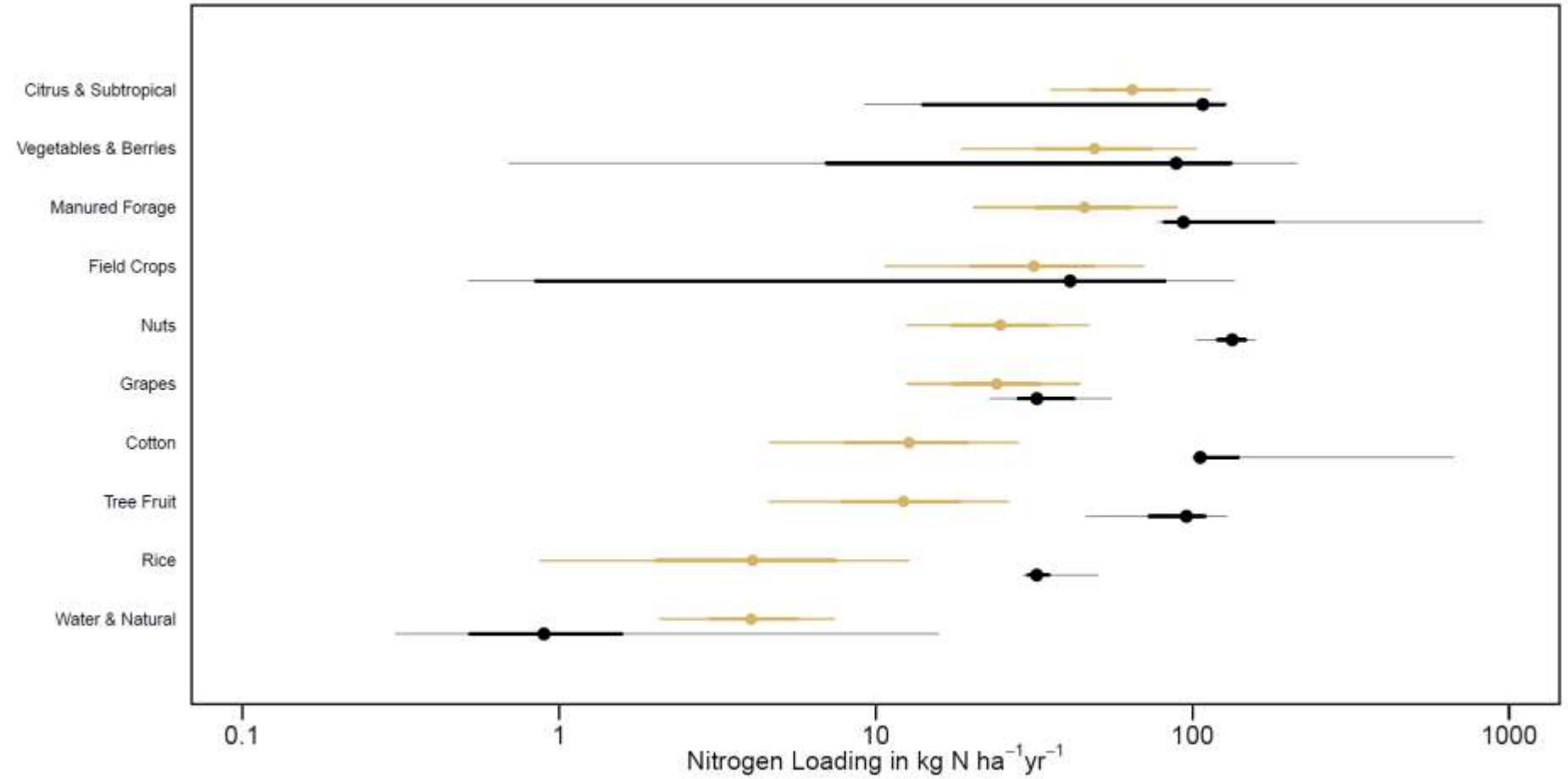


Ransom et al., HESS (in review)

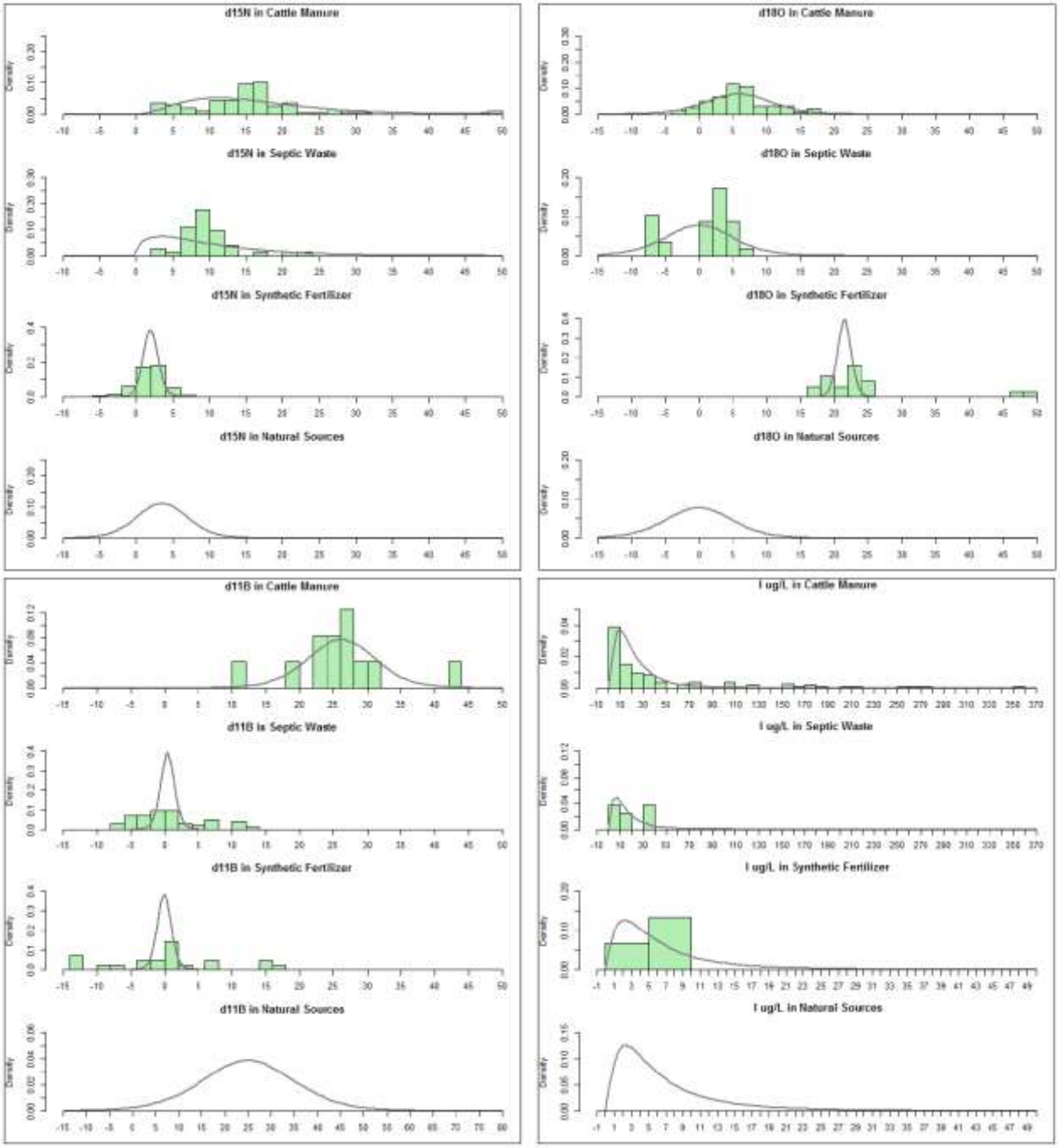
Comparison of N Loading to Groundwater, by Landuse

N Mass Balance Based Estimate

Groundwater Nitrate Based Estimate



Bayesian Estimation of Source Fractional Contributions



Sources:

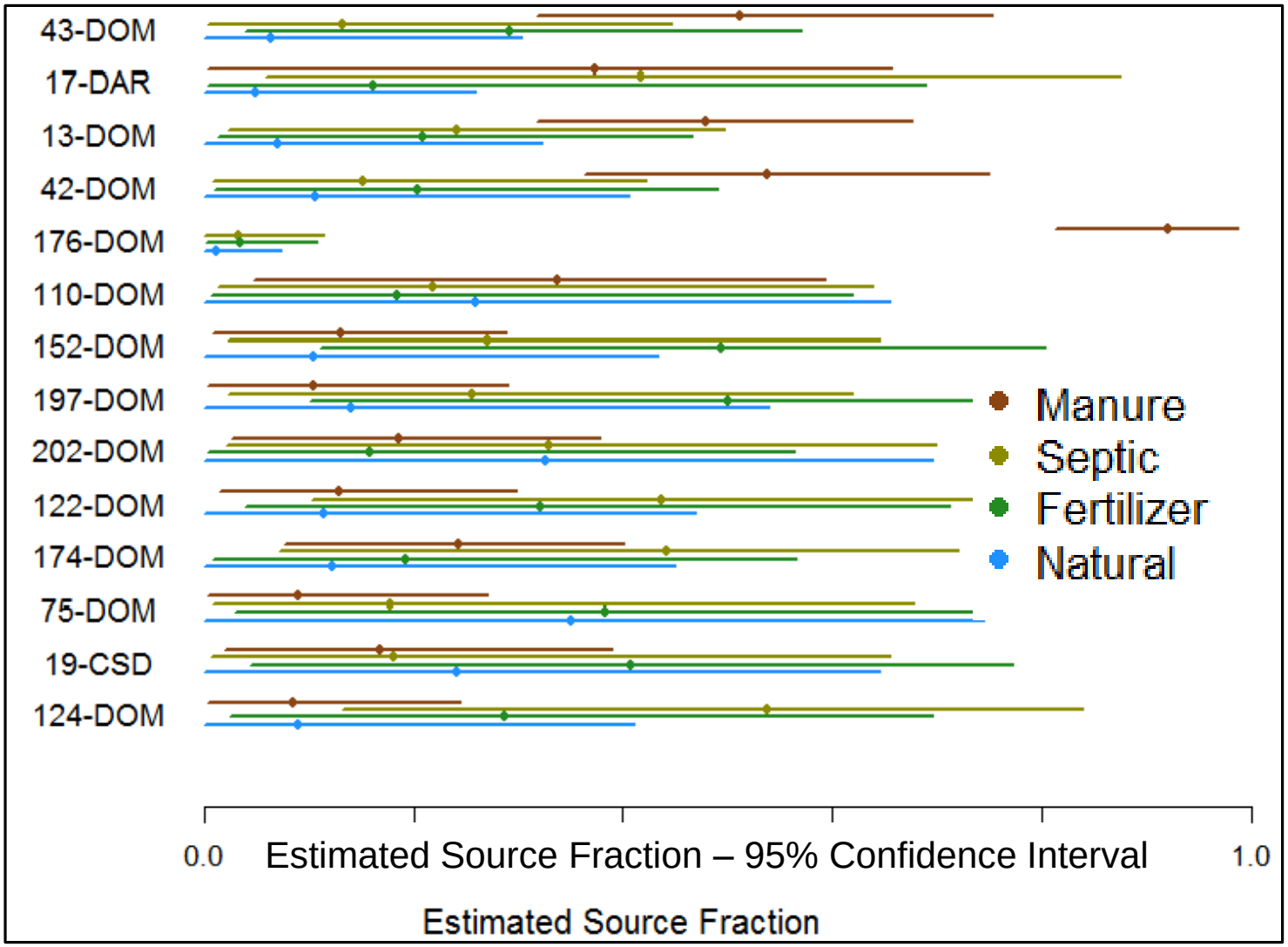
- Synthetic fertilizer
- Manure
- Septic systems
- Natural sources

Tracer:

- Nitrate 15N
- Nitrate 18O
- Boron-11
- Iodide

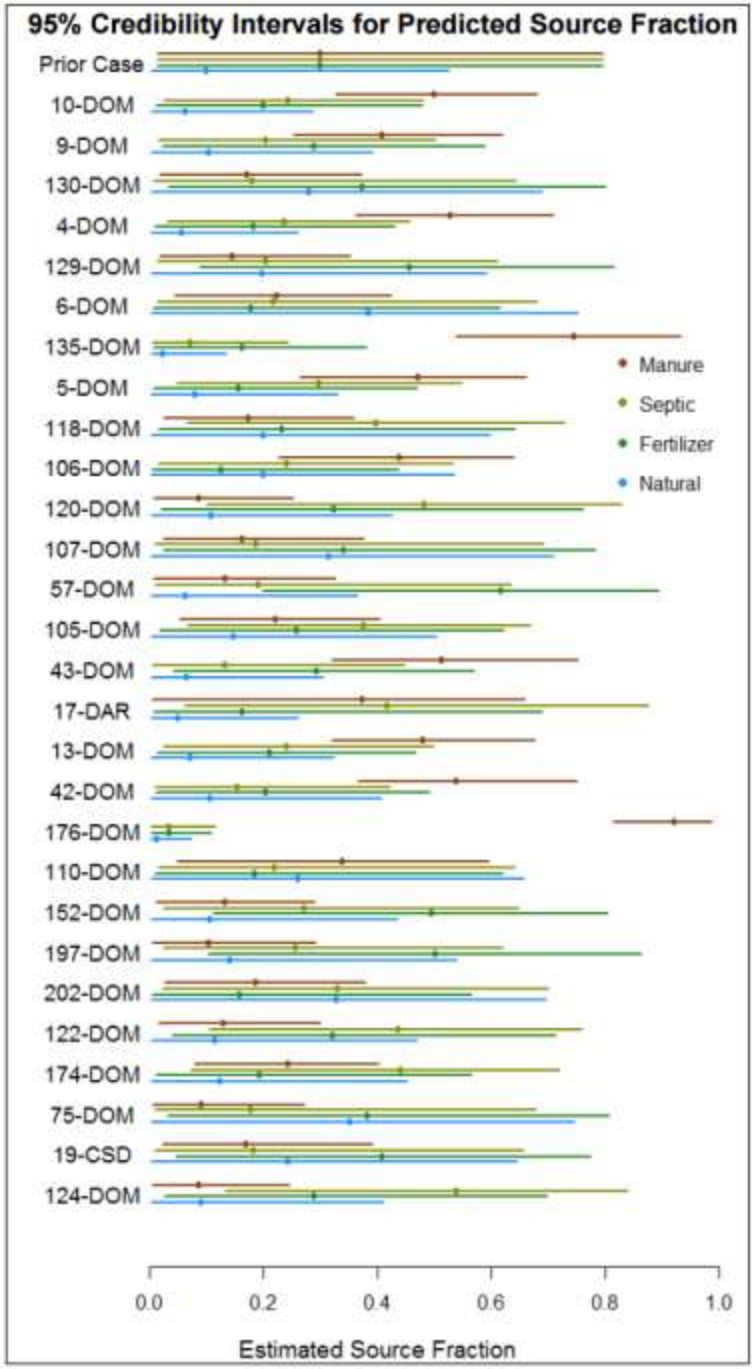
Ransom et al., WRR (submitted)

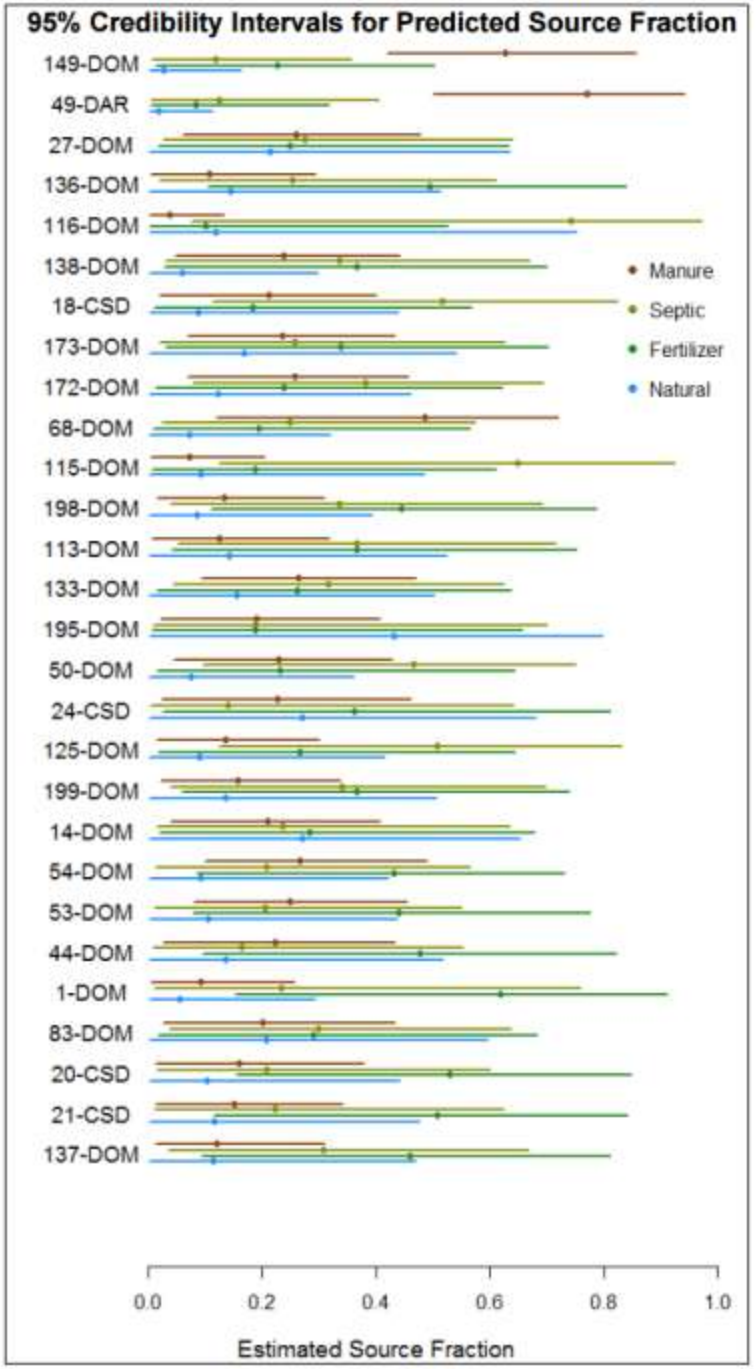
Bayesian Estimation of Source Fractional Contributions using Nitrate and Boron isotopes, Iodide



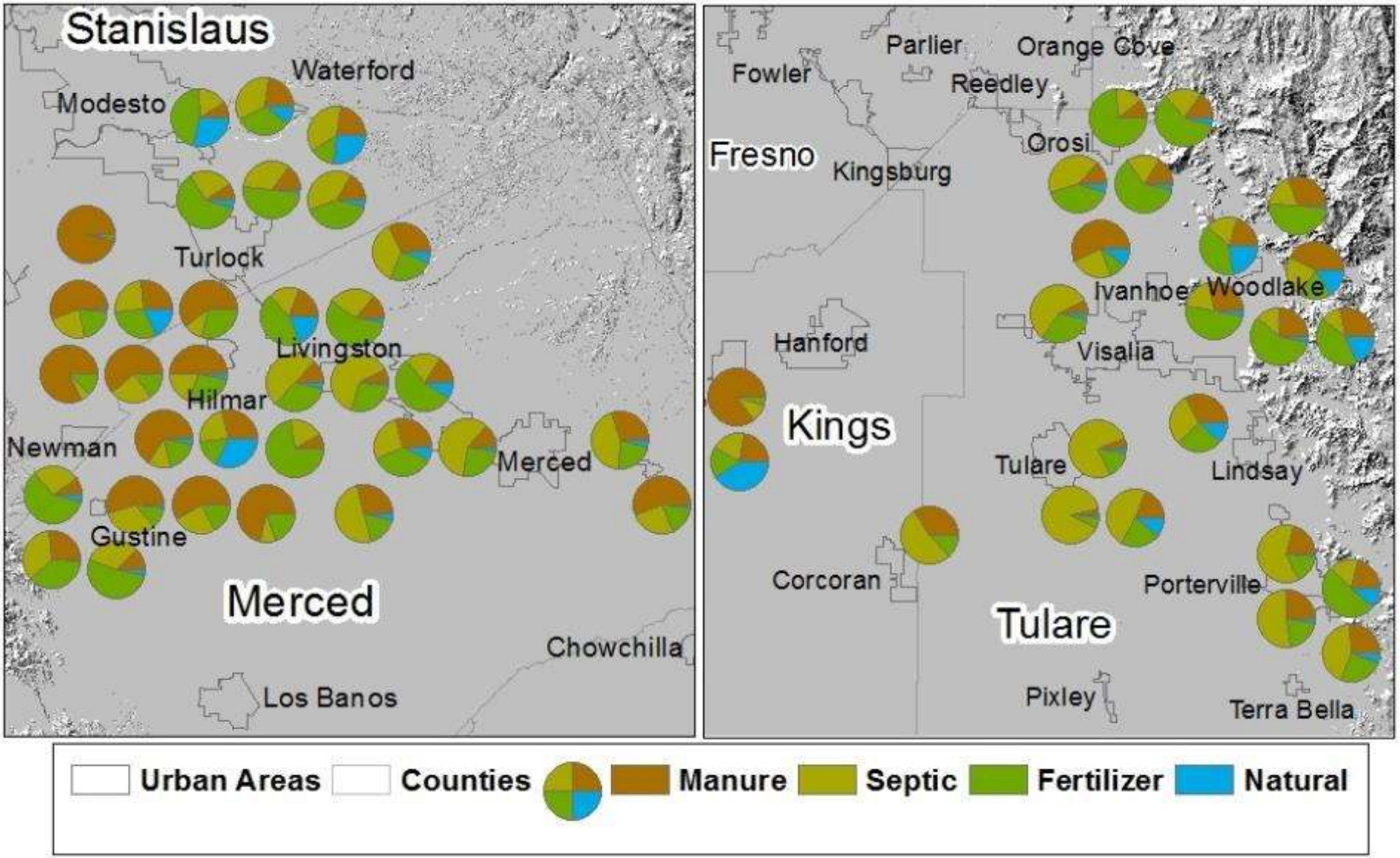
Model produces a probability distribution of fractional contribution from each source to overall nitrate value, for each well.

Ransom et al., WRR (submitted)


95% Credibility Intervals for Predicted Source Fraction
Prior Case
10-DOM
9-DOM
130-DOM
4-DOM
129-DOM
6-DOM
135-DOM
5-DOM
118-DOM
106-DOM
120-DOM
107-DOM
57-DOM
105-DOM
43-DOM
17-DAR
13-DOM
42-DOM
176-DOM
110-DOM
152-DOM
197-DOM
202-DOM
122-DOM
174-DOM
75-DOM
19-CSD
124-DOM
Manure
Septic
Fertilizer
Natural
0.0
0.2
0.4
0.6
0.8
1.0
Estimated Source Fraction

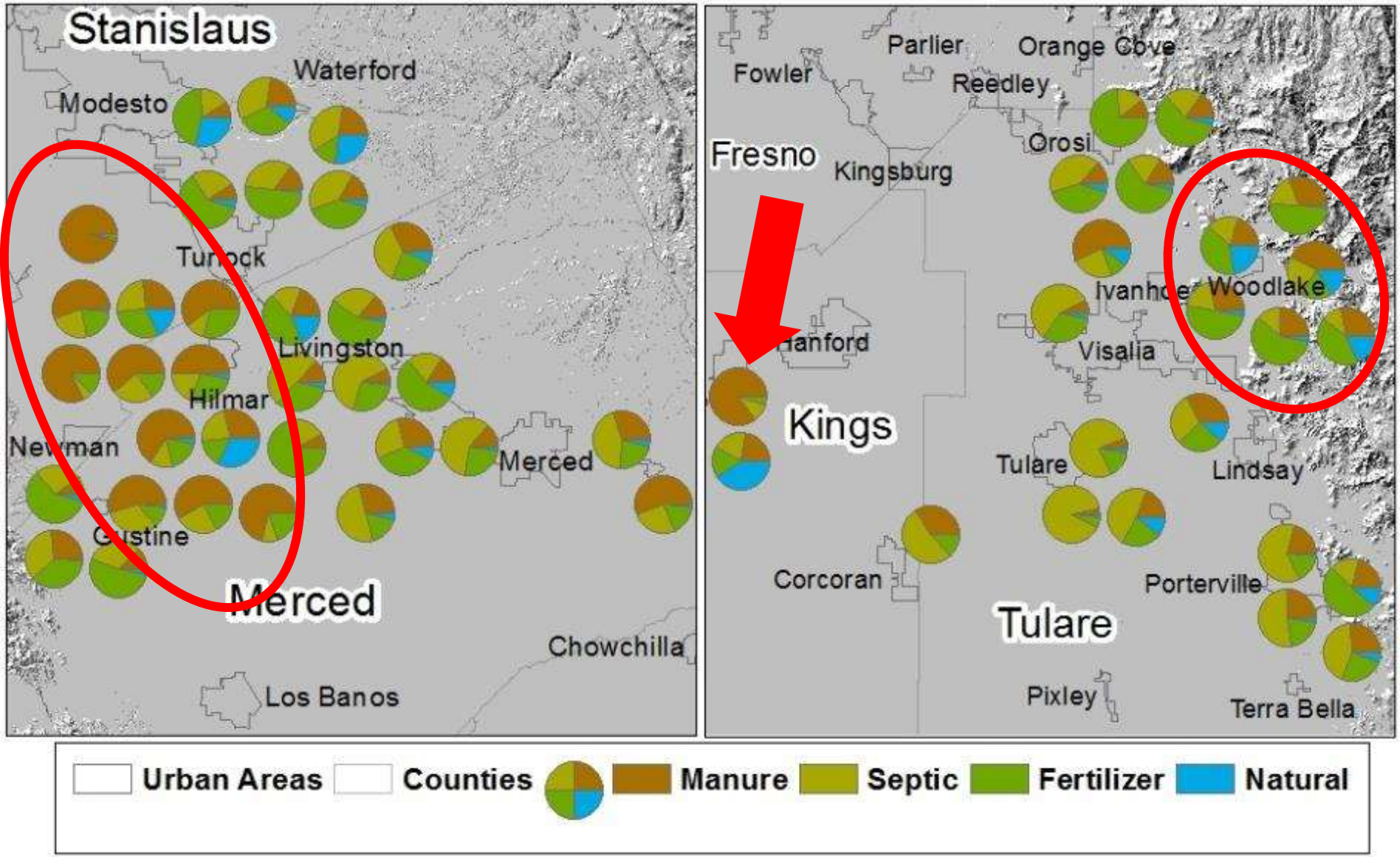

95% Credibility Intervals for Predicted Source Fraction
149-DOM
49-DAR
27-DOM
136-DOM
116-DOM
138-DOM
18-CSD
173-DOM
172-DOM
68-DOM
115-DOM
198-DOM
113-DOM
133-DOM
195-DOM
50-DOM
24-CSD
125-DOM
199-DOM
14-DOM
54-DOM
53-DOM
44-DOM
1-DOM
83-DOM
20-CSD
21-CSD
137-DOM
Manure
Septic
Fertilizer
Natural
0.0
0.2
0.4
0.6
0.8
1.0
Estimated Source Fraction

Bayesian Estimation of Source Fractional Contributions



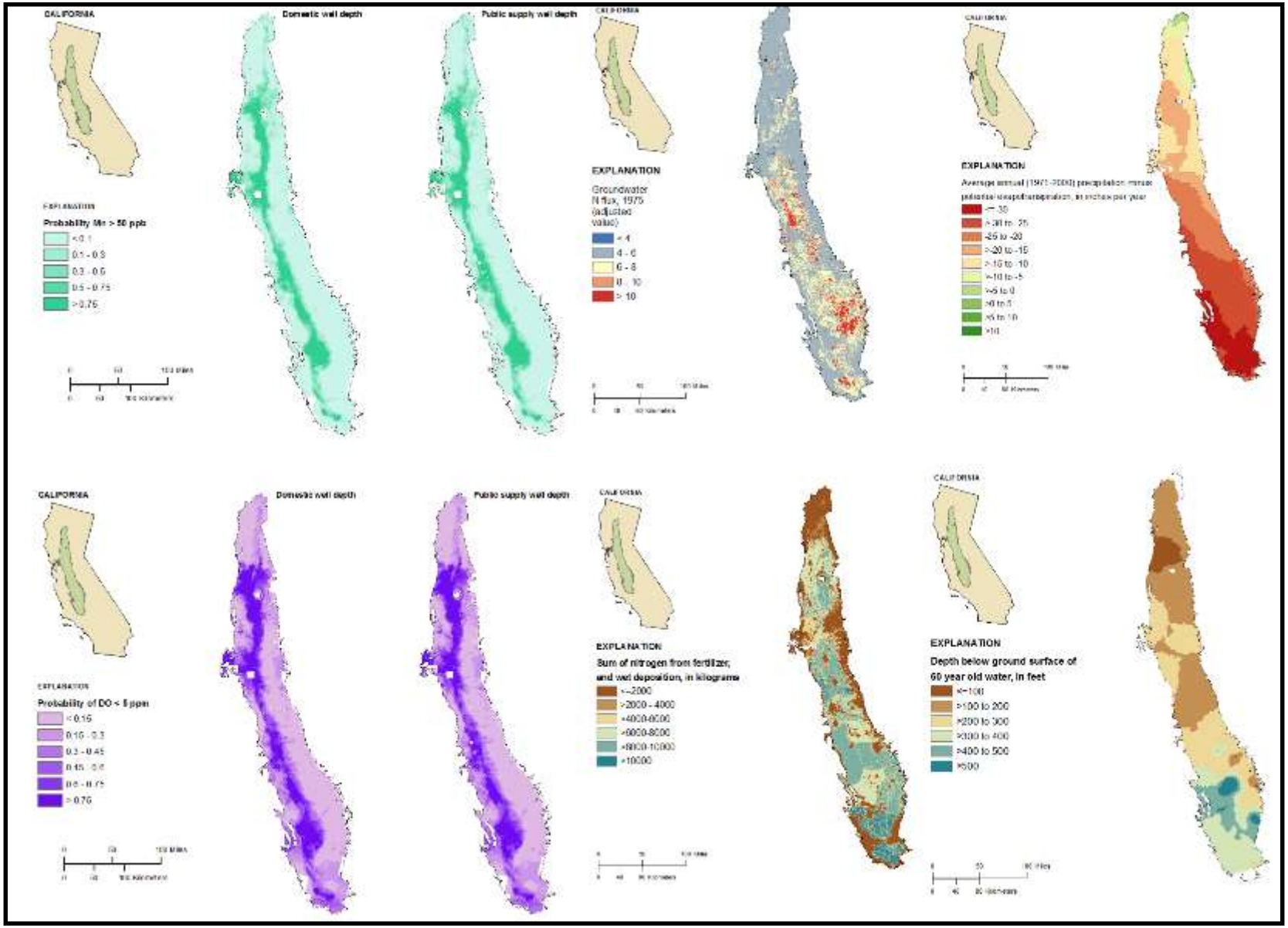
Ransom et al., WRR (submitted)

Bayesian Estimation of Source Fractional Contributions



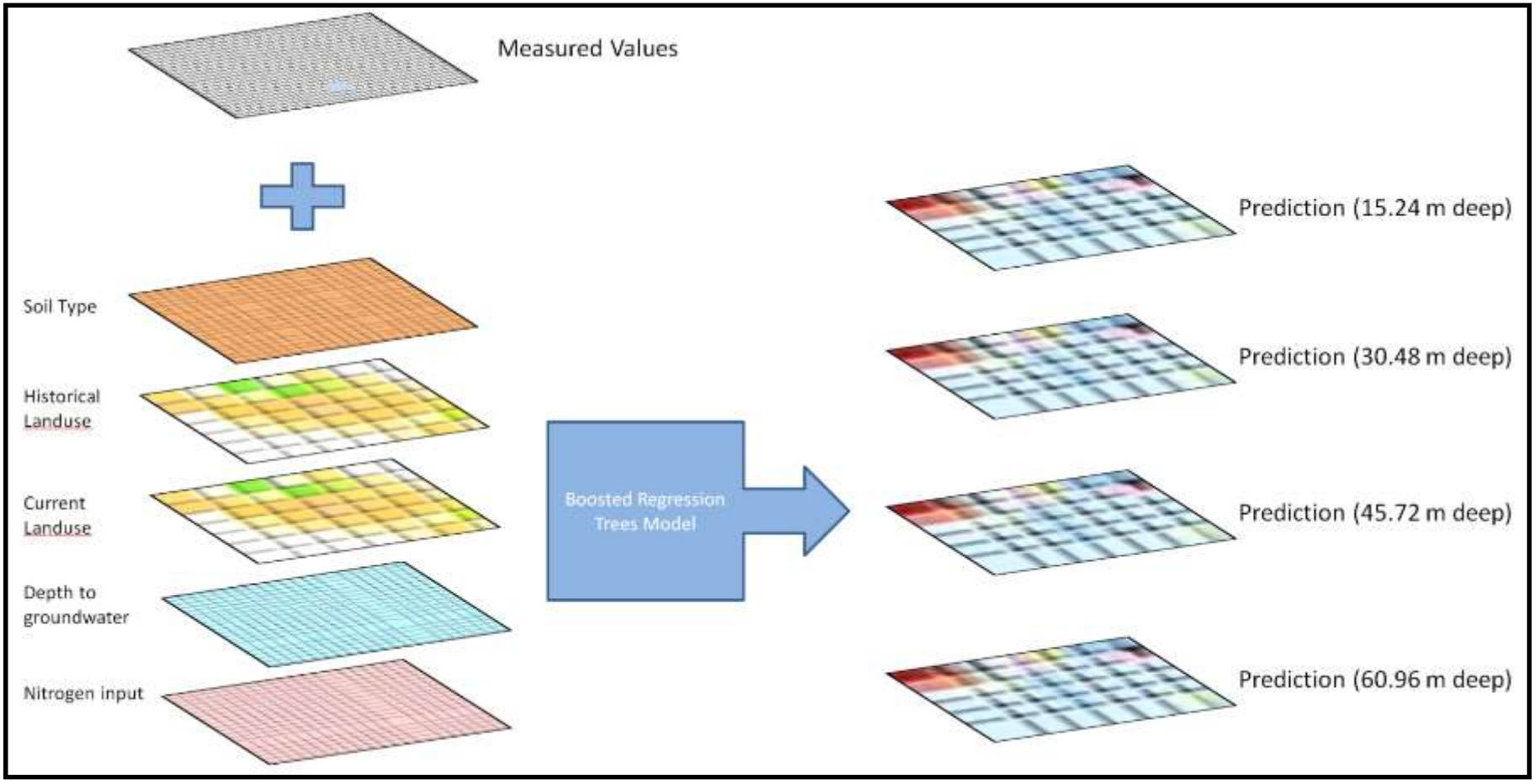
Ransom et al., WRR (submitted)

Data Scouring to Understand Groundwater Nitrate



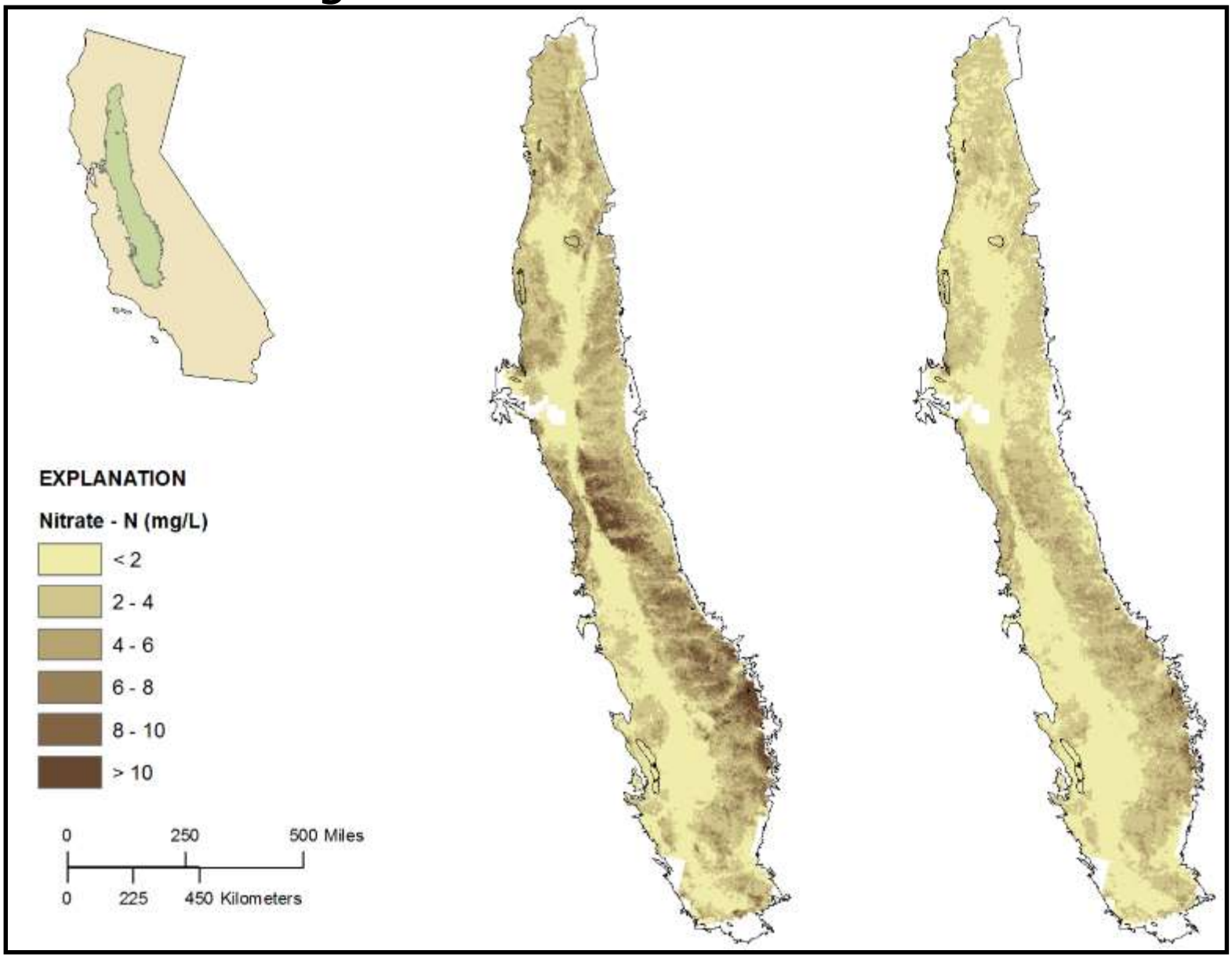
Ransom et al., STotEnv 2017

Data Scouring to Understand Groundwater Nitrate



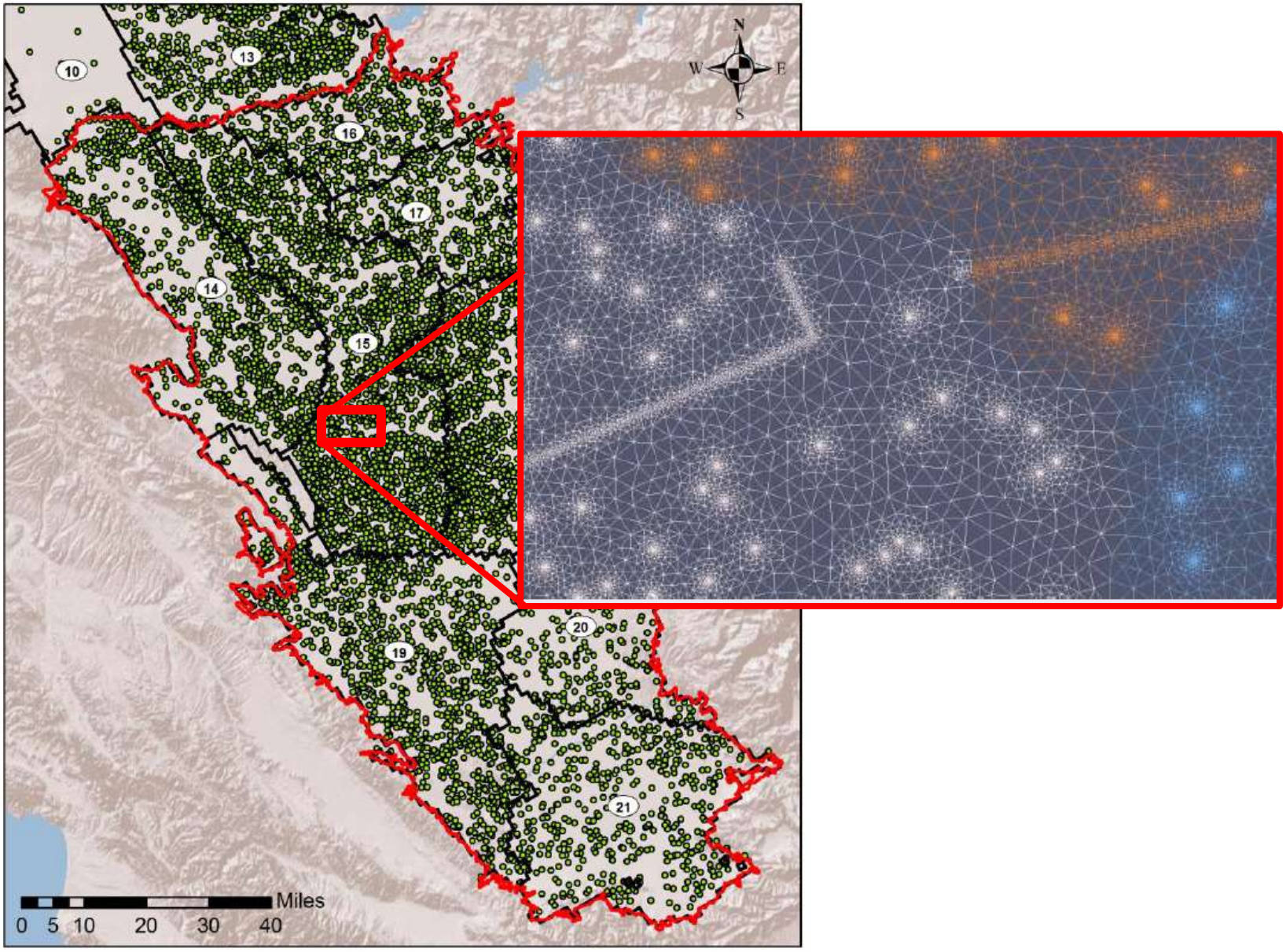
Ransom et al., STotEnv 2017

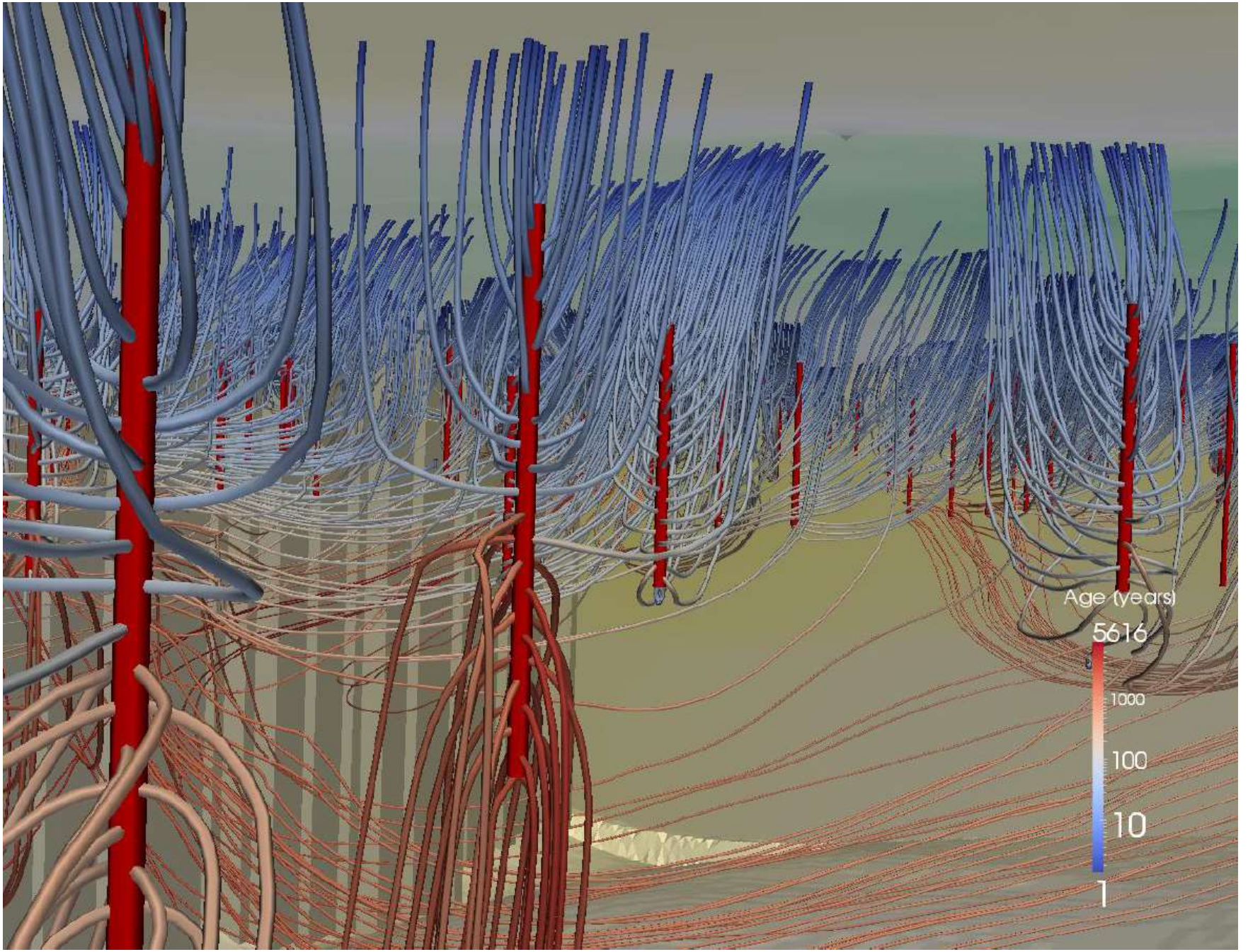
Data Scouring to Understand Groundwater Nitrate

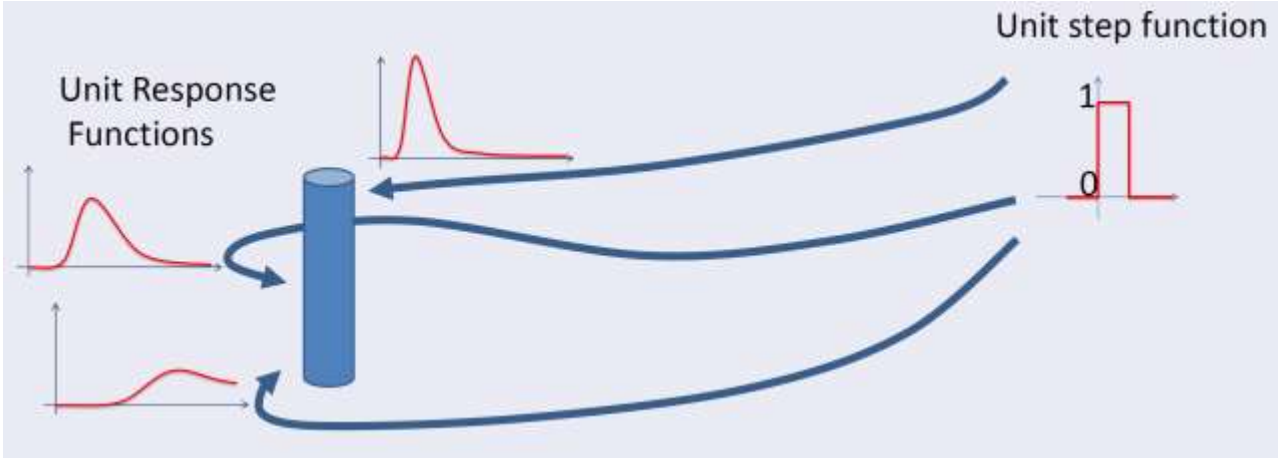


Ransom et al., STotEnv 2017

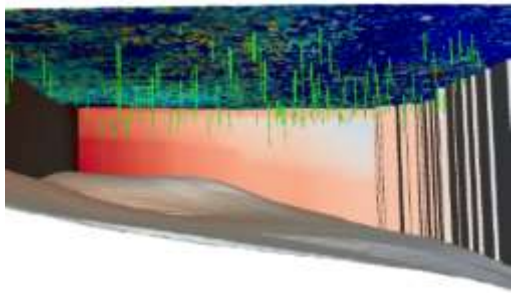
Numerical Model: Capture Wells and Streams at High Resolution

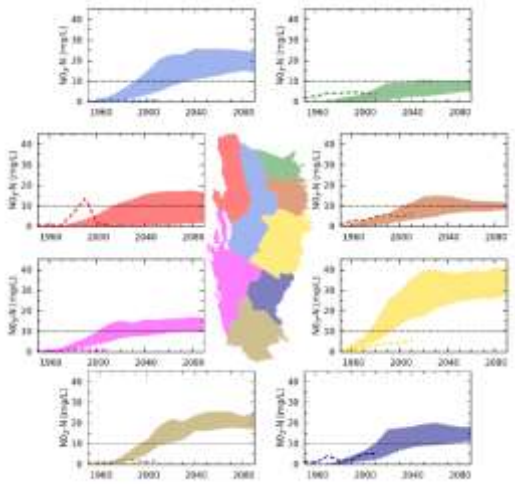


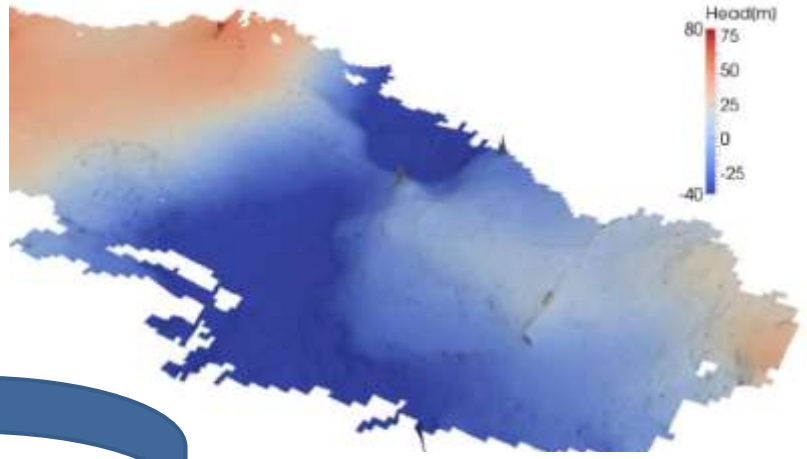

Age (years)
5616
1000
100
10
1

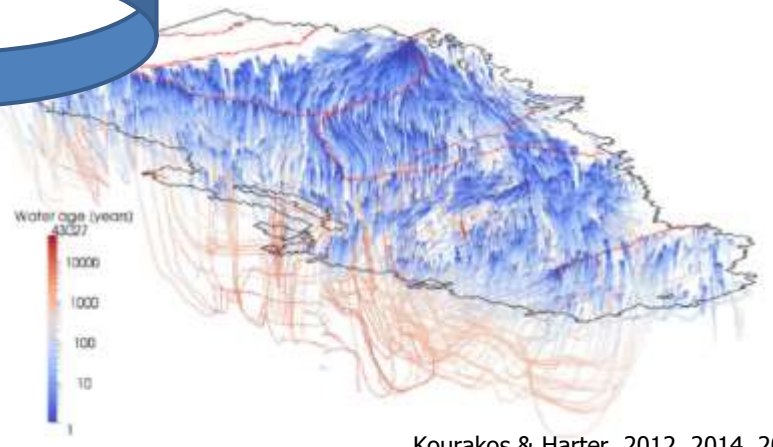

Unit step function
Unit Response
Functions
1
0

Aquifer Scale Analysis of NPS Pollution Impacts & Remediation









Kourakos & Harter, 2012, 2014, 2014