

SBX2 1 Nitrate in Drinking Water: UC Davis “N Tracking Analysis” to Estimate Potential Groundwater N Loading



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All technical details are documented in Viers et al. (2012), <http://groundwaternitrate.ucdavis.edu/files/139110.pdf>

Purpose and Expected Outcome

SBX2 1 (Perata, 2008) – Water Code Section 83002.5: “To **improve understanding of the causes of groundwater contamination** [...], the State Water Resources Control Board [...] shall develop pilot projects in the Tulare Lake Basin and the Salinas Valley that **focus on nitrate contamination** and do all of the following:

(a) (1) [...] utilizing existing data [...] along with the collection of new information as needed [...]:

- (A) **Identify sources, by category of discharger**, of groundwater contamination due to nitrates in the pilot project basins.
- (B) **Estimate proportionate contributions to groundwater** contamination by source and category of discharger.

(emphasis added for clarity)

[...]”



Data Elements 1 – N Leaching Estimation

1. Some N Leaching to groundwater was estimated using literature-derived or permit-specified leaching values (spatial scale identified in parentheses):
 - Lawns (available maps of urban area boundaries)
 - Golf courses (parcels in DWR landuse survey)
 - Urban wastewater system leaching (available maps of urban area boundaries)
 - Wastewater treatment plants, food processors (location from discharge permit records)
 - Septic systems (estimated density/location based on US census, 1990)
 - Dairy lagoons and corrals (digitized/mapped from aerial photos)
 - Alfalfa (leguminous crop) (parcels in DWR landuse survey)
2. Farmland N leaching to groundwater (except alfalfa) was estimated by N mass balance (by individual parcels in DWR landuse survey):

N leached to groundwater =

N inputs to farmland *MINUS* N outputs from farmland root zone

(that is: N outputs other than N leached to groundwater)

Data Elements 2 – Potential Farmland N Inputs

- Synthetic fertilizer N
- Wastewater treatment plant / food processor effluent N
- Biosolids N
- Dairy manure N (on dairy-farm or exported)
- Atmospheric deposition N
- Irrigation water N



Data Elements 3: Potential Farmland N Outputs

- Atmospheric losses N (ammonia volatilization, denitrification)
- Harvested N
- Surface runoff N
- *Groundwater leaching N (estimated)*
- *Storage changes in perennial crops/root zone N*: we assumed to be negligible due to long-term averaging of N fluxes, recycling of plant residues, and lack of significant, wide-spread build-up of organic matter across the project area soils over the past decades.



Explaining the Mass Balance Approach to Estimate N Leaching to Groundwater

Mass balance requires that:

$$\begin{array}{l} \text{Synthetic fertilizer N} \\ + \\ \text{Wastewater effluent N} \\ + \\ \text{Biosolids N} \\ + \\ \text{Dairy manure N} \\ + \\ \text{Atmospheric deposition N} \\ + \\ \text{Irrigation water N} \end{array} = \begin{array}{l} \text{Atmospheric losses N} \\ + \\ \text{Harvested N} \\ + \\ \text{Surface runoff N} \\ + \\ \text{Leaching N to groundwater} \\ + \\ \text{Storage Change in N in root zone} \end{array}$$



Explaining the Mass Balance Approach to Estimate N Leaching to Groundwater

After setting “storage change in N” to zero and rearranging the mass balance equation, we obtain the following formula to estimate N leaching to groundwater:

$$\begin{array}{c} \boxed{\begin{array}{c} \text{Leaching N} \\ \text{to} \\ \text{groundwater} \end{array}} = \boxed{\begin{array}{c} \text{Synthetic fertilizer N} \\ + \\ \text{Wastewater effluent N} \\ + \\ \text{Biosolids N} \\ + \\ \text{Dairy manure N} \\ + \\ \text{Atmospheric deposition N} \\ + \\ \text{Irrigation water N} \end{array}} - \boxed{\begin{array}{c} \text{Atmospheric losses N} \\ + \\ \text{Harvested N} \\ + \\ \text{Surface runoff N} \end{array}} \end{array}$$



Spatial Scale: Resolution of Available Data

- Many different spatial scales – examples:
 - Aerial N deposition: modeled for California at a model grid resolution scale of several miles
 - Wastewater treatment plant: very specific N data, local maps
 - Nitrate in irrigation water: average (one number) for each groundwater sub-basin
 - N application and N harvest: by crop type (58 crop types; no distinction by soil, farm, ownership, irrigation type, location etc.)
 - Atmospheric losses of N from root zone: 10% of total N application (uniform across study area)
 - Landuse
 - DWR landuse maps: high resolution (landuse parcels, meter scale accuracy)
 - County Agricultural Commissioner reports: county total landuse acreages



Spatial Scale: Assessment/Analysis

- N Mass Balance / Estimation of Nitrate Loading to Groundwater was performed at 4 different scales (resolution):
 - 50 m x 50 m grid cells for spatial mapping (“pixels”)
 - Discharger category totals and averages
 - County totals and averages (Fresno, Kern, Kings, Monterey, Tulare)
 - Study area totals and averages (Tulare Lake Basin & Salinas Valley)



The next slide shows, in map form, the mass balance procedure used to estimate groundwater N loading. Please note that

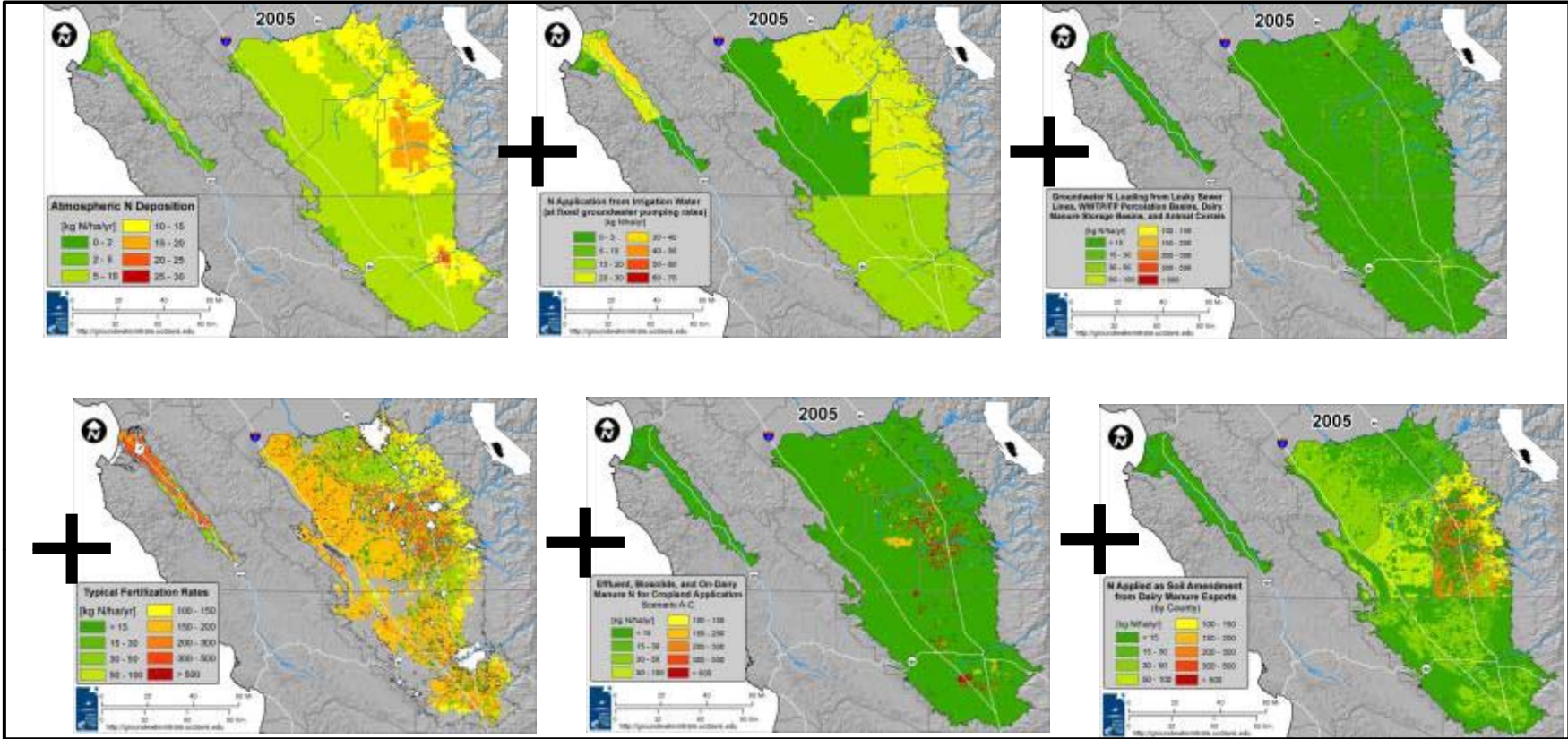
- Storage change of N in the root zone is assumed to zero.
- The atmospheric loss N output is assumed to be 10% of all N inputs. Hence, it is accounted for by multiplying the sum of all N inputs with 0.9 before subtracting the two other outputs (harvest and runoff).
- The spatial resolution of the maps is 50 m x 50 m pixels (about 1 acre). The mass balance was computed separately for each pixel.

The second slide (after the next) shows the mass balance equation at a different spatial (resolution) scale: The pie-chart represents N fluxes aggregated over the entire study area.

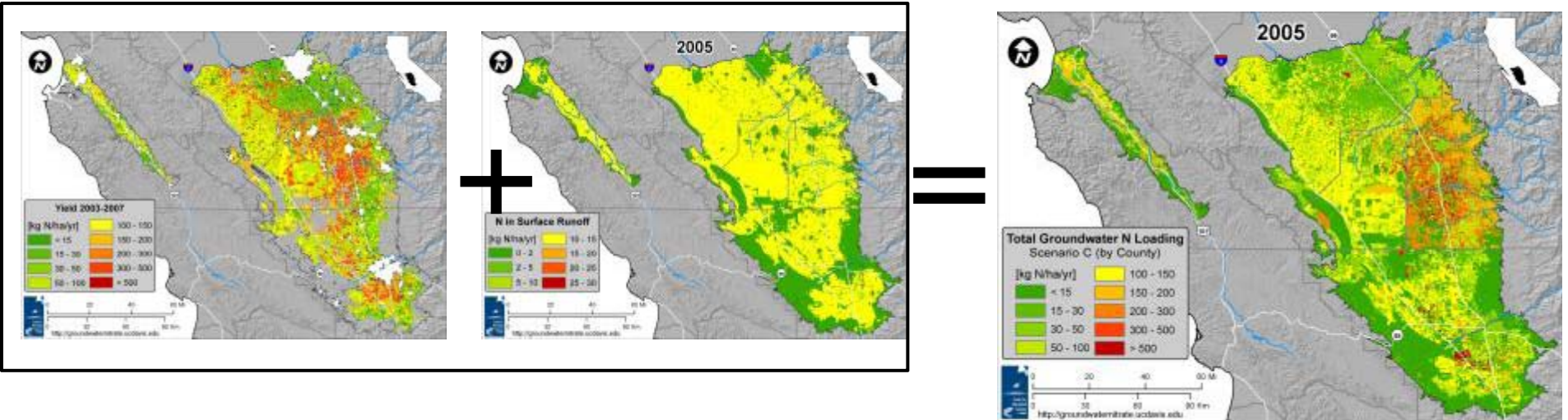
- Left half = N inputs
- Right half = N outputs



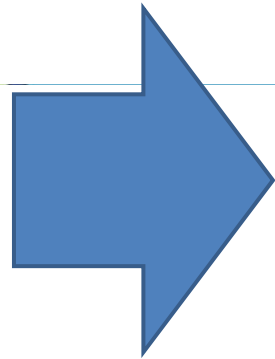
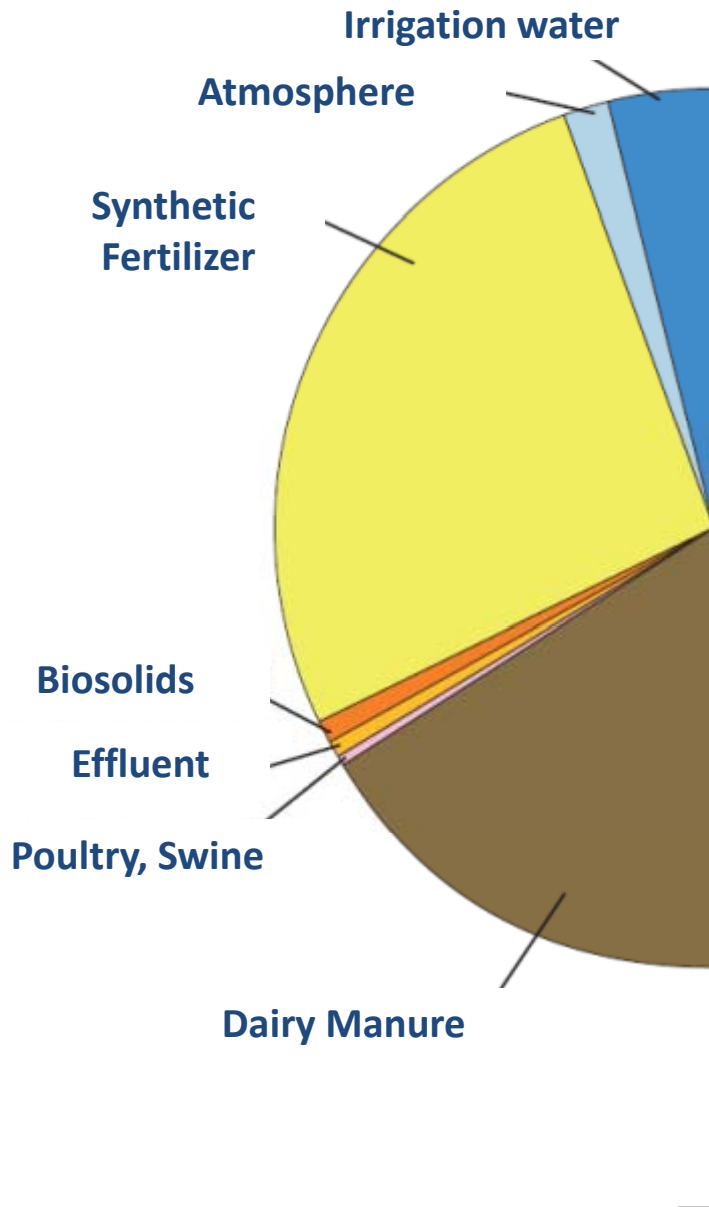
Scale:
50 m



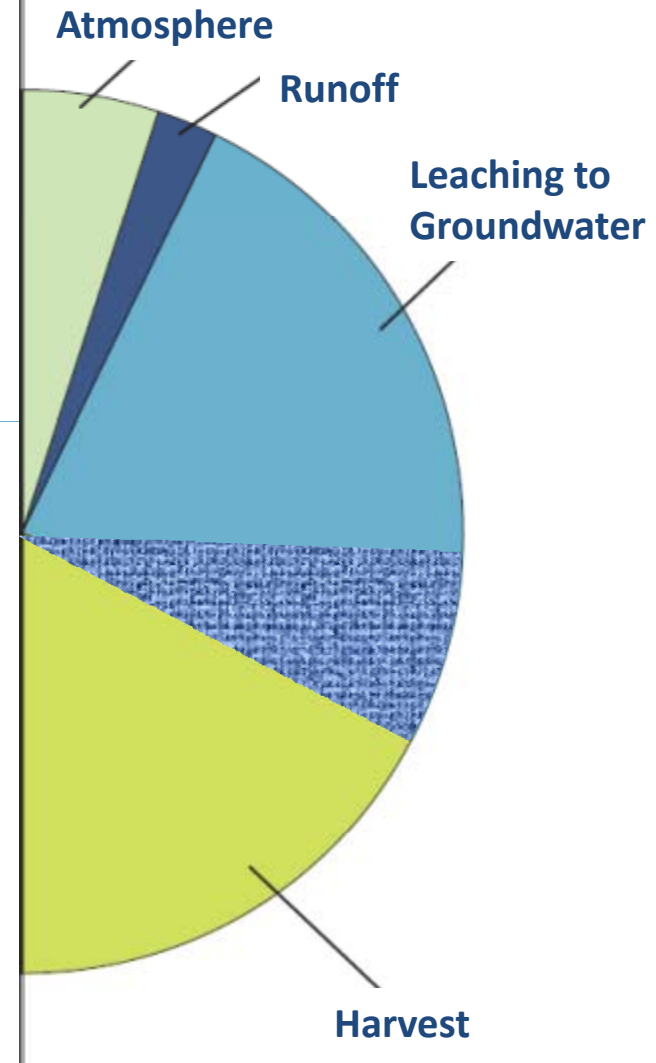
● 0.9



**Total Nitrogen Inputs:
420,000 tons N/yr**



Scale:
Study Area



**Total Nitrogen Outputs:
420,000 tons N/yr**

Temporal Resolution

- Annual nitrogen fluxes, which are averaged over five-year periods:
 - 1943-1947 => “1945” period
 - 1958-1962 => “1960” period
 - 1973-1977 => “1975” period
 - 1988-1992 => “1990” period
 - 2003-2007 => “2005” period



The next slide shows, in map form, the temporal evolution of N leaching to groundwater. The spatial resolution of these maps is 50 m x 50 m pixels (about 1 acre).

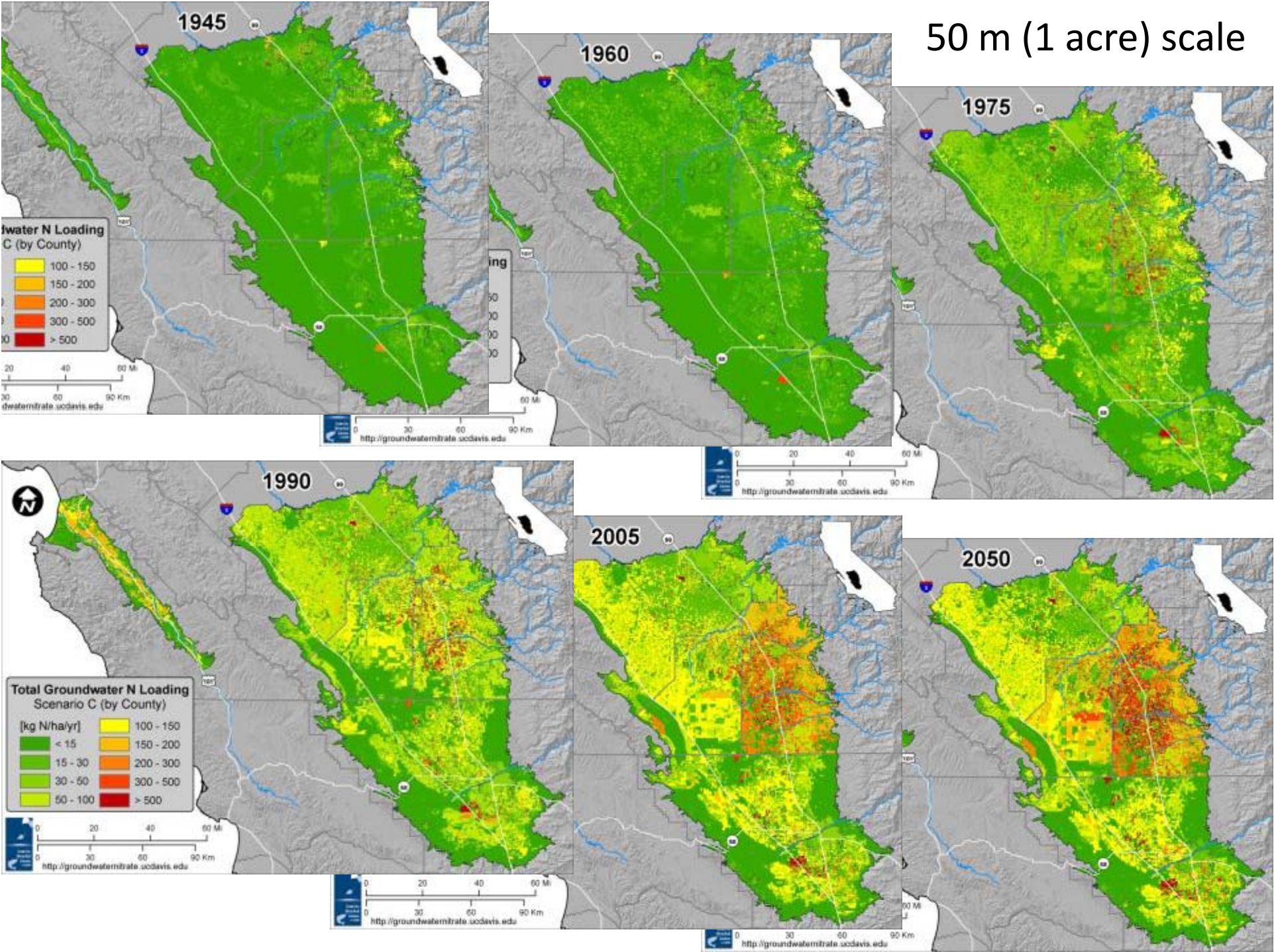
The second slide (after the next) shows the temporal evolution of four elements of the mass balance equation in aggregated form for the entire study area:

- Synthetic N inputs
- Dairy manure N inputs
- Harvested N outputs

- *also shown*: Total acreage harvested



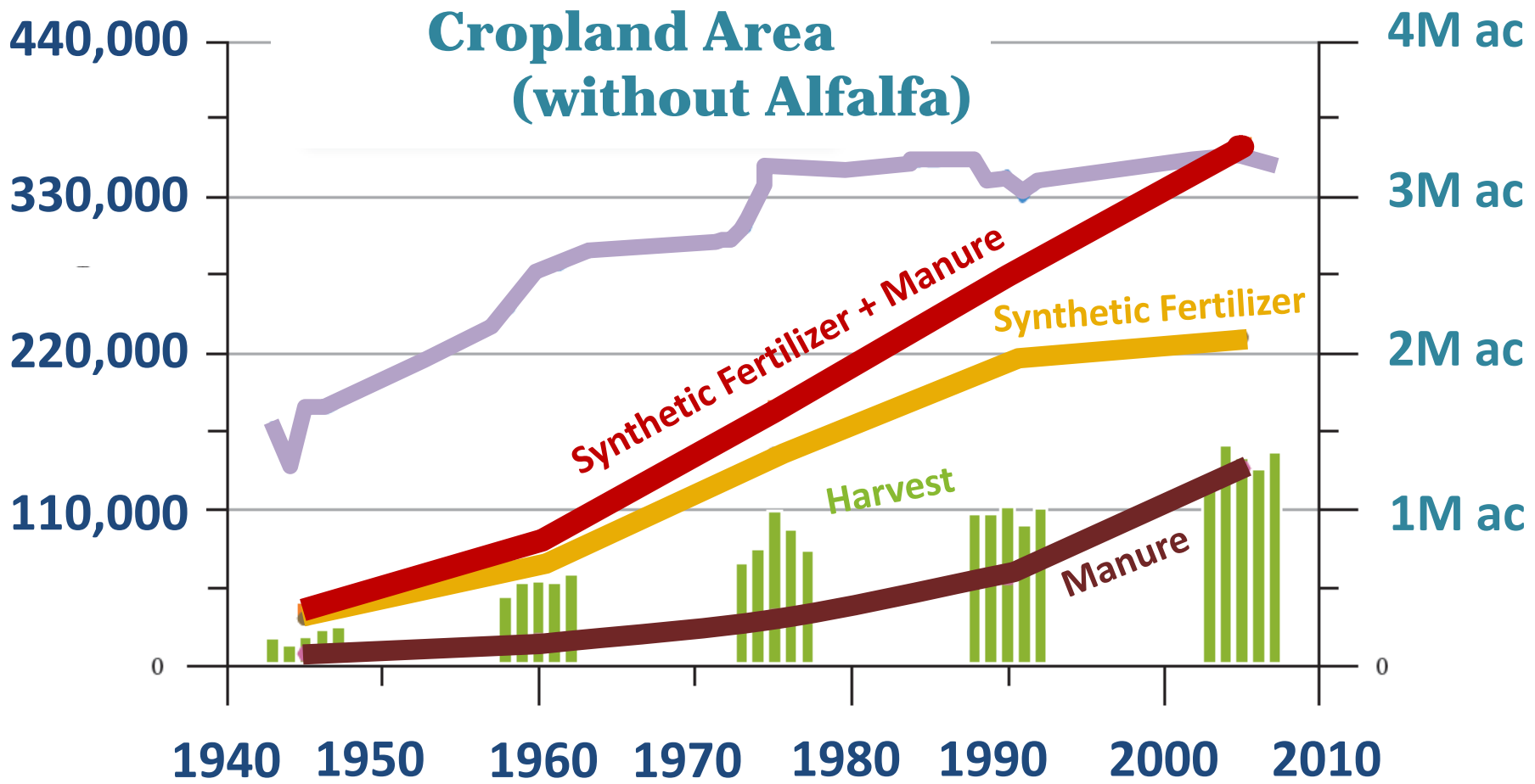
50 m (1 acre) scale



study area scale

tons N/yr

Cropland Area



Reporting Mechanisms

- All data collected from existing sources



Benefits

- Provides scientifically best estimate of “proportionate contribution to groundwater contamination by source and by discharger category” (SBX2 1), GIVEN available data, funding, and scope/purpose of the study
- Identifies long-term trends
- Provides overall magnitude of N fluxes at crop category / county / study area level
- Shows patterns of spatial distribution of potential groundwater nitrate loading



Challenges in Applying the Approach to Field / Farm / Township Scale

- Estimates are uncertain for a specific field/farm due to variability in soils/irrigation/farm practices (no available data)
 - Atmospheric losses (volatilization, denitrification) variable, few specific measurements available (here: 10% of total land applied nitrogen, appropriate at county scale)
 - Harvested N based on reported county average crop yields per acre (county ag commissioner) and USDA estimates of moisture and nitrogen content per yield unit. No crop/farm/field specific data available.
 - Synthetic fertilizer N use based on crop-specific surveys by USDA, UC Davis. No crop/farm/field specific data available.
 - Short-term N storage changes in the root-zone and in perennials not included.
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