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:

Inputs		Outputs
Synthetic fertilizer N + Wastewater effluent N + Biosolids N + Dairy manure N + Atmospheric deposition N + Irrigation water N	=	Atmospheric losses N + Harvested N + Surface runoff N + Leaching N to groundwater + Storage Change in N in root zone

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:

Leaching N to groundwater	=	Synthetic fertilizer N + Wastewater effluent N + Biosolids N + Dairy manure N + Atmospheric deposition N + Irrigation water N	-	Atmospheric losses N + Harvested N + Surface runoff N

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

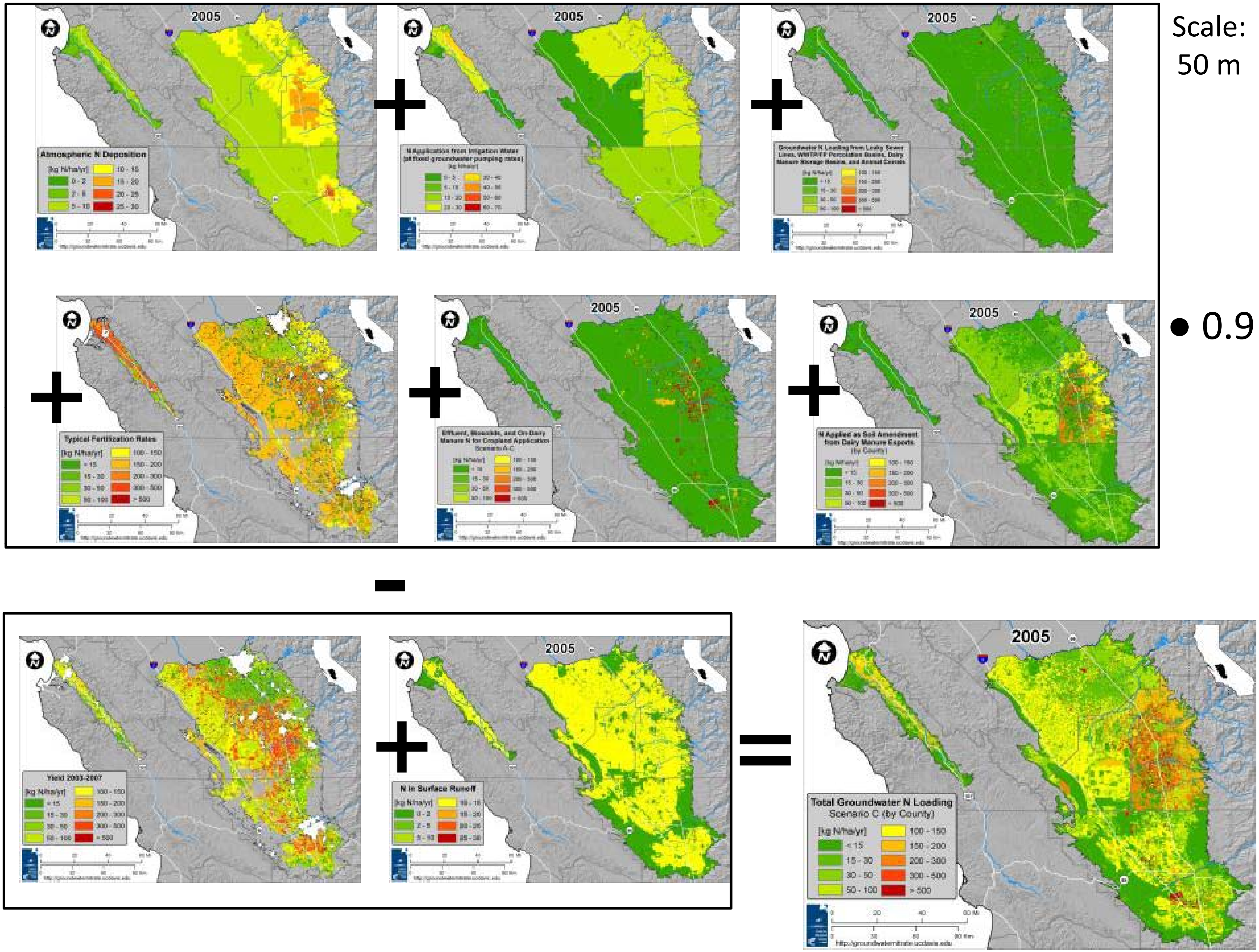
- N Mass Balance / Estimation of Nitrate Loading to Groundwater was performed at 4 different scales (resolution):
  - 50 m x 50 m grid cells for spatial mapping ("pixels")
  - Discharger category totals and averages
  - County totals and averages (Fresno, Kern, Kings, Monterey, Tulare)
  - Study area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

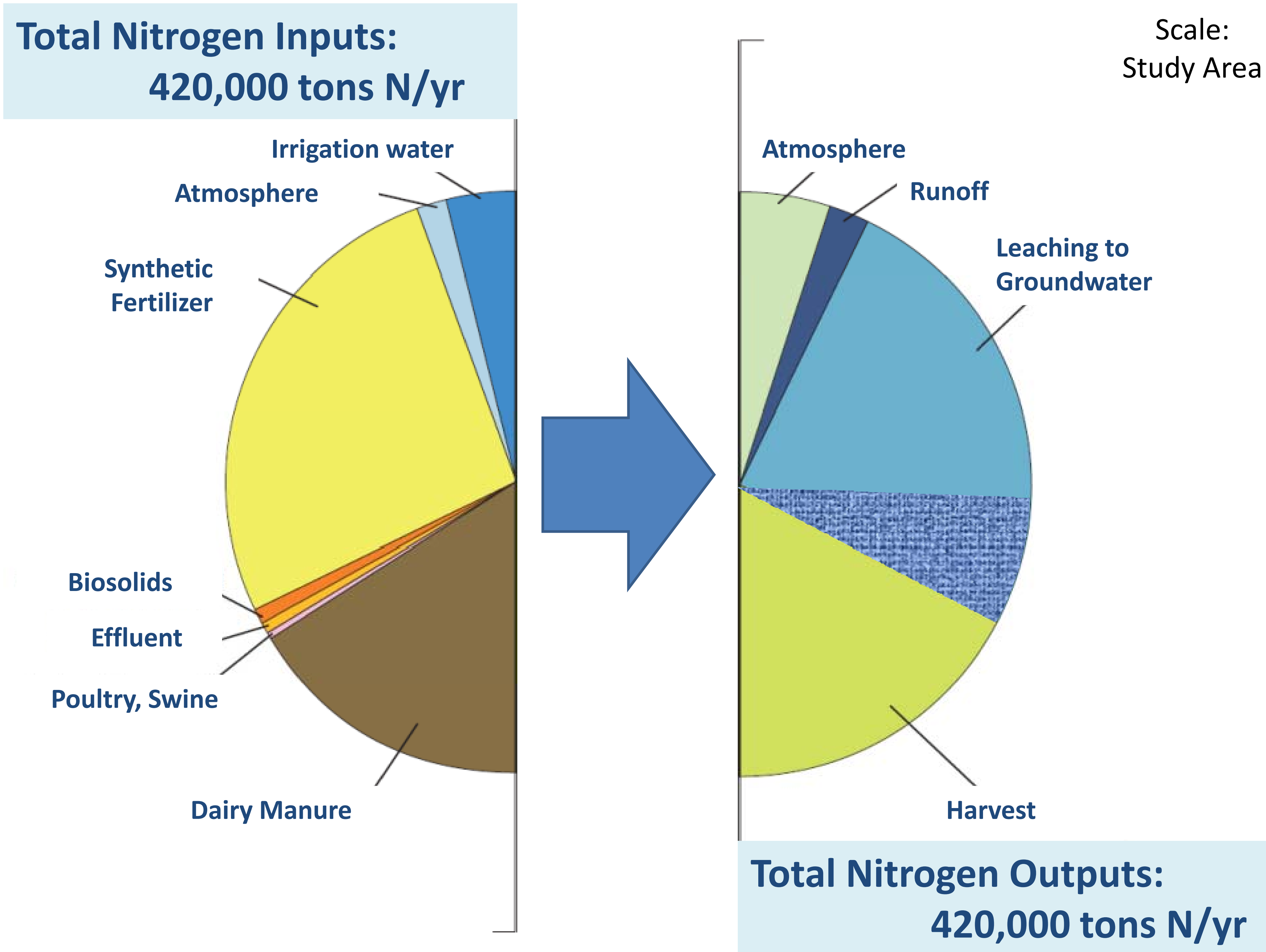
- Storage change of N in the root zone is assumed to zero.
- The atmospheric loss N output is assumed to be 10% of all N inputs. Hence, it is accounted for by multiplying the sum of all N inputs with 0.9 before subtracting the two other outputs (harvest and runoff).
- The spatial resolution of the maps 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
2005
Atmospheric N Deposition
Typical Fertilization Rates
Yield 2003-2007
N in Surface Runoff
Total Groundwater N Loading
Scenario C (by County)
[kg N/ha/yr]
< 15
15 - 30
30 - 50
50 - 100
100 - 150
150 - 200
200 - 300
300 - 500
> 500
http://groundwaternitrate.ucdavis.edu


Total Nitrogen Inputs:
420,000 tons N/yr
Irrigation water
Atmosphere
Synthetic Fertilizer
Biosolids
Effluent
Poultry, Swine
Dairy Manure
Scale:
Study Area
Atmosphere
Runoff
Leaching to Groundwater
Harvest
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

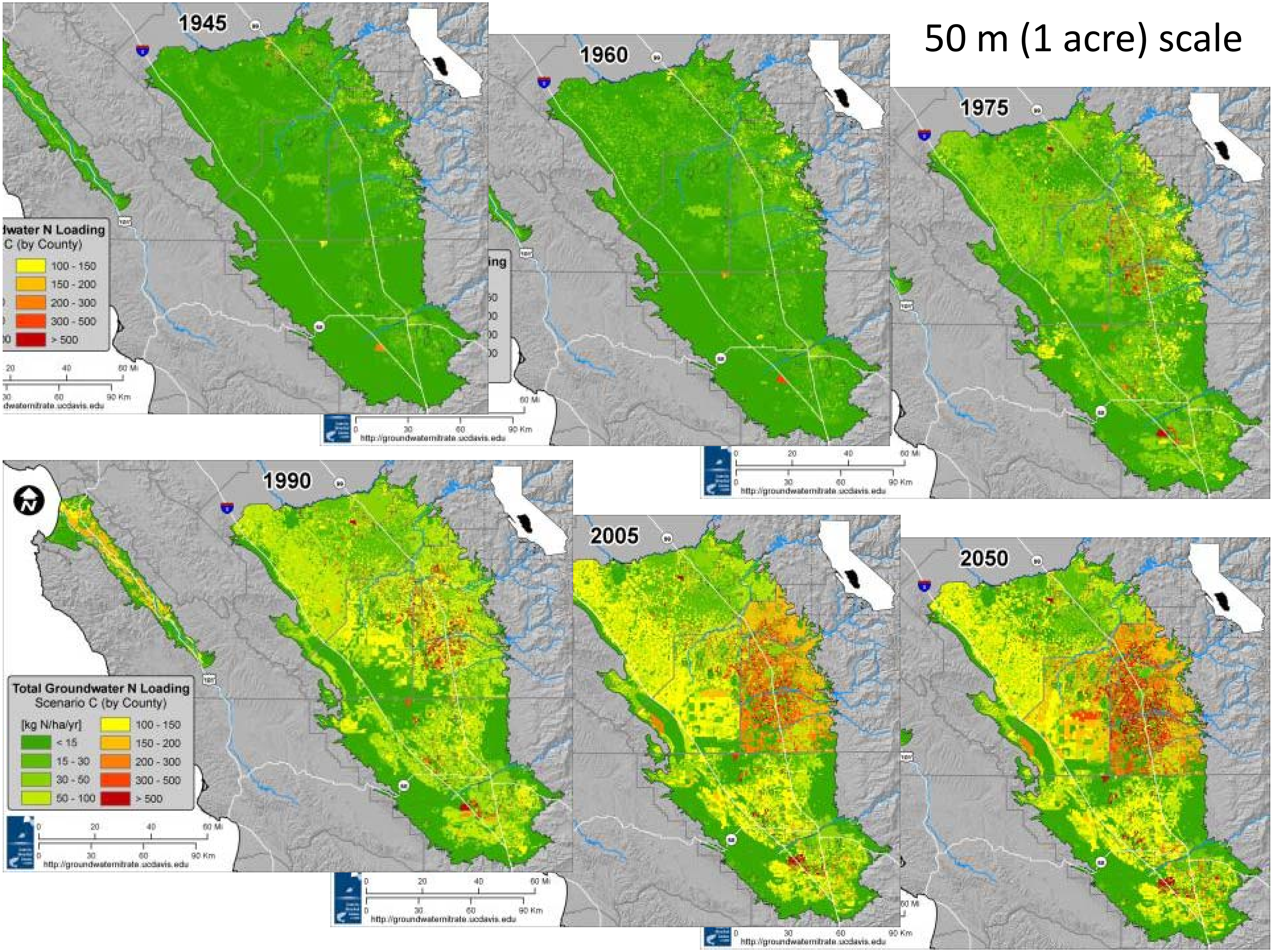
The next slide shows, in map form, the temporal evolution of N leaching to groundwater. The spatial resolution of these maps is 50 m x 50 m pixels (about 1 acre).

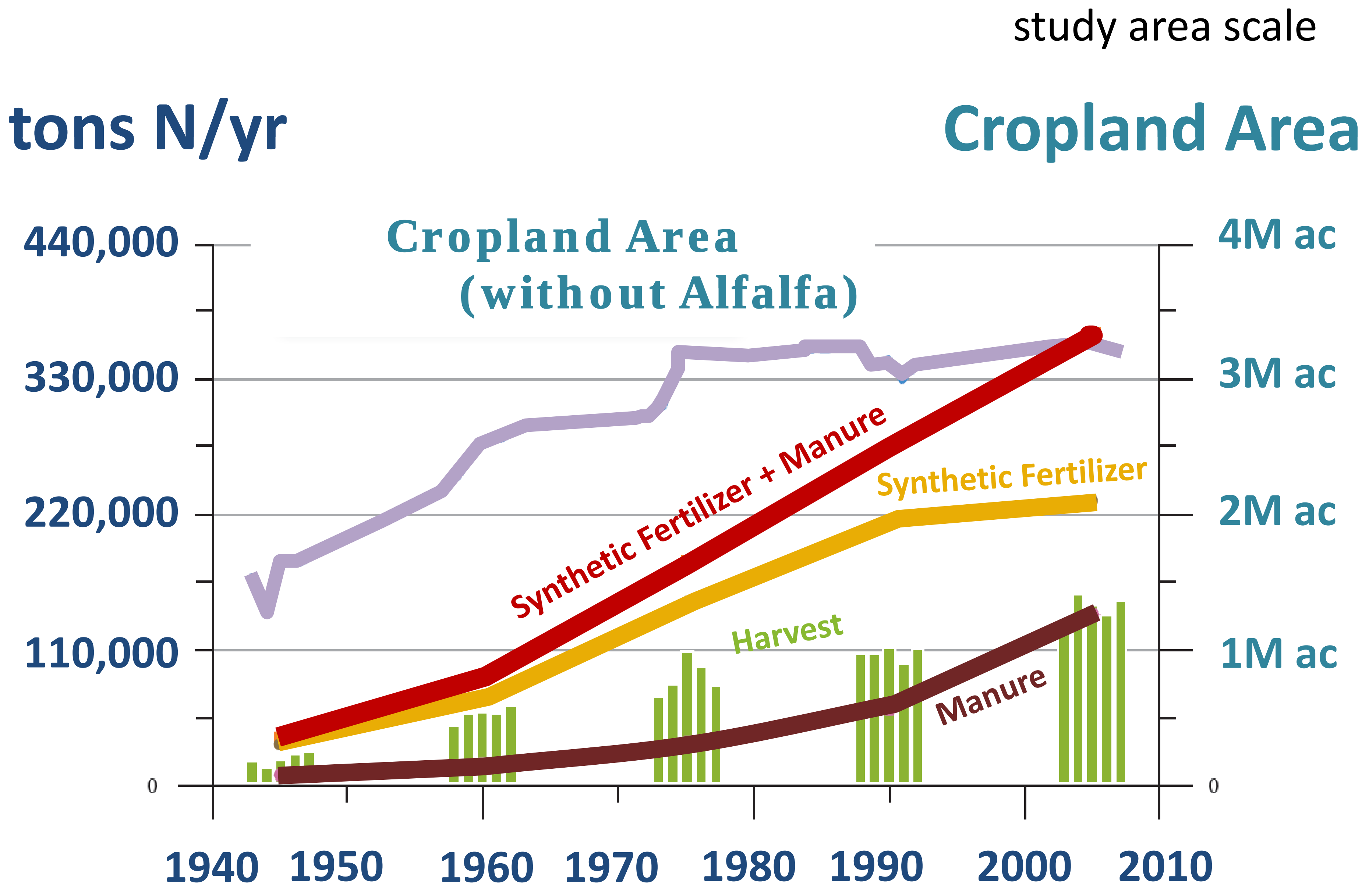
The second slide (after the next) shows the temporal evolution of four elements of the mass balance equation in aggregated form for the entire study area:

- 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
Cropland Area
(without Alfalfa)
440,000
330,000
220,000
110,000
0
4M ac
3M ac
2M ac
1M ac
0
Synthetic Fertilizer + Manure
Synthetic Fertilizer
Harvest
Manure
1940
1950
1960
1970
1980
1990
2000
2010

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.