The California Nitrogen Assessment

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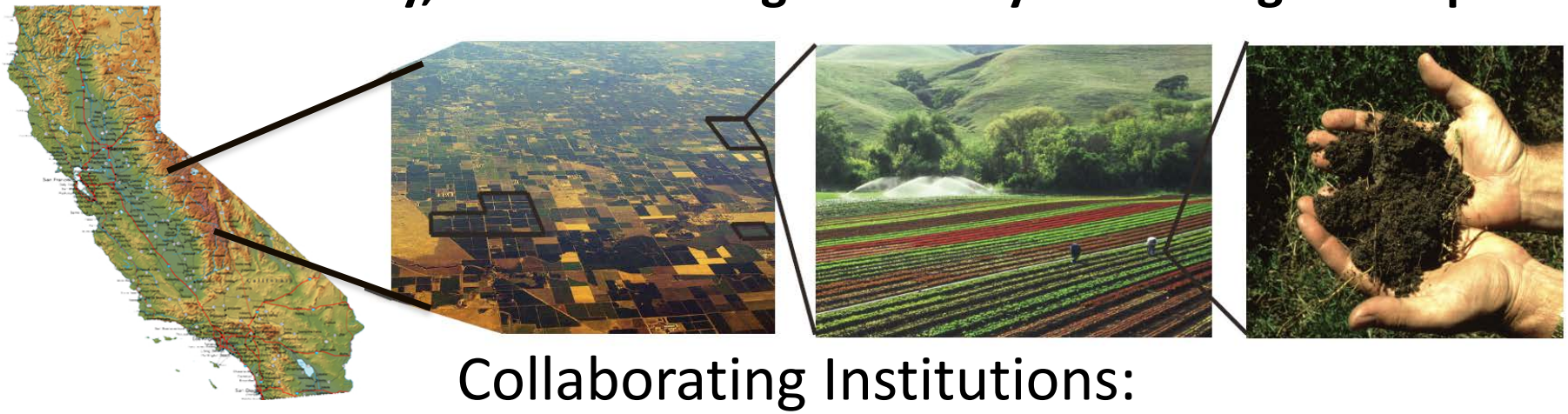
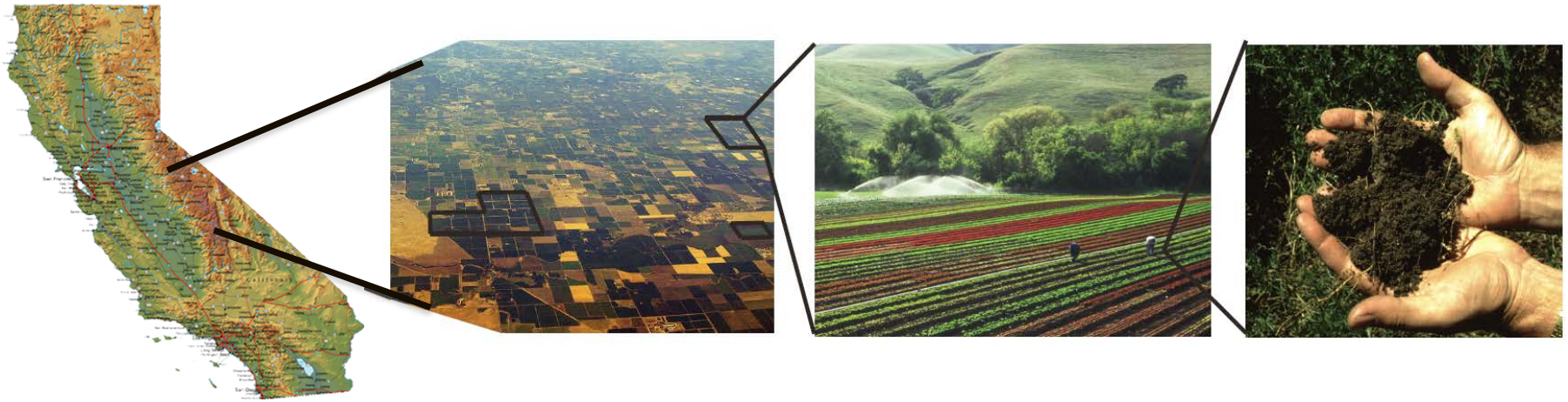


Collaborating Institutions:

Agricultural Sustainability Institute at University of California, Davis
UC Sustainable Agriculture Research and Education Program
UC Agricultural Issues Center
Kearney Foundation for Soil Science
California Institute for Water Resources, UC ANR
Water Science and Policy Institute, UC Riverside

Supported by the David and Lucile Packard Foundation, UC Division of Agriculture and Natural Resources, and the W.K. Kellogg Foundation

Introducing the California Nitrogen Assessment



California Nitrogen Assessment Goals

Gain a **comprehensive view of N flows in the state**, with emphasis on agriculture's roles.

Provide useful insights for stakeholders into the **balance between the benefits of agricultural nitrogen and the effects of surplus nitrogen** in the environment.

Compare options, including practices and policies.

Move beyond "academic business as usual" to more effectively **link science with action** and to produce information that informs both policy and field-level practice.

California Nitrogen Assessment
Overarching questions

The CNA is based on stakeholder-driven questions

What are the big sources of nitrogen pollution in California?

What are the policy challenges and opportunities?

What are the impacts of N management on society and human health?

What practices are most effective in mitigating nitrogen pollution?

Underlying drivers of nitrogen flows in California

Underlying Drivers of California N flows

Dominant underlying drivers of California's N cycle fall into two broad categories:

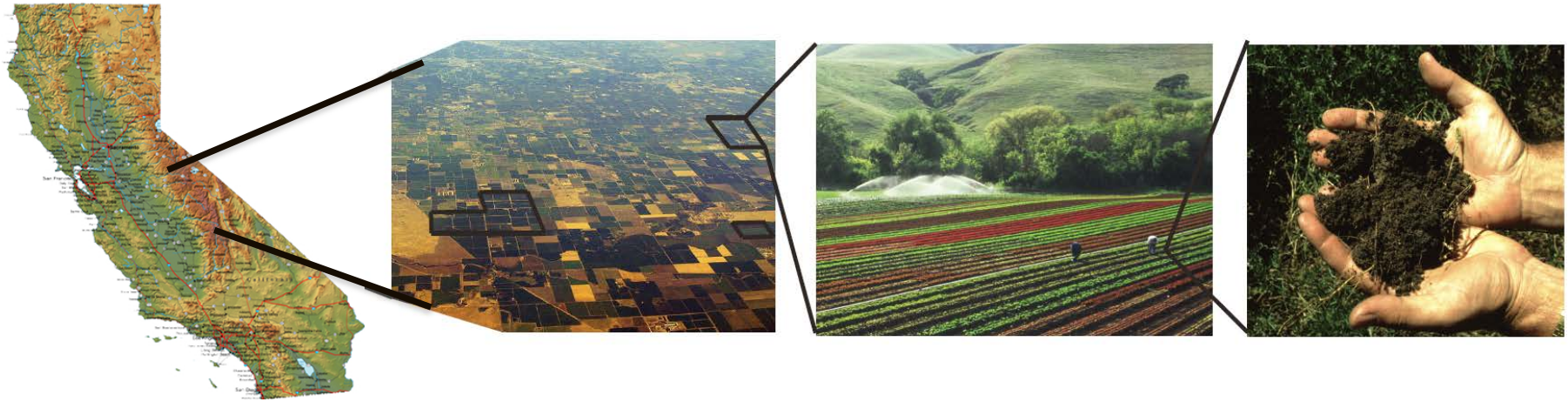
- Drivers affecting levels of agricultural production
- Drivers of fossil fuel combustion

Environmental regulations have reduced N pollution from fossil fuel combustion.

Over the last fifty years, world population doubled and global income quadrupled. The resulting increase in global demand for many of California's main agricultural exports (pistachios, almonds, rice, walnuts, and oranges) is driven by rising per capita incomes and perceptions of quality.

To date, policies have had little effect on nitrogen flows in California agriculture.

Direct drivers of California's nitrogen cycle



Big Direct Drivers

Despite increases in ***fuel combustion*** since 1980 (stationary sources have increased 3 fold), ***emissions have declined steadily***.

Fertilizer use– inorganic and organic– represents the most significant modification of the N cycle. ***Synthetic N Fertilizer*** sales in California have risen dramatically since World War II and increased by at least 40% since 1970. However, ***consumption has leveled off in the past 20 years***.

Manure management is an important N recycling point in the food system. California's livestock herd has continued to grow, but ***the fate of manure is largely unknown***. Until recently, manure management decisions were made without much regard to N consequences.

A California nitrogen mass balance for 2005

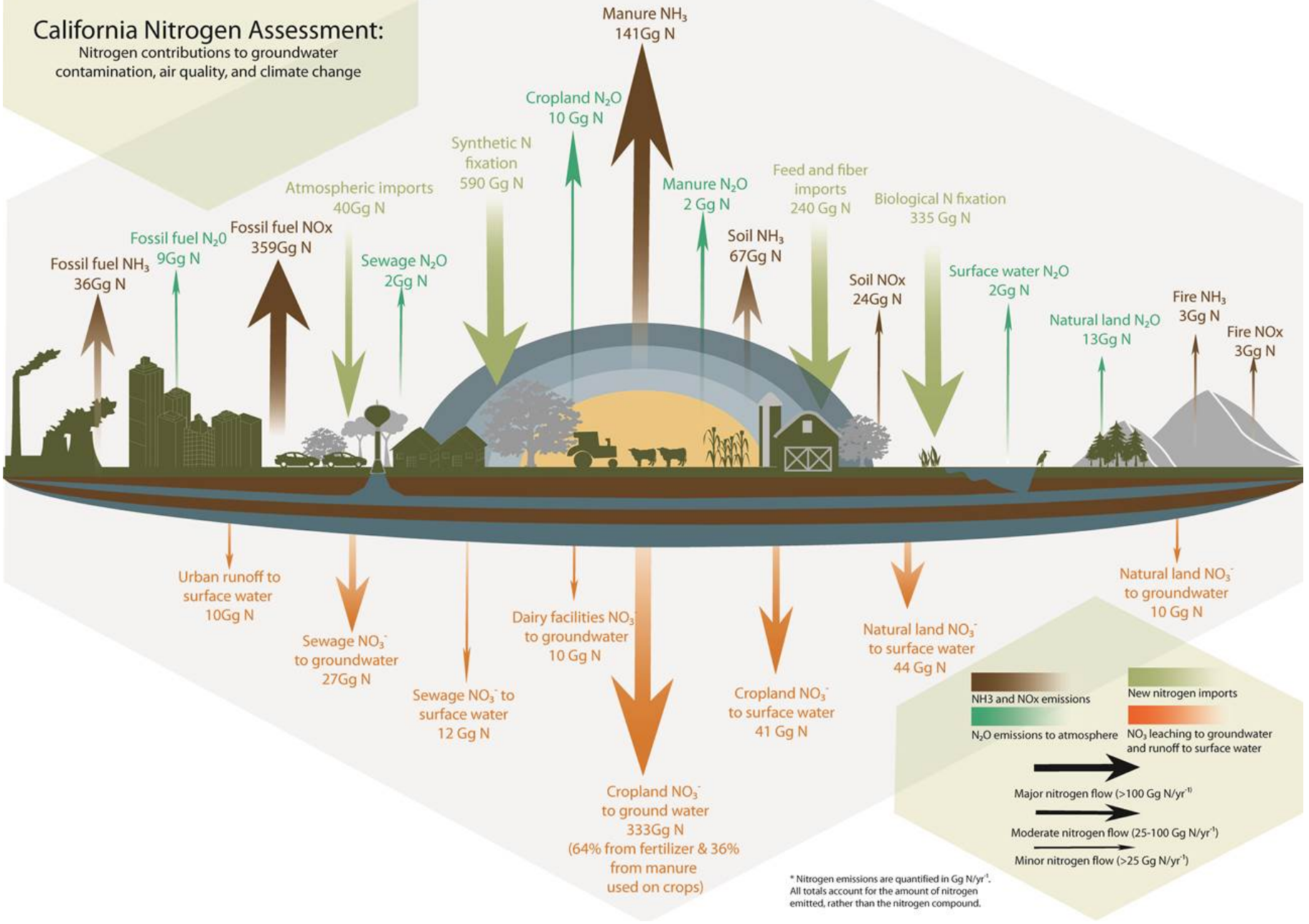
Guide to Nitrogen Chemistry

Compound	Form
N_2 : Nitrogen gas	Gas
N_2O : Nitrous Oxide	Gas
NO_x (NO, NO_2) : Nitrogen oxides	Gas
NH_3 : Ammonia	Gas
NO_3^- : Nitrate	Water soluble ion

*N_2 is inert, all others are reactive forms of nitrogen.

California Nitrogen Assessment:

Nitrogen contributions to groundwater contamination, air quality, and climate change



* Nitrogen emissions are quantified in Gg N/yr^{-1}. All totals account for the amount of nitrogen emitted, rather than the nitrogen compound.

Mass balance: main messages

Synthetic fertilizer is the **largest statewide import** (519 Gg N yr^{-1}) of N in CA.

Manure production is the **second largest N flow** (416 Gg N yr^{-1}) in CA.

Biological N fixation on natural land (139 Gg N yr^{-1}) **is completely overshadowed by N from human activity**.

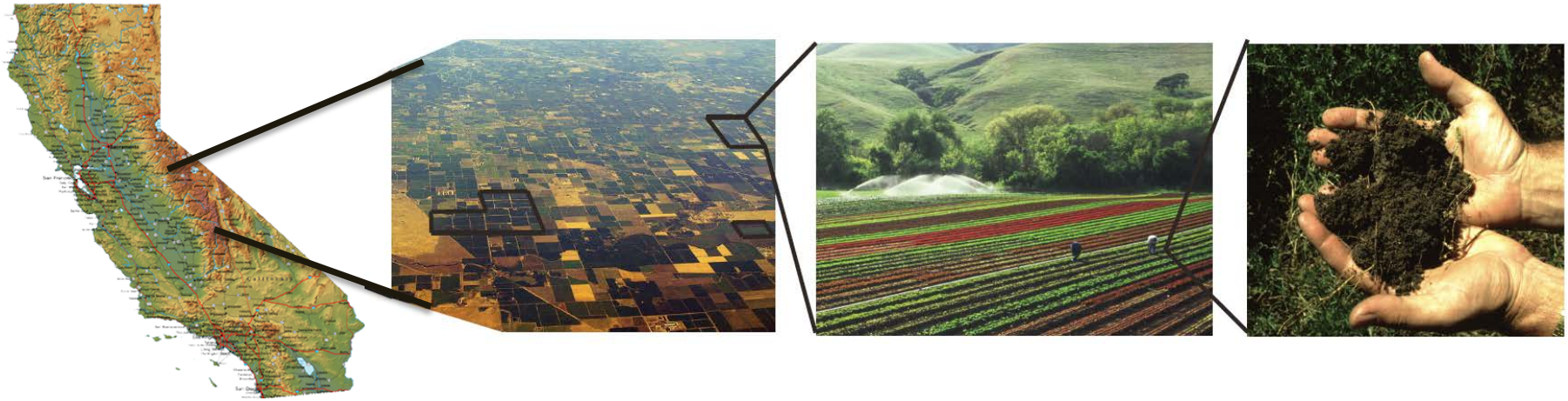
Nitrous oxide (N_2O) production is a moderate (38 Gg N yr^{-1}) pathway for N.

Ammonia is not tracked as closely as other gaseous N emissions.

Atmospheric N deposition rates in parts of CA are **among the highest in the US.**

Leaching from cropland (333 Gg N yr^{-1}) dominates (88%) N flow to groundwater.

Ecosystem services and human well-being



Human Well-Being: Nutrition

CA Fruits and Vegetables (50% of US production)
Contribute to under-consumed nutrients - folate, magnesium, potassium, vitamins A, C and K, and dietary fiber.

CA Tree Nuts (almost 100% of US production)
Some evidence that they reduce risk factors for heart disease.

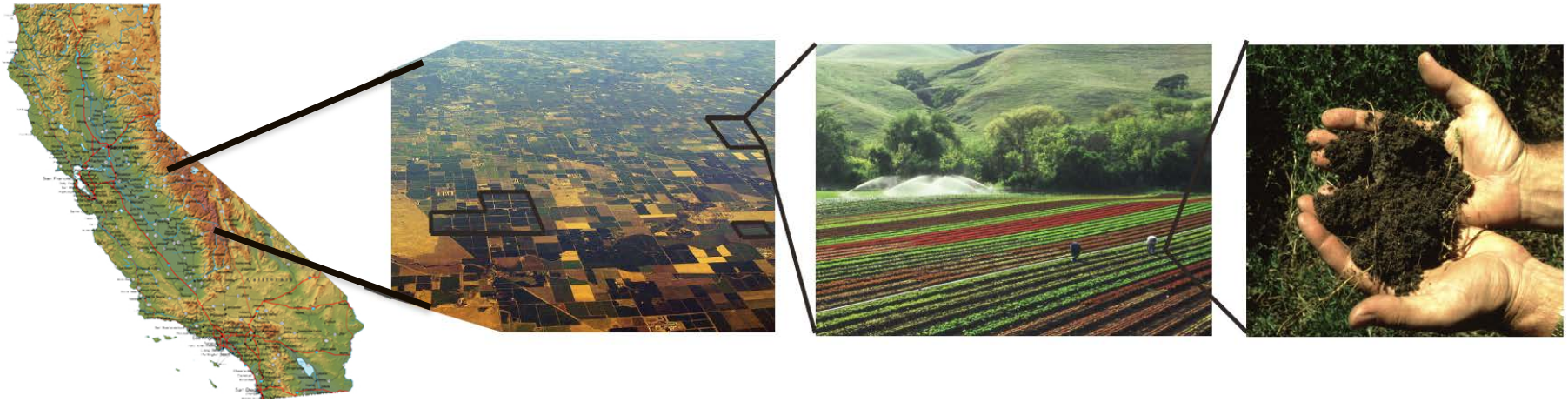
CA Dairy (21% of US production)
Linked to bone health (children and adolescents) and reduced risk of cardiovascular disease, type II diabetes and lower blood pressure (adults).

Caution: higher yields from higher N application has been shown to lower nutrient concentrations in some crops.

Health Impacts of Nitrate/Nitrite in Drinking Water and Food

Condition	Level of Uncertainty	References
Foods are major source of nitrate/nitrite	Well-established	Matallana, 2010; Tamme, 2010
Nitrate/nitrite has positive health impacts in some cases	Well-established	Gilchrist, 2011; Lundberg, 2011
Nitrate/nitrite is a risk factor for methemoglobinemia – "Blue Baby Syndrome"	Generally accepted	EPA 1990; Zeman 2002; Sadeq 2008; VanDerslice 2009
Exposure to nitrate/nitrite higher in agricultural areas	Generally accepted	Harter 2009; Boyle et al. 2012
Nitrate/nitrite is carcinogenic	Provisionally agreed by most	IARC, 2010
Lower income and minority communities face higher exposures to nitrate in drinking water	Tentatively agreed by most	Firestone 2006; Balazs 2009
Nitrate/nitrite is associated with adverse birth outcomes	Suggested but unproven	Tabacova et al. 1997, 1998

Scenarios for the future of nitrogen management in California agriculture



Scenarios

None of the scenarios by themselves lead to sufficient improvement in groundwater quality to fully address human health concerns by 2030.

Responses: Technologies and practices

Practical approaches to mitigation?

Underlined = technology "on the shelf"

Limit the introduction of new nitrogen

- **Increase nitrogen use efficiency in cropping systems-** including nutrient budgeting and monitoring, modified placement and timing of fertilizer, irrigation management, fertilizer formulation, crop breeding

- **Increase nitrogen use efficiency in animal production**- precision feeding, staged feeding, breeding

- **Improve efficiency in transportation and energy sectors**

- Change diets and reduce food waste

Practical approaches to mitigation?

Underlined = technology "on the shelf"

Mitigate the movement of N among environmental systems

- **Minimize manure volatilization-**manure collection, separation of liquids from solids, composting manure, anaerobic digestions
- **Switching fertilizer sources** (problems, limited gains)
- **Transform waste management** – source separation, widespread N treatment
- **Manage N at landscape level** – manage natural vegetation, increase biodiversity

Adapt to an N rich environment

- **Treat drinking water-** ion exchange, biological and chemical denitrification, development of alternative sources, blending
- Develop the adaptive capacity of agricultural systems- i.e modified fertility programs

Responses: Policies and institutions

Technologies and practices that can reduce nitrogen pollution from agriculture certainly do exist …

… but they typically are costly (in money and management)…

… thus voluntary adoption tends to be low.

California will be living with the consequences of past nitrate leakages to groundwater for decades to come.

For communities where drinking water supplies are unsafe because of high nitrate concentrations, point-of-use treatment or some other approach will be needed to assure safe drinking water for all California communities.

The general lack of evidence, rigorous experimentation, comparative study, or integrated assessment of the impact of alternative policy instruments for controlling nitrogen pollution from agriculture is a major barrier to development of sound policy.

California Nitrogen Assessment Timeline

2008 Stakeholder Engagement and Outreach

- Over 100 stakeholder questions were collected into 5 overarching categories that define the direction of the Assessment

Nitrogen Assessment production

- 44 authors collaboratively produced 8 chapters in response to stakeholder questions

Scientific Review

- Each chapter independently and publicly reviewed by outside experts for scientific legitimacy
- Authors publicly respond to scientific reviewer comments
- External Review Editors act as referees to ensure adequacy of authors' responses

Stakeholder Review

- Each chapter publicly reviewed by stakeholders
- Authors publicly respond to stakeholder reviewer comments
- External Review Editors ensure adequacy of authors' responses

2015 Project conclusion and publication

CNA Stakeholder Review

Upcoming stakeholder review webinars

- May 28, 9:30-10:30AM
  Chapter 7: *Responses: Technologies and practices*

- June 12, 12:00-1:00 PM
  Chapter 8: Responses: *Policies and institutions*

- Mid-June, date TBA
  Chapter 5: *Ecosystem services and human well-being*