The California Nitrogen Assessment

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Collaborating Institutions:

- Agricultural Sustainability Institute at UC Davis
- UC Sustainable Agriculture Research & Education Program (SAREP)
- UC Agricultural Issues Center
- Kearney Foundation for Soil Science
- California Institute for Water Resources
- Water Science and Policy Institute, UC Riverside

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Californians’ quality of life depends on our abundant food and vibrant agricultural landscapes.
All Californians have a stake in a thriving agricultural sector and agricultural communities in our state, both now and for future generations.

Nitrogen is indispensable to the productivity of California agriculture.

And yet, only about half the nitrogen applied ends up where we intend; the balance leaks, polluting our air and water, with detrimental effects on our environment and human health.

Getting California's nitrogen balance right requires broad collaboration over the coming years, with farmers and ranchers leading the way to produce solutions.

What an assessment *is*, and what it is *not*.

An assessment is a critical evaluation of information for purposes of guiding decisions on a complex issue in the public interest.

Stakeholders provide the questions that guide the assessment.

The CNA is based on stakeholder questions

What are the big sources of nitrogen pollution in California?

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

What practices are most effective in mitigating nitrogen pollution?

What are the policy challenges and opportunities?

What an assessment *is*, and what it is *not*.

An assessment is not a research project.

Most sources and data should already be collected, peer-reviewed, and in the public domain. Gap-filling and new calculations using existing data are permissible.

Quantifying Uncertainty

Reserved wording to describe uncertainty

Amount of Evidence

Amount of Agreement

	Limited	Medium	High
High	Agreed but unproven	Agreed but incompletely documented	Well established
Medium	Tentatively agreed by most	Provisionally agreed by most	Generally accepted
Low	Suggested but unproved	Speculative	Alternate explanations

What an assessment *is*, and what it is *not*.

The CNA is time bounded. The CNA was launched in 2009 and the text for the final publication was finished in July 2015.

Assessments rely primarily on peer-reviewed publications, for which the time period from the initial research activities to final publication commonly extends to two years or more.

Drivers of nitrogen flows in California

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Underlying Drivers of the Nitrogen Cycle

Human population and economic growth

Market opportunities for California commodities

Agricultural production costs and technological change

Petroleum and natural gas prices

Underlying Drivers: Global

Over the last 50 years, **world population doubled and global income quadrupled.** The resulting increase in global demand for food has been a fundamental driver of expansion of agricultural production in California. **These positive effects on California agriculture are likely to continue.**

Long-term **reduction of transport costs and reduction of international trade barriers** increased access to international markets since the 1950s. **The future course of these drivers is uncertain, particularly regarding energy prices and trade policy.**

Long-term decline in synthetic N fertilizer prices resulted in a large increase in N use from the 1950s through the 1970s. Thereafter, N prices were relatively stable relative to the prices of crops until 2000. Fertilizer price increases in the past decade have exceeded increases in crop prices. **Uncertainty about synthetic N prices stems directly from uncertainty about energy prices,** including possible effects of climate change mitigation policies on fossil fuels.

Direct Drivers of Nitrogen Cycling in California

Nitrogen fertilizer use
(synthetic & organic sources)

Manure management

Fossil fuel combustion

Industrial processes

Wastewater management

Changes in land use

Big Direct Drivers

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

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***.

A California Nitrogen Mass Balance for 2005

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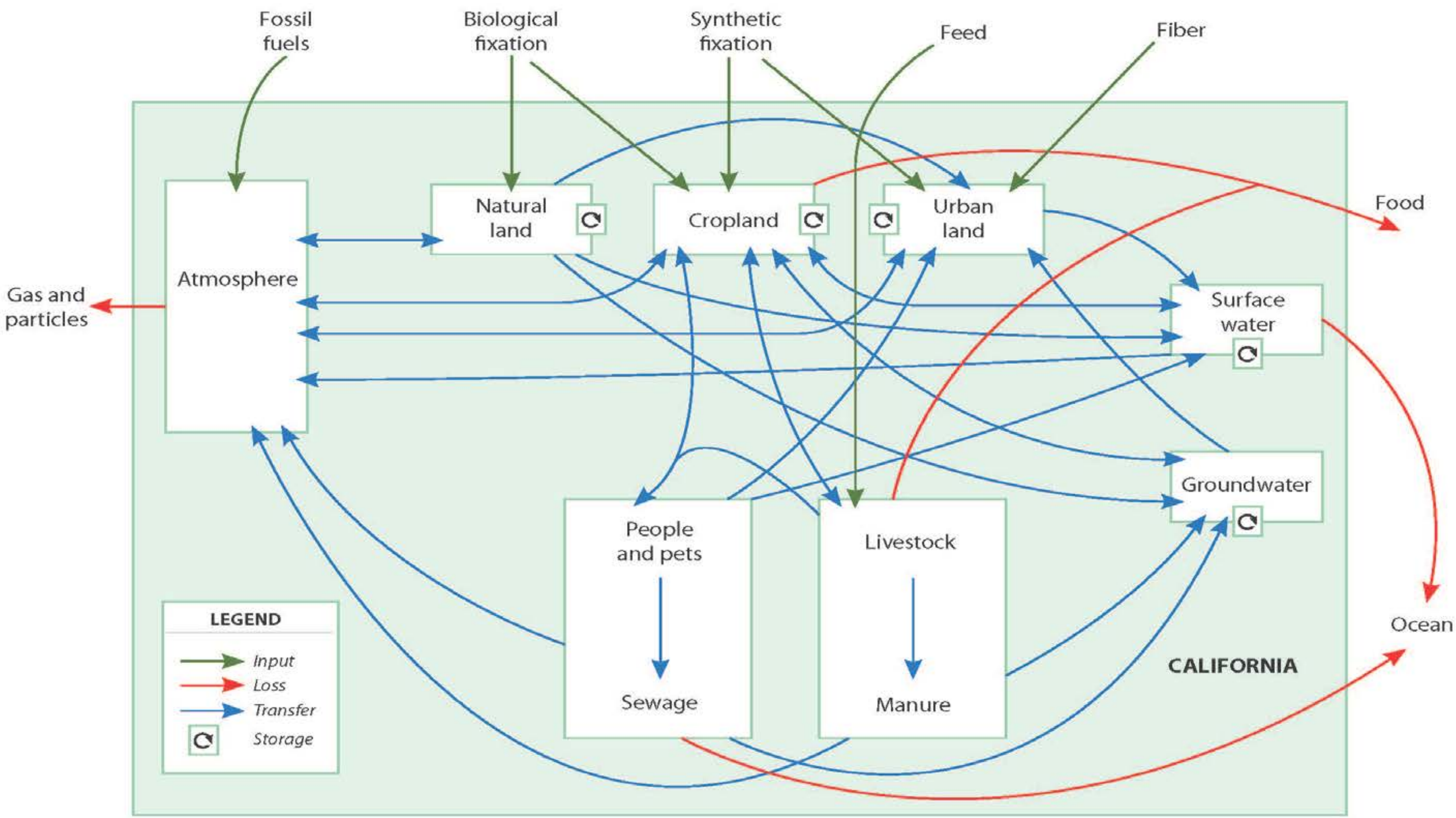
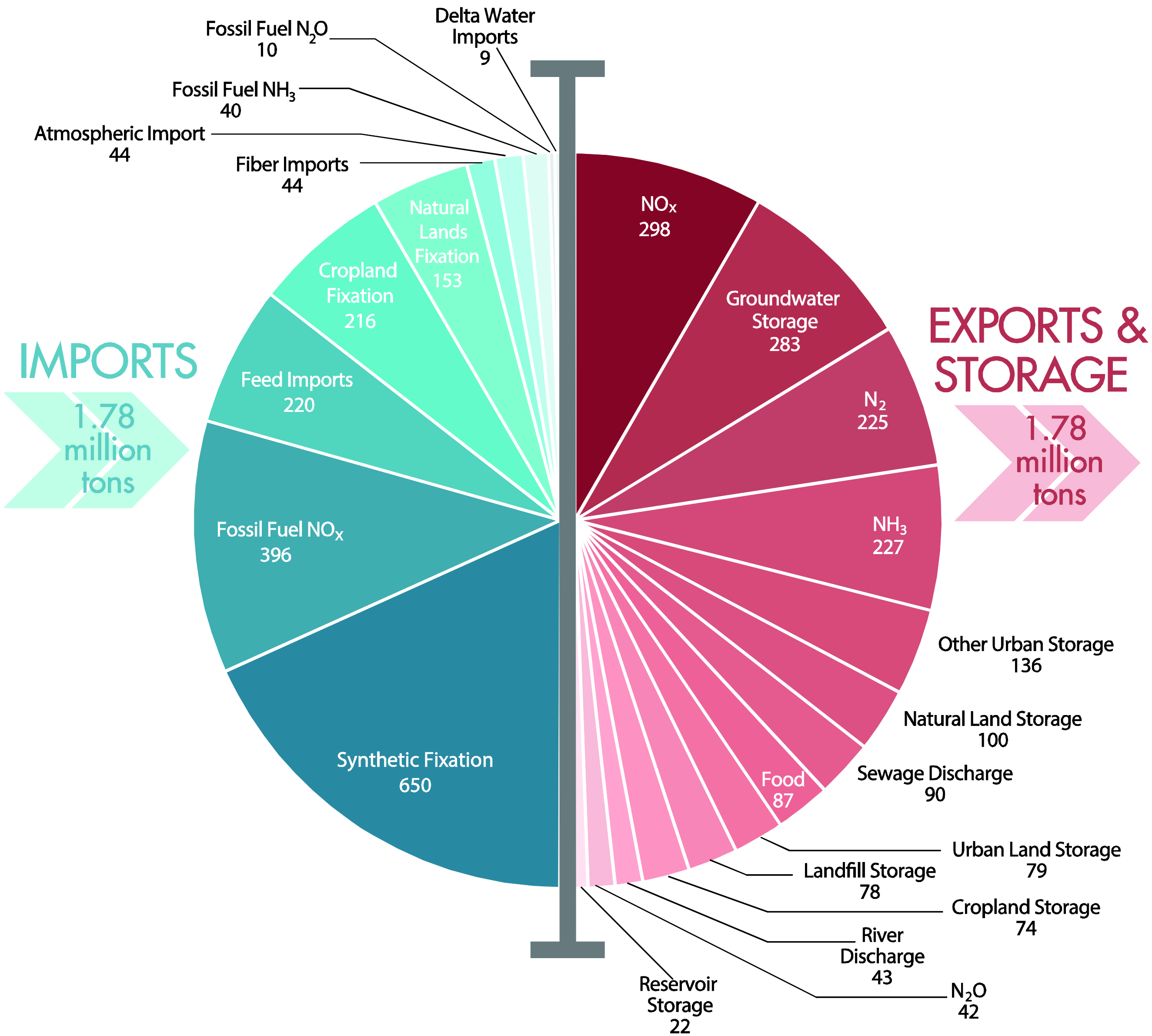
Flows of Nitrogen in California



Statewide N inputs = 1.8 million tons/year, roughly 1% of global human N inputs



Agriculture is the largest source of nitrogen in California.

Synthetic fertilizer accounts for 32% (514,000 tons) of new nitrogen entering CA each year, and animal feed accounts for another 12% (220,000 tons).

On average, about half the nitrogen applied to crops is lost to the environment.

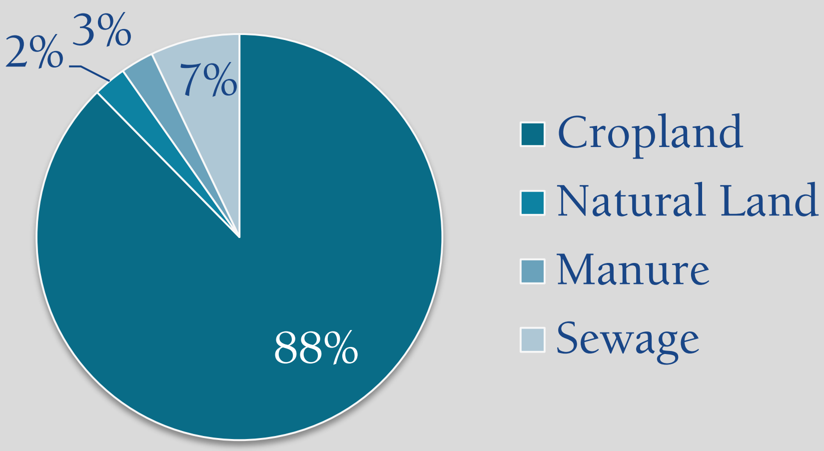
This varies greatly by soil type, crop, and farm management practices.

Groundwater N Mass Balance

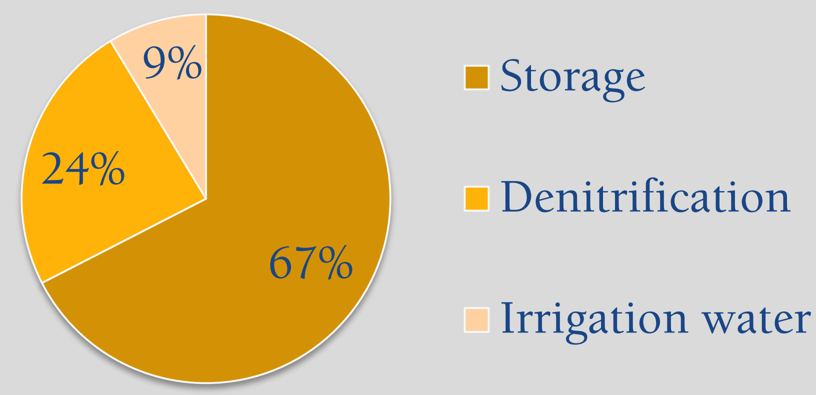
Gross NO_3 groundwater inputs = 23% of statewide N

Net NO_3 groundwater storage = 16% of statewide N

N inputs to groundwater: 418 thousand tons



N outputs + net storage: 419 thousand tons



Nitrogen’s impact on environment and human health

Nutrition and Human Health

CA Fruits and vegetables – 50% of U.S. production

contribute to many under-consumed nutrients and dietary fiber

CA Tree nuts – almost 100% of U.S. production

Some evidence that nuts are linked to reduced risk for heart disease

CA Dairy – 21% of U.S. production

Linked to bone health, reduced risk of cardiovascular disease and type II diabetes

Clean Water

High levels of nitrate in drinking water can harm human health. Relatively low concentrations of nitrite and nitrate are found in drinking water from the state's surface water.

In contrast, nitrate levels in groundwater have increased over the past several decades, and some parts of the state now exceed federal standards for safe drinking water.

Scientific uncertainty of groundwater nitrate health impacts

	Low Agreement	Medium agreement	High agreement
Low evidence	Nitrate increases risk of adverse birth outcomes		
Medium evidence		Nitrate and nitrite increase the risk of cancer Exposure to nitrate/nitrite in water is higher among low income minority communities in CA	Groundwater nitrate levels in many CA regions have increased over the past 5 decades, and are likely to continue increasing
High evidence		Human exposure to nitrate/nitrite levels is higher in ag regions Nitrate consumption increases the risk of “blue baby syndrome.”	Groundwater nitrate levels are higher in CA’s major ag regions. Foods are an important source of nitrate. Nitrate has some therapeutic health benefits.

People in agricultural areas, particularly those with domestic wells, are more likely to be exposed to high levels of nitrate in their drinking water than those in urban and suburban areas.

A disproportionate number of these residents are of Latino ethnicity and are considered low income.

Potential health impacts of nitrogen, combined with increasing concentration of nitrogen in groundwater and the difficulty of remediating groundwater contamination, create an urgent challenge to protect California's vulnerable communities today.

Technological options for improvement

Key Control Points:

Agricultural N Use Efficiency & Cropland Management

Energy and Transportation Sector Efficiency

Manure Management

Wastewater Management

Consumer Choices and Food Waste

Target Specific N Transfers

A single type of source is generally responsible for more than 50% of each N transfer.

Minimize volatilization from manure.

Minimize NO_3- leaching from croplands.

Minimize N_2O emissions from soils.

Reduce NO_x emissions from fuel combustion.

Transform wastewater management.

Potential for Mitigation with Current Technologies

- Increase fertilizer N use efficiency
- Improve manure management
- Increase access to wastewater treatment
- Reduce fuel emissions

→ Reduce N released to environment by **25-30%**

Galloway et al. 2008; SAB 2011

Mitigative effects of cropland management practices on the fate of nitrogen

		Yield	NH_3 to atmosphere	N_2O to atmosphere	NO_3^- to groundwater	NO_3^- to surface water	Barriers
Well established	Increasing soil drainage	positive	positive	positive	negative	positive	cost, logistics, information
	Genetic improvement	positive	negative	uncertain		positive	cost, information
	Switching irrigation technology	n		uncertain	uncertain	positive	cost
	Edge of field	n	n	negative	positive	positive	logistics
Generally accepted	Reducing N rate	uncertain	positive	positive	positive	positive	logistics, cost, information
	Changing N placement & timing	positive	positive	uncertain	positive	positive	cost, information, regulation
Provisionally agreed by most	Conservation tillage	n	negative	uncertain	positive	positive	cost, logistics, science & technology
	Agricultural residue	negative	positive	negative	negative	positive	science & technology, logistics
Tentatively agreed by most	Diversify crop rotations	n	n	uncertain	positive	positive	cost
Agreed but incompletely documented	Manage fallow periods	n	negative	uncertain	positive	positive	cost
Agreed but unproven	Switching N source	n	positive	uncertain	uncertain	uncertain	logistics
Speculative	Organic amendments & practices	uncertain	negative	uncertain	uncertain	uncertain	cost, logistics, information, science & technology, regulation

$ = cost; = logistics; = information; = science & technology; = regulation; = labor

= positive mitigative effect; = negative mitigative effect; = uncertain; n = no effect

The Solution Center for Nutrient Management

ucanr.edu/sites/Nutrient_Management_Solutions

Nutrient management resources and knowledge sharing tools for the California agricultural community

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Trade-offs of Nitrogen Reduction Efforts

Minimization of ammonia volatilization from manure can increase nitrate leaching and nitrous oxide emissions.

Reducing nitrate leaching from cropland can increase nitrous oxide emissions.

Decreasing leaching inhibits flushing of salts.

Reducing nitrogen oxide emissions from fuel combustion can increase ammonia emissions.

Decreasing ammonium and nitrate from wastewater can increase nitrous oxide emissions.

Assessment of Nitrogen Policy Instruments

A policy assessment uses a body of evidence to answer these questions:

- What are the policy goals?
- Have existing policies been successful in achieving their stated goals?
- Why or why not, and at what cost?
- What can we learn from past policy successes or failures in designing future policies?

Policy assessment is not policy advocacy

Assessment of Policy Instruments

Categories we assessed

Emission standards
Emission charges or abatement subsidies
Tradable emission permits
Auction-based abatement contracts

Criteria to assess policy instruments

Adaptability
Institutional compatibility
Distributional effects
Cost effectiveness
Technological feasibility
Environmental effectiveness

Case study: North Carolina's Neuse River Basin

Goal: reduce N loading by 30% in 6 years

Instrument:

Farmer participation required in 1 of 2 options

- Participate in Local Nitrogen Strategy that would include specific plans for each farm, with a collective 30% reduction in N loadings
- Implement standard best management practices

Impact: Nutrient loading decreased by 42% in 6 years, exceeding goal

Key Lessons:

- Including nonpoint sources was critical in achieving nutrient reduction
- Flexibility is crucial for cost-effectiveness
- Success hinged on collaboration among agencies, stakeholders, and the public

Case study: Mississippi River Basin

Goal: Reduce hypoxic zone to <5000km^2, a 40-50% reduction in N loading

Instrument:

- Voluntary actions with incentives and education, focused on nonpoint source agricultural sources
- States expected to create state-level nutrient reduction strategies

Impact: Goals have not been met. As of 2013, 9 out 12 states involved have developed strategies

Key Lessons:

- Participation in costly voluntary efforts tends to be low in the absence of private returns or compensation
- Establishment of nutrient reduction plans can help clarify challenges and focus research efforts.

For communities where drinking water supplies are unsafe because of high nitrate concentrations, point-of-use treatment or other short-term solutions are needed in combination with lasting safe drinking water solutions.

Thank you!

Find the book, executive summary, and additional materials at **asi.ucdavis.edu/nitrogen**

For information resources on nutrient management for farmers and consultants, please see the Solution Center for Nutrient Management, at **http://ucanr.edu/sites/Nutrient_Management_Solutions/**

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