

**Improving Nitrogen Management and
Reducing Nitrogen Pollution in California:**

**A Multi-scale, Multi-stakeholder Strategy for
Agriculture and the Environment**

A response to the David and Lucile Packard Foundation's Request for
Contributions to the Development of the Agriculture and Environment Grantmaking Strategy

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I. Background: Successes and Dilemmas of High-Productivity Agriculture

Nitrogen (N) is the most crucial mineral element for the global food supply. The tradeoffs involved in agricultural N use represent many of the sustainability issues related to the intensification of agriculture — reliability of the food supply, environmental quality, and human well-being — and are intimately linked with some of the greatest challenges we face in the 21st century: global climate change, depletion of fossil fuels, and mounting pressure on land, air, and water resources from growing human population and rising incomes.

The conversion of atmospheric N₂ to plant-available ammonium (NH₄⁺) through the Haber-Bosch process, central to the dramatic increases in agricultural productivity during the 20th century, has supported unprecedented growth in human population worldwide. Globally, artificial sources of newly-fixed N now exceed natural sources (60:40), resulting in an N cascade that can have serious impacts on our environment. High productivity through heavy N fertilization is thus obtained at a cost. How high that cost is and who actually faces it, where, and when, are not generally known.

California, with the largest and most diverse agriculture in the U.S., epitomizes the successes and dilemmas of ever-higher-productivity agriculture. The state earns over \$30 billion annually from agriculture, which accounts for over 13% of national agricultural production with less than 4% of the nation’s farmland. Specialty fruit and vegetable crops, dairy production, and beef cattle ranching dominate California’s agricultural land and water use. As a direct consequence, both fertilizers and animal waste contribute to N pollution. Manure generated by California’s dairy herd contains amounts of N equivalent to the waste produced by a human population of 50 million. Whether it originates from cropping or livestock, much of this agricultural N “leaks,” creating environmental impacts that are only partially documented: eutrophication and anaerobic “dead zones” in certain rivers; pollution of estuaries and coastal areas; high fluxes of nitrous oxide (N₂O), a potent greenhouse gas; and nitrate contamination of groundwater, which, when used as drinking water, increases health risks.

II. A Strategy for Impact

A range of options could be developed to mitigate the interlinked problems of N pollution. These include practices to increase N-use efficiency in cropping and better waste management in the livestock sector; restoration and rehabilitation of wetlands and other “filter” elements in watersheds; innovative institutional models to catalyze cooperation toward these ends; and appropriate policies, regulations, rewards, and market incentives to spread the adoption of best practices. These opportunities span many scales and types of decision makers. Success in addressing these issues will require partnerships for research, active learning, and effective communication to identify, develop, and spread cost-effective interventions.

Although the beneficial roles of nitrogen in agricultural production are well-established, the causes, location, extent, and severity of the associated environmental problems are only partially documented. Moreover, these environmental problems are not of equal concern and the feasibility of eliminating all environmental impacts is doubtful. Practical research needs to be done to set priorities for action (where, when, by whom, and how intensively), as well as identify cost-effective means to act, since there are few financially-viable or organizationally-feasible options available “off-the-shelf.”

Goals and objectives: The primary goal of this strategy is to better manage N use in California agriculture to reduce N pollution. This will achieve the following objectives: (1) benefit the economy, environment, and public health in California; (2) create practical, cost-effective models for multi-scale, multi-stakeholder action that can be applied to N pollution and other agriculture – environment challenges; (3) build public awareness and support for policies, regulations, rewards, and market incentives to promote innovation and effective action; and (4) inspire initiatives in other states, the nation, and across the world. These objectives address Packard Foundation draft objectives numbered 2, 3, 4, 5, 6, 11, and 12.

Desired impacts at a range of scales: By managing N use and reducing N leaks, this strategy has the potential to effect change at a range of spatial and temporal scales, including mitigating global climate change by reducing agricultural N₂O emissions, and enhancing biological diversity conservation, ecosystem functions, and public health in specific California watersheds. The activities listed in the next section follow a loosely-nested hierarchy, where results at one scale inform the solutions generated in another. For example, workable prototypes developed at the farm, ranch, and watershed scale feed into policy initiatives at the state and national level, which are, in turn, necessary for significant global impacts. Major categories of desired impacts include:

- **Policies, public programs, and public-private partnerships** that improve incentives to increase N-use efficiency and reduce pollution;
- **Innovative multi-stakeholder partnerships for action** at the watershed scale to enhance landscape elements, such as wetlands, that filter N pollution; and
- **Widespread adoption of best practices on farms and ranches** to reduce N pollution of water and the atmosphere, including biological management of soil fertility and livestock waste-management systems that permit bioconversion to fuel feedstock.

III. Examples of Activities That Integrate Science and Action to Produce Desired Impacts

The activities described below sketch key opportunities to link science and action to yield significant improvements in N management and reductions in pollution. As shown in Figure 1, a combination of activities is needed to achieve desired impacts.

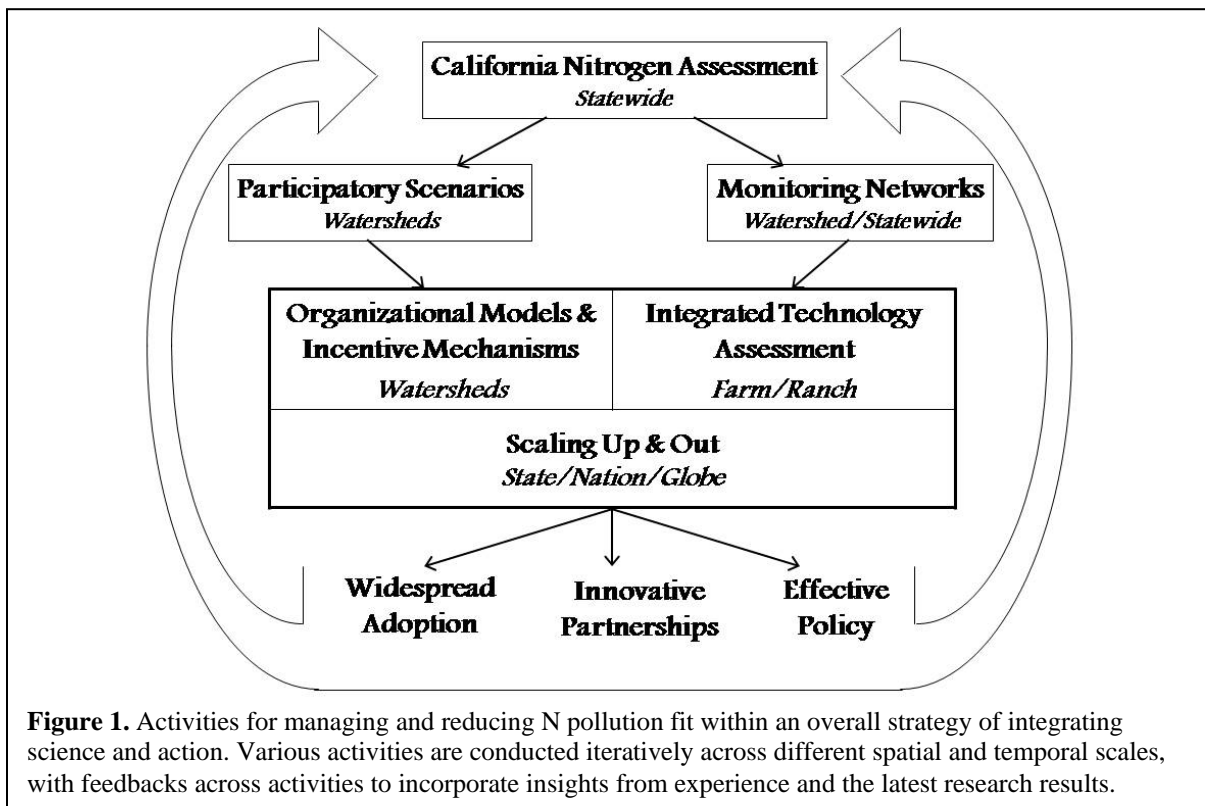


Figure 1. Activities for managing and reducing N pollution fit within an overall strategy of integrating science and action. Various activities are conducted iteratively across different spatial and temporal scales, with feedbacks across activities to incorporate insights from experience and the latest research results.

California Nitrogen Assessment. Several forms of N are mobile in the soil, water, and atmosphere, and there is still considerable uncertainty about their aggregate flows and ultimate impacts in the environment. The first step in reducing this uncertainty is to use existing data to develop **N budgets** for California’s major agricultural production systems, possibly on a region-by-region basis. As a next step, a more-detailed assessment of the spatial and temporal aspects of major N flows would be conducted to identify the processes that cause some crop and livestock systems to use and leak much more N than others. Using **wedge analysis**, these component issues would be assigned priority in order of the most significant opportunities to reduce pollution, increase agricultural productivity, and enhance profitability through

improved N management. Ideally, this N assessment would be conducted as part of the broader ecosystem assessment under development for California agriculture, to engage scientists with stakeholder groups in creating the “big picture” framework for identifying critical tradeoffs across the different components of the N issue, and between this issue and other agriculture-environment challenges faced in the state.

Watershed Monitoring Networks. Monitoring N flows in selected watersheds and on cooperating farms and ranches will serve a dual purpose: (1) providing **data to fill key gaps** in the California Nitrogen Assessment, described above, and (2) **establishing benchmarks** for the impact of the overall strategy outlined in this document. Current N monitoring efforts are partial and fragmented, and have not capitalized on some new, promising techniques (e.g. stable isotope analysis and remote sensing). There is an opportunity for collaboration between scientists and farmers, ranchers, and other resource managers to develop easy-to-use and scientifically-valid **tools for measurement** of N flows in soil, air, and water. Initially, these monitoring tools will be developed within selected watersheds, but can later be deployed for widespread adoption.

Participatory Scenarios in Selected Watersheds. Multi-stakeholder, participatory scenario exercises will help identify **practical response options for specific watersheds**. These exercises will build on analyses of the California Nitrogen Assessment and will be linked to the monitoring networks described above. At a richer level of practical detail than would be possible for the statewide assessment, scientists, community members, and other stakeholders will be organized to assess, in a spatially explicit way, the N flows from crop and livestock systems through their watershed. Such assessments will help identify **critical N pathways**, and locate environmental “hot spots” and options for action in real operational settings. **Place-based watershed teams** will provide the organizational foundation for the activities described below, and facilitate communication between organizations that operate at various scales.

Integrated Technology Assessments. Innovative management practices may have unforeseen repercussions on biophysical processes, economic viability, and the surrounding environment. Moreover, uncertainty in the paths of drivers (e.g., climate, energy prices, commodity markets, and labor costs) means that much is unknown about the key determinants of future profitability for California agriculture. Thus, there is an ongoing need for collaboration between scientists, farmers, and ranchers on integrated **technology assessment spanning agronomic, economic, environmental, and social considerations**. Such collaborations can be used to explore N-efficiencies for animal feeds and fertilizers, and to better manage and mitigate the effects of off-site movement of N. There also are important opportunities to evaluate practices that have been used elsewhere, and to adapt these techniques to California’s conditions. Linked to this activity would be the development of a **user interface** for growers and livestock producers, through which they can calculate ecosystem N costs/benefits across a range of soil types, climate scenarios, and production options.

Testing Organizational Models and Incentive Mechanisms in Selected Watersheds. The appropriate incentives to encourage farmers, ranchers, and other resource managers to put alternative agricultural methods into practice do not yet exist. Our challenge is to **engage policymakers** and create institutions that can catalyze and **support cooperation** among stakeholders to achieve collective goals, such as watershed restoration. By building on data and experience generated by place-based monitoring networks and scenarios teams, activities designed to explore pilot approaches and demonstrate their potential for impacts will combine innovative practices and incentive schemes at various spatial and temporal scales. These activities will test, validate, and adapt innovations for more-general use through targeted research, communication networks, and partnerships that take an integrative approach to N pollution problems and opportunities. Innovative **prizes and other rewards** will be used to recognize individuals, small teams, and community groups that achieve real, measurable impacts; social entrepreneurs that create model programs; and multidisciplinary teams of scientists and stakeholders that conduct path-breaking integrative science.

Scaling Up and Out. Achieving significant impact will require complementary activities in the **synthesis, translation, and communication of results** so that farmers and ranchers, community groups, policymakers, activists, and others can lead the change process through individual initiatives, collective action, and advocacy of appropriate public policies and programs. In addition to their roles in the foregoing activities, **UC Cooperative Extension specialists and county farm advisors** and their non-governmental and private sector counterparts (e.g., irrigation advisors and other professional farm management advisors) have indispensable roles to play in associated outreach and extension activities. From the outset, it will be important to nurture **coalitions to spread information** on cost-effective, environmentally-sound practices, and to press for environmental incentives and safeguards in state and national policies.

IV. Timeframe, Resource Allocation, and Other Operational Principles in a Consortium Structure

The program outlined above would require over ten million dollars and a decade or more to implement. The premise underlying this strategy is that prospects for real impact depend on the integration of activities across multiple stakeholders, spatial and temporal scales, and scientific disciplines. A consortium structure, involving many institutions and individuals, is one way that such integration could be achieved. There are, of course, financial and organizational costs associated with establishing and managing such consortia, which need to be appraised carefully. On the other hand, these costs could also be viewed as an investment in creating permanent capacity to link science with action on N pollution and other agriculture-environment challenges. Moreover, this effort could be built on the land grant heritage of the University of California, rather than starting from scratch. Building on existing networks and a recently-completed stakeholder typology, an appropriate starting point would be consultation with a wide range of stakeholders (farmers and farm workers, ranchers, agricultural organizations, agro-industries, government agencies, environmental and public health NGOs, and other groups) to set the stage for building effective statewide and watershed coalitions. Potential consortium members include:

- Agricultural Sustainability Institute (ASI) at UC Davis, which links sustainable agriculture initiatives across all divisions of the College of Agricultural and Environmental Sciences at UC Davis, the University of California, and other partners across the state
- UC Agricultural Experiment Station (AES) and the Division of Agriculture and Natural Resources (ANR), including faculty, cooperative extension specialists, county farm advisors, and statewide programs, such as the Sustainable Agriculture Research and Education Program (SAREP), the Kearney Foundation for Soil Science, the Agricultural Issues Center, and various centers for research on watersheds and water resources.
- Farmers, ranchers, agricultural industry groups (e.g., Farm Bureau, various commodity groups)
- NGO partners (e.g. Roots of Change Fund, California Alliance with Family Farmers; Great Valley Center; Natural Resources Defense Council, Sustainable Conservation, and many others)
- Government agencies (e.g., California Department of Food and Agriculture, Department of Resources, California and US Environmental Protection Agency)
- UC faculty and students (including Berkeley, Davis, Riverside, Santa Cruz); CSU campuses (Fresno, Chico, Cal Poly San Luis Obispo and Pomona), and private universities (e.g. Stanford, Santa Clara).

The consortium will seek solutions across various scales — starting with stakeholders’ perceptions of opportunities for action to improve N use efficiency and to reduce N pollution, and their specific priorities for research to support such action. The consultations would be a prerequisite for specific budget allocations across activities. Operational principles that should guide this effort include maintaining a balance between usefulness to stakeholders and scientific credibility; ensuring the legitimacy of the process through maintaining balances among regional interests, large and small operators, producers and consumers, etc; and disciplinary balance across production, environmental, and social science disciplines.