

**UCDAVIS**

**AGRICULTURAL  
SUSTAINABILITY INSTITUTE**

*College of Agricultural and Environmental Sciences*

**The California Nitrogen Assessment  
and Related Activities**

**December 15, 2009**

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Report to the David and Lucile Packard Foundation  
on the Anchor Grant to Advance Nitrogen Science  
and to Support Development of a Center of  
Excellence for Agriculture and the Environment

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## INTRODUCTION

This report outlines the progress of the Agricultural Sustainability Institute program as outlined in the proposal *Anchor Grant to Advance Nitrogen Science and to Support Development of a Center of Excellence for Agriculture and the Environment*, awarded to ASI from the David and Lucile Packard Foundation in 2009.

The Anchor Grant proposal divided ASI's proposed work into three activities – the California Nitrogen Assessment, Interdisciplinary Research Teams, and Strategic Communications, which are all addressed in this report. However, we note that these three activities are becoming closely intertwined in implementation, and will become even more so in the coming year.

Within this report, the "California Nitrogen Assessment" section is organized along the lines of a formal ecosystems assessment framework, progressing from *Process Design and Engagement*, through *Conceptual Framework, States and Trends, Scenarios*, and, finally, *Responses/Interventions*. The work of the assessment thus far has been to build the knowledge foundation to analyze states and trends and outreach needs in the context of the assessment. Responses and interventions work reliant on this knowledge base will be undertaken during the following year, and is addressed briefly in *Responses/Interventions*.

To date, Strategic Communications (Activity III) have been largely implemented through the work of the California Nitrogen Assessment (Activity I), so these two items are addressed simultaneously in the report, particularly within the *Process Design and Engagement/Strategic Communications* portion of the "California Nitrogen Assessment" section.

The "Interdisciplinary Research Teams" section addresses the second project activity, listing the development of the interdisciplinary research teams through junior faculty awards and other work related to institutional capacity building.

The "Project Evaluation" section outlines our preliminary work in mapping and monitoring progress towards project outcomes.

The "2010-2011 Implementation Plan Summary" section provides a broad outline of upcoming anchoring activities and events and describes how they will provide venues for interaction between the nitrogen assessment and institutional capacity building aspects of the project. The final section ("Administrative Update") provides an administrative update on project personnel hired, the technical advisory board, and the graduate seminar and its role in the assessment.

Many figures and graphics are referenced throughout the report and can be found in the "Appendices," outlined in the "Table of Contents."

Finally, it should be noted that, in keeping with the complexity of the issues being addressed and the nature of an ecosystem assessment approach, the preliminary results and strategies presented in this report are likely to be adapted and refined as new findings emerge from our review of data and literature, and as we continue to engage with external stakeholders.

## CALIFORNIA NITROGEN ASSESSMENT

This section highlights progress, sample outcomes, and next steps in each of the main stages of the California Nitrogen Assessment. Appendix A provides a tabulated, stage-by-stage accounting of the status, preliminary findings, and next steps of each specific activity.

### A. PROCESS DESIGN AND ENGAGEMENT/STRATEGIC COMMUNICATIONS

This section outlines the outreach and communications portion of the California Nitrogen Assessment (Activity I) with the understanding that these activities also build into Strategic Communications, which is listed as Activity III of the initial grant proposal. We submit this as a paired progress update of both outreach and communications in the CNA and in the strategic communications of ASI. The overlap between the outreach and communications work of the CNA and ASI Strategic Communications are noted throughout.

#### **Philosophy and Practice**

Successful engagement with key stakeholder groups is vital to establishing the overall assessment goals of credibility, relevance, and legitimacy. This engagement also builds the foundation for future ASI efforts that involve stakeholder interaction, and supports the creation of an ASI-based network for knowledge transfer, action, and input on issues relevant to agricultural sustainability in California.

Our communications and outreach strategy is built around identifying and involving key stakeholder groups and addressing their needs and desires – while ensuring the assessment meets its goals of being credible, relevant, and legitimate.

All of our communications and outreach efforts are built around the central communications and outreach goal for the California Nitrogen Assessment:

*To identify and engage key stakeholder groups, communicate the initiation, progress, and findings of the California Nitrogen Assessment, and incorporate stakeholder input in a way that ensures the assessment's credibility, relevance, and legitimacy.*

Based on the stakeholder outreach and engagement that we have done thus far, careful reading of *Ecosystems and Human Well-being: A Manual for Assessment Practitioners*, and discussion among team members, we have crafted a comprehensive 15-page communications plan (see Appendix E) and are refining our outreach and communications strategy for the remainder of the assessment to be mindful of these findings and the overall goals of the assessment.

#### **Implementation**

Thus far, we have engaged – both through one-on-one discussions and in meetings, and via phone and e-mail contact – dozens of organizations, groups and individuals from all of the key stakeholder groups that we have identified (those groups are listed in the CNA Communications Plan, and a breakdown of those stakeholders by affiliation is in Appendix C). Aside from these stakeholders, we have also reached out to over 150 employees of University of California Cooperative Extension (UCCE), and many UCCE farm advisors will be participating in a survey that we will be conducting in early 2010. When we include the UCCE farm advisors that we have contacted, our database of contacts for the assessment includes nearly 300 people.

We held a large forum in Sacramento in July 2009, which brought together several dozen representatives from the agricultural industry, government, research institutions, and human health and

environmental NGOs. This initial meeting led to a series of questions that we have synthesized and are using to guide the work of the assessment, and show to additional stakeholder groups for feedback and use as a discussion tool (See Question Tree, Appendix B). As a follow-up to this meeting, we will be conducting another large meeting in Sacramento or Davis in the middle of 2010. We have also held a series of smaller stakeholder meetings and grower consultations around the state, with more to follow early in 2010 (See Map of Outreach Meetings, Appendix D).

We have created a Web site for our project: <http://nitrogen.ucdavis.edu> and are working to update the ASI Web site and integrate the nitrogen Web site into the new ASI site, which will have a variety of features, including the ability to embed video and promote social networking tools, as well as enable users to comment on products and findings and sign up to receive updates about ASI and its projects. It will also have a more user-friendly and aesthetically-appealing look and feel (See Appendix I).

### **Observations**

Throughout the initial six months of the engagement process, we identified room for improvement – and we have actively adapted our strategy to better engage stakeholders and achieve our broader assessment goals.

Experiences in our stakeholder meetings to date have led us to believe that ASI and the California Nitrogen Assessment must be flexible in how we choose to initiate discussion about the issues addressed by the assessment.

While the assessment is addressing the ways in which nitrogen flows through the state's agroecosystems and the effects excess N can have on human health and the environment, some stakeholders are not yet prepared to discuss nitrogen in these terms. Thus, although the initial intent of our stakeholder consultations was to *frame questions* for the assessment, we have found that our stakeholder meetings need to take a variety of forms based on stakeholders' level of awareness regarding nitrogen use as a *problem* in need of a *solution*.

Here are some examples of the knowledge divide that we have seen with select stakeholder groups:

- 1) Grower awareness of nitrogen use efficiency (NUE): Growers do not typically see nitrogen application as problematic. Some of them realize that nitrogen can be a groundwater pollutant, but by and large they do not acknowledge that their use of nitrogen is inefficient in terms of plant uptake and leakage to the environment. They believe that they are using nitrogen efficiently and that those farmers who do not will go out of business – thus a farmer who remains in business *must* be an efficient user of N fertilizer. When confronted with statements such as “approximately 50 percent of nitrogen applied to fields is leaked and not taken up by crops,” they say that this may be true on other, inefficient farms, but not on *their* farm.
- 2) Community health impacts: Communities such as those in the Central Valley who are faced with nitrogen-related health impacts are largely unaware that among the myriad health issues they face may be the problem of high nitrate concentrations in groundwater or air pollution related to nitrous oxides. While many communities are aware that they face negative health outcomes, and researchers we spoke with mentioned community awareness of a range of ailments such as asthma or illnesses caused by unsafe water, those community members who can trace the cause of their health problems back to nitrogen are few, if they exist at all.

We have made a variety of other observations throughout our outreach work, including the observation that our outreach focus may need to shift as different systems and practices become apparent as prominent contributors to the flows and hot spots of nitrogen pollution. We will continue to adapt our outreach strategy to the changing scientific knowledge gathered by our assessment team and the emerging needs of our stakeholders.

### **Future Action: Making Strategic Refinements**

#### *Strategic Refinement 1: Stakeholder Meeting Objectives and Format*

- *Issue:* As the assessment progresses, the approach to the stakeholder meetings needs to take a new form in order to address stakeholder and project needs.
- *Refinement (Outreach):* Revisit purpose of stakeholder meetings and focus more on interactions with stakeholders that get them engaged in the assessment and lead towards progress on overall assessment goals. For example, use grower forums to glean information from growers about practices while also *raising awareness* about nitrogen in other contexts.

#### *Strategic Refinement 2: Expanding Stakeholder Outreach*

- *Issue:* Now that we have refined the list of commodity systems we are going to be examining in the assessment, we realize we need to expand the number and range of types of producers involved in our stakeholder assessment.
- *Refinement (Outreach):* Expand stakeholder outreach to reach more producers statewide; hold additional meetings with growers in the southern part of the state.

#### *Strategic Refinement 3: Convening a Stakeholder Advisory Board*

- *Issue:* Our technical advisory board, while distinguished, lacks the perspective of assessment users and the nonscientists that many of the products of the assessment are intended to reach.
- *Refinement (Outreach/Communications):* Create a stakeholder advisory board to complement the technical advisory board and the External Advisory Board of ASI. The CNA Stakeholder Advisory Board will be comprised of members who represent the stakeholders in our communications plan. This group is different from the ASI external advisory board because it will include the key individuals involved in the scenarios we plan to undertake as part of the assessment. These members will act as representatives and liaisons to the stakeholders they represent, and will be a sounding board for the materials that we produce as part of the project. We also envision board members as key messengers for change among the constituent groups they represent and as crucial members in the outreach network ASI is working to create.

#### *Strategic Refinement 4: Creating Public Awareness*

- *Issue:* There is a general lack of public awareness about nitrogen pollution as a problem and about nitrogen fertilizer as a major agronomic input. We are trying to go beyond merely producing multimedia materials – we want to make sure those materials are valued and used by the right people.
- *Refinement (Communications):* Although our original proposal called for creation of a Web site, we have learned more about the steps we need to take that will make that site useful and engaging. Building the nitrogen site has also accelerated the process of updating ASI's Web site, which will be up and running in early 2010. In addition to the nitrogen assessment Web site, we will create a series of videos, graphics, and other media that helps explain different aspects of the N cycle and issues of nitrogen in agriculture related to the work of the CNA. We will share this content with journalistic enterprises such as *Grist.org* and other content distributors. This

helps create awareness among the public related to the work of the CNA and the importance of better managing agricultural nitrogen.

*Strategic Refinement 5: Developing Understanding and Consensus Across Stakeholder Groups*

- *Issue:* Stakeholders exist on vastly different planes of knowledge, understanding, and awareness of issues related to nitrogen in California.
- *Refinement (Outreach/Communications):* Include stakeholder-driven scenario building as one of the assessment products. This will help build consensus between stakeholders who currently hold widely divergent perspectives on the importance of nitrogen pollution and nitrogen fertilizer use in agricultural sustainability. It will also play a key role in envisioning a future for California agriculture that uses nitrogen more sustainably, and the stakeholder-generated scenarios will hopefully play into quantitative models the CNA team will create.

*Strategic Refinement 6: Understanding Human Health Impacts*

- *Issue:* Although health impacts are a stated reason for conducting the nitrogen assessment, our inquiries have uncovered that the state of scientific knowledge on the human health impacts of nitrates in groundwater is far from a consensus. Thus far, although conventional wisdom suggests that nitrogen does have very real effects on human health, we have had a hard time finding documented links to relevant studies on health impacts.
- *Refinement 6 (Communications):* Refine communications message to point to lack of data on impact of nitrates in groundwater on public health, and need for the assessment to clarify major research holes. We also need to clarify the human health impacts of nitrogen as an air pollutant. Because of the prominence of human health issues in both our original grant proposal and because human health is an issue commonly mentioned in the context of this assessment, we are considering the need for additional input on the assessment from someone in the field of public health – which may mean hiring a professional or graduate student with expertise in this area.

*Strategic Refinement 7: Targeting Stakeholders*

- *Issue:* Our stakeholder network may be broad enough to reach many constituents, but not targeted enough to effect change.
- *Refinement 7 (Outreach):* Although we are targeting growers as a major stakeholder group for our initial outreach, we believe that as results emerge we may need to more closely target key players in California agriculture if we wish our work to be disseminated and used as a tool for potential change. As part of both ASI strategic communications and the California Nitrogen Assessment, we wish to strengthen our knowledge about which stakeholders play important roles in catalyzing change in agriculture, and hope to map them and reach out to them strategically during the work of the assessment and beyond.

## **B. CONCEPTUAL FRAMEWORK**

Central to the coherence of an assessment is the design or adoption and use of a conceptual framework—a common understanding of what the assessment aims to do.

A conceptual framework is a “concise summary in words or pictures of the relationships between people and nature, including how those relationships are changing over time” (Tomich et al., in *Ecosystems and Human Well-being*, Ash et al.). When we began the California Nitrogen Assessment, we were using the conceptual framework adapted from a figure in our grant proposal (first exhibit in Appendix F). We have since created multiple drafts of the conceptual framework that better reflect our understanding of nitrogen systems in California agriculture, and are more comprehensive and visually appealing. We are currently working with multiple versions of two central conceptual frameworks approved by the technical advisory committee (See the second and third exhibits in Appendix F), but we have not yet made much use of those drafts as a tool for stakeholder engagement.

### **Conceptual Framework and Assessment Team**

Within our team, wrestling with the conceptual framework has been a useful exercise, forcing us to discuss the terms in which we are framing the drivers of change and stocks and flows of nitrogen and to build a shared understanding amongst our team. Thus far, we have found the conceptual framework most useful as an internal tool to guide the project focus and our engagement with various audiences. We have also used our evolving “boxes-and-arrows” conceptual frameworks (See the first and third exhibits in Appendix F) as a guide to create the draft “Table of Contents” for the assessment document (See Appendix L).

### **Conceptual Framework and Stakeholder Engagement**

We have faced challenges introducing various models of the conceptual framework in order to engage stakeholders who come from a broad spectrum of backgrounds and interests. We strive to provide a balance between nitrogen’s integral role in food production and its related benefits to society in our outreach endeavors, while also acknowledging the potential environmental and human health effects. However, since many stakeholders do not even think about nitrogen in these terms, our focus has been on engaging them at an introductory level, as we work toward developing a shared understanding of both the benefits and problems associated with nitrogen, rather than on collaborating with them to produce a conceptual framework. Thus, we have used a basic framework depicting the nitrogen cycle in agriculture (See the third exhibit in Appendix F) as a tool for engagement with growers, and a set of questions generated by stakeholders as a tool for engagement with other stakeholders (See Appendix B). This is based on the concept that “a conceptual framework seeks to draw attention to a subset of components and relationships that are believed to be most important for understanding the system” (Tomich et al., in *Ecosystems and Human Well-being*, Ash et al.).

### **Conceptual Framework for Future Use**

As noted in *Ecosystems and Human Well-Being*, “A conceptual framework that is not developed through engagement with participants and stakeholders but is instead ‘imposed’ on those who have to use it can turn out to be a rather fruitless exercise” (Tomich et al., Ash et al.). We plan to develop further processes for engaging stakeholders in collaboratively creating a conceptual framework, perhaps through our scenario exercises (see Scenarios section). The challenge will lie in finding a balance between introducing nitrogen as an issue and developing our existing frameworks in collaboration with stakeholders. As we continue to engage our stakeholders, we will work with them over time to build one or more conceptual frameworks based on their increasing understanding of the issues of nitrogen in California agriculture.

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## C. STATES AND TRENDS

### I. DRIVERS OF NITROGEN USE IN CALIFORNIA AGRICULTURE

Nitrogen use in California agriculture is shaped by factors that range from the field level to the global level – including climate, soils, elevation, public investment in infrastructure, technology adoption, regulatory constraints, trade policy, and changing consumer demand. This section focuses on identifying and quantifying indicators related to the drivers of nitrogen use in California agriculture. To reveal trends in these data, special attention is being made to obtain consistent time-series data at scales ranging from the county to the state to the nation to the world.

UC Agricultural Issues Center researchers Tom Rosen-Molina and Marcia Kreith are compiling and critically assessing existing data related to the following indicators of these drivers:

- Production (by commodity tonnage, numbers of animals, harvested and planted acreage, production value, yields)
- Agricultural inputs including expenditures (feed, fertilizer, manure, pesticides, electricity, petroleum fuel and oil, labor, rent, taxes, etc.)
- California’s international exports (value of individual commodities, shares of production value and quantity, top export destinations and amounts to those markets)
- Incoming commercial domestic shipments and numbers of plants and animals, recorded at pest exclusion border stations
- Land use (developed, cropland, forestland, pasture and rangeland)
- Conversion of crop and grazing lands to urban and built-up areas
- Farm characterization (farmer demographics, legal organization, size distribution by sales)
- Applied water use of surface and groundwater supplies in wet, normal and dry years
- Precipitation
- Temperature
- Population and demographic trends (county and state level)
- Standard of living metric (GDP per capita, consumption per capita)
- Commercial fertilizer imports, exports, production, consumption

Below we highlight changes over time in two of these indicators (area of cropland and export value). First, while harvested crop area has remained relatively constant over the past 40 years, the crop mix has changed dramatically (Table 1, below). The crop area for some commodities such as barley and cotton has been substantially reduced while the area of orchards and vineyards has almost doubled. As a result, we would expect changes in N flows because the fertilization rate and other relevant practices as well as the agronomic efficiency varies among crops.

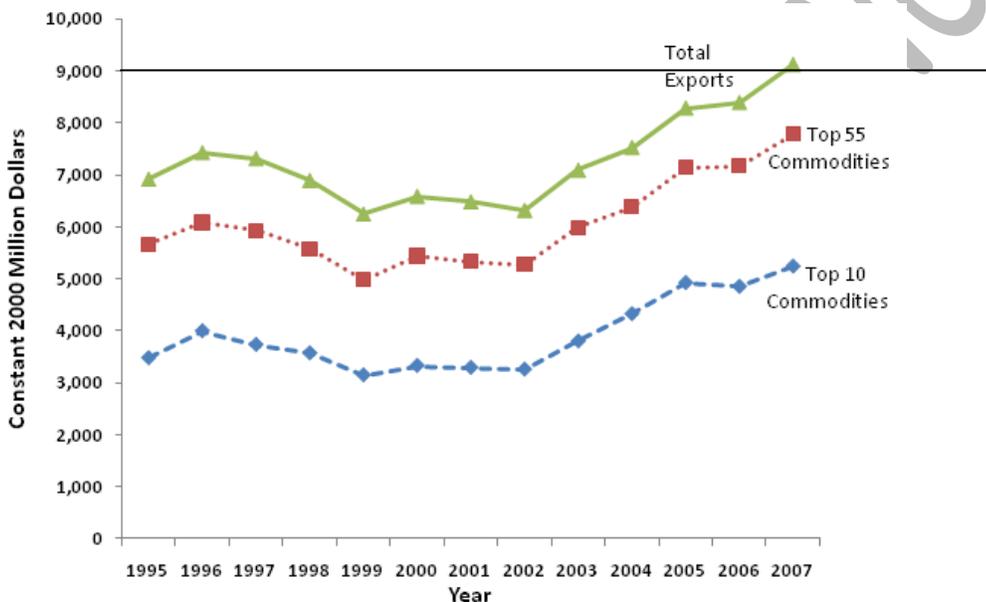
**Table 1: California harvested cropland, 1964-2007**

	1964	1982	1987	1992	2002	2007
	1000 acres					
Orchards and vineyards	1,520	2,158	2,153	2,246	2,872	2,826
Hay, all types <sup>a</sup>	1,702	1,416	1,533	1,531	1,953	1,723
Vegetables and melons	626	895	883	1,017	1,197	1,170
Cotton	759	1,313	1,084	1,066	695	471
Rice	343	567	399	401	531	531
Wheat for grain	267	929	562	569	410	354
Barley for grain	1,319	583	270	204	75	44
Other crops <sup>b</sup>	1,310	904	793	727	733	513
<b>Total harvested cropland</b>	<b>7,846</b>	<b>8,765</b>	<b>7,676</b>	<b>7,761</b>	<b>8,466</b>	<b>7,633</b>

Source: U.S. Department of Commerce Census Bureau, Census of Agriculture (1964-1992); USDA National Agricultural Statistics Service, Census of Agriculture (1997-2007).<sup>a</sup> Hay includes alfalfa, small grain, wild grass silage and green chop varieties. <sup>b</sup> Residual obtained by subtracting all reported crops from total harvested cropland. Dry beans, potatoes and sugarbeets are in this group.

Changes in the export markets are also driving changes in California agriculture. The export value of California goods has been rising since 2003 after a period of stagnation that lasted from 1996 to 2002 (Figure 1, below). The total value of exports of the top 10 commodities leveled off over the past three years at around \$5 billion, while the combined top 55 commodities have continued to increase in export value. Recent growth in exports of California agricultural products is due to increased trade of California’s “minor” commodities. Thirty-five of the top 55 export commodities experienced growth of 5 percent or more from 2006 to 2007. In contrast, 14 commodities showed decreased export value of 5 percent or more. The remaining 6 commodities experienced little to no change (<5 percent) in export value from 2006 to 2007. Changes in export value reflect both price changes and quantity changes. In turn, quantity changes reflect the difference between quantity produced and quantities shipped to U.S. domestic markets. Changes in export values reflect increased export demand and may therefore be a driver for land use change when high value export crops are being grown in greater quantities. The resulting changes in crop mix once again will affect overall nitrogen use because of differences in practices between crops. In addition, currency exchange rates constitute a driver for these changes in exports, because part of the increases in California agricultural exports can be attributed to a weaker dollar in relevant markets.

**Figure 1: California’s agricultural exports, 1995 – 2007**



Source: AIC Issues Brief No. 35, 2008. <http://www.aic.ucdavis.edu/oa/briefs.html>

As we continue to identify trends in these indicators, we will explicitly develop the links between drivers of nitrogen use and nitrogen flows. In addition, we will characterize the quality of the data gathered and, whenever possible, quantify uncertainty in the various indicators.

## II. BIOGEOCHEMISTRY

The goal of the biogeochemistry component is to calculate a mass balance for the state of California. To achieve this we are identifying and quantifying the sources of new inputs of reactive nitrogen and losses of all forms of nitrogen for the state as a whole.

The dominant stocks of nitrogen (N) are stored in plants, soils, and groundwater. Preliminary calculations suggest that aboveground plant biomass represents a stock of approximately 10 million tons of N and the surface soil (top 20 cm) contains 100 million tons of N, while the groundwater storage pool is unknown. While the size of the pools mentioned above may be changing as well, we have focused on the fluxes of N, especially the new inputs of N. These new inputs represent N that is either fixed from  $N_2$  within California or N that is imported in solid, dissolved, or gaseous form from outside the state.

### Inputs

We have defined the following as the terms representing new inputs of reactive N to California

- Biological N fixation (crops and natural lands)
- Fertilizer (synthetic and imported organic)
- N deposition from fossil fuel combustion
- Gross imports of food/feed/fiber

The largest component of N fixation in the state is from alfalfa which is grown on over 1,000,000 acres. The N fixation associated with this crop represents a nitrogen input of 180,000 tons annually (see Table 1, pg. 15). There has been a small increase (~10%) in the amount of alfalfa grown over the last 30 years (Figure 1, at left). While natural lands occupy a much larger acreage than alfalfa, the fixation rate is thought to be much lower representing a new N input of ~100,000 tons. However, this flux represents the only input of reactive N not directly related to human activity.

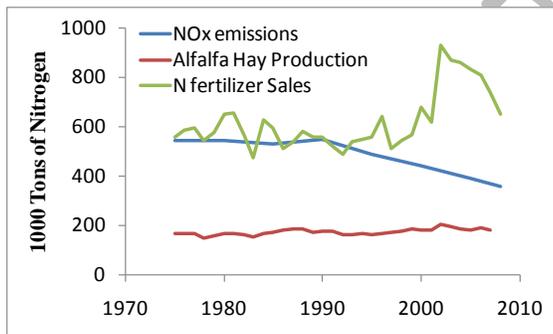


Figure 1. Change over time in the largest new sources of reactive N to California

Synthetic fertilizer sales are quantified by the California Department of Food and Agriculture annually. With the exception of a large jump during the years 2002-2006, the amount of fertilizer sold has varied from 475,000 to 675,000 tons of N (Figure 1). There is a large amount of manure applied in California, but this is not a new source of reactive N in the system as it is accounted for in the animal feed. However, it is possible that there is a small import of other organic fertilizers to the state.

Atmospheric deposition of nitrogen consists of oxidized ( $NO_x$ ) and reduced ( $NH_x$ ) forms of reactive N as a result of both dry and wet deposition. Most of the N deposited is from sources in California as the air is relatively clean coming off the Pacific Ocean. The source of  $NO_x$  is almost exclusively fossil fuel combustion and as such

represents a new source of N to California. The source of  $\text{NH}_x$  is a mixture of fossil fuel combustion (a new source of N) as well as volatilization of ammonia from fertilizer, manure, and natural soils. This  $\text{NO}_x$  is the dominant form of reactive N in the atmosphere, but has been decreasing steadily over the last decade because of the use of catalytic converters in cars (Figure 1, previous page). There are modeled results of N deposition in the state for 2002 that suggest 223,000 tons of N land in CA, some fraction of that is actually recycled N. However, this value is significantly lower than the  $\text{NO}_x$  production which suggests that California must be exporting  $\text{NO}_x$  to downwind states.

It is very difficult to quantify the gross import of food and feed to California, but we are still attempting to find the data sources that would allow these calculations. However, it is possible to estimate net imports. First, we calculated the N harvested in each agricultural commodity in the state based on the average production for 2003-2007 and the N content for crops and livestock. We compare this value to the daily N requirements of the people, pets, and livestock (dairy cows and broilers). Based on this calculation it appears that while California produced more food than its people consume, there needs to be a net import of almost 300,000 tons on N in feed for animals. Based on railroad waybill data, this feed arrives by train from Iowa and Nebraska and is largely corn and a few other grains. Surprisingly, the feed demand of broilers is even greater than dairy cows even though the value of the chickens is 10 times lower.

## Outputs

We have identified five potential sources of N export from California (see Table 2).

- Soil gas losses
- Fossil fuel combustion export
- Surface water discharge to the ocean
- Groundwater storage
- Wastewater discharge to the ocean

Soil gas losses are likely dominated by the production of inert  $\text{N}_2$ . However, the largest source of the greenhouse gas nitrous oxide ( $\text{N}_2\text{O}$ ) is from agricultural soils related to the use of N fertilizer. We calculate a loss of 14,000 tons of N as  $\text{N}_2\text{O}$  annually both by scaling up from the median  $\text{N}_2\text{O}$  emission rate from the few field measurements in California or using the standard direct emission factor of 1.25% of fertilizer application based on the synthesis of global emissions of  $\text{N}_2\text{O}$  related to fertilizer application (Stehfest and Bouwman 2006). The median of the emission factor based on the field data for California was 1.4%, similar to the global average. A

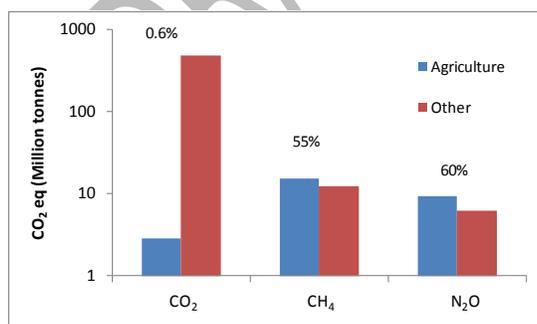


Figure 2. California Greenhouse Gas emissions by gas with the relative contribution of the agricultural sector for each gas.

Source: California Air Resources Board

small amount of  $\text{NO}$  is also emitted from soils, but this is dwarfed by the amount of  $\text{NO}_x$  in the atmosphere from fossil fuel sources. While agriculture is the most important source (60%) of  $\text{N}_2\text{O}$  emitted in California,  $\text{N}_2\text{O}$  is a relatively small contributor (2.8%) to the overall greenhouse gas emissions for the state, and the agricultural sector (5%) is relatively small compared to the overall greenhouse gas emissions (Figure 2, at left).

Our current best estimate suggests that a large fraction of the

$\text{NO}_x$ , and perhaps some  $\text{NH}_3$  as well, is exported from the state as N deposition appears to be lower than the production.

Surface water is a relatively minor export of nitrogen from California. In part this may be due to the relatively small discharge of water from the more highly polluted watersheds such as the Santa Ana. In addition, there are relatively few large discharges of wastewater effluent into rivers in the state.

So far we have not been able to estimate the current loss of nitrate ( $\text{NO}_3^-$ ) from soils from leaching. While there are abundant measures of  $\text{NO}_3^-$  in groundwater, we are still working on finding data on the current leaching rates below the rooting zone to the unsaturated subsoil and groundwater.

Because of the location of the population centers in the state, a relatively large fraction of the wastewater treatment in California is discharged directly into the ocean after the solids have been removed during primary treatment. This flux of at least 82,000 tons of N represents the discharge for approximately 25 million people. The solids which contain 38,000 tons of N are largely recycled to non-food agricultural land and do not represent a loss of N. A very small amount of  $\text{N}_2\text{O}$  and  $\text{N}_2$  are also produced during wastewater treatment.

### **Internal Cycling**

Other internal fluxes are also important to understand. Over 100,000 tons of manure N are produced annually from dairy cows alone. Large quantities of agricultural byproducts, biosolids, and compost are either fed to animals or spread on fields. For a more in depth look at how N is flowing within the state, we will construct mass balances for individual subsystems in the state. For example, we can do input and export calculations for subsystems such as the human food subsystem, the alfalfa-dairy subsystem, or the wastewater subsystem in the same way we did for the whole state to determine where the largest fluxes of nitrogen are occurring and how the subsystems are interacting.

### **Future work**

So far we have compiled a significant number of data sources to get a rough estimate of the N mass balance. At this point, it appears that California is a large sink for nitrogen (we can account for almost 1000 tons more of inputs than outputs). There are several areas where we will focus on improving our estimates:

- 1) The export of  $\text{NO}_x$  and  $\text{NH}_3$  from California.
- 2) Gas losses from soils including natural lands and turfgrass areas (which cover approximately 3 million acres)
- 3) Leaching of  $\text{NO}_3^-$  - below the rooting zone.
- 4) Determination whether California is a net sink for N (i.e. are the inputs and exports so different)
- 5) Assessment of the uncertainty of the data sources
- 6) Identification of hot spots of N and areas at risk

**Table 1: Inputs of new reactive N to California.**

Headings in bold are the sums of the indented subcategories below with the exception of N deposition. The value of 223 tons of N is based on the results of the CMAQ model and the values for NO<sub>x</sub> and NH<sub>x</sub> below are from ARB emission data. The new reactive N in deposition should only come from sources outside of California (i.e. transport across the Pacific Ocean) or fossil fuel combustion in California. Some component of deposition, especially NH<sub>x</sub>, represents internal N cycling within California, e.g. redeposition of ammonia volatilization from livestock manure. At present, however, the modeled estimate of total N deposition is lower than the estimated fossil fuel emissions.

Nitrogen Flow	Nitrogen (1000 tons N)	Calculation
<b>Biological Nitrogen Fixation</b>	<b>290</b>	
Natural Systems	106	Mean rate*area
Ag Systems (Alfalfa)	184	Tonnage*N content
<b>N fertilizer</b>	<b>650</b>	
Synthetic	650	CDFA tonnage reports
Imported Organic	?	
<b>N deposition</b>	<b>223</b>	CMAQ model results
NO <sub>x</sub> from fossil fuel combustion	415	Average of 2000 and 2005 ARB emissions
NH <sub>x</sub> from fossil fuel combustion	30	2005 ARB emission
<b>Net Food/Feed Imports</b>	<b>268</b>	
People Food	202	11 lbs N/person/year
Pet Food	55	8.8 lbs N/dog/year or 2.4 lbs N/cat/year
Cow Feed	271	401 lbs N/cow/year
Chicken Feed	334	2.4 lbs N/chicken/year
Crop Production	-268	Crop tonnage* Nitrogen content
Milk Production	-95	Milk tonnage * Nitrogen content
Meat/Egg Production	-48	Tonnage*N content
<b>Total Nitrogen inputs</b>	<b>1431</b>	

**Table 2: Total N exports from California.**

Nitrogen Flow	Nitrogen (1000 tons N)	Calculation
<b>Agricultural Soil Gas Losses</b>	<b>132</b>	
N <sub>2</sub> O	13	Mean N <sub>2</sub> O emission * acreage
N <sub>2</sub>	119	Upper limit of N <sub>2</sub> O:N <sub>2</sub> ratio from field measurements
NO	9	Mean NO emission * acreage
<b>Fossil Fuel Combustion Exports</b>	<b>192</b>	
NO <sub>x</sub>	192	Production - Deposition
NH <sub>x</sub>	?	Production - Deposition
<b>Surface Water – Total Dissolved N</b>	<b>27</b>	N concentration * water volume
<b>Groundwater - NO<sub>3</sub><sup>-</sup></b>	<b>?</b>	
<b>Wastewater</b>	<b>92</b>	~20 million people connected to treatment facilities that discharge to the ocean
N <sub>2</sub> O	1	Emission from ARB
N <sub>2</sub>	9	Fixed N <sub>2</sub> O:N <sub>2</sub> ratio as above
NH <sub>4</sub>	82	NH <sub>4</sub> content * discharge to ocean
<b>Total Nitrogen exports</b>	<b>251</b>	

### III. MANAGEMENT PRACTICES AND TECHNICAL OPTIONS

Much of the agricultural production system is beyond the producer's control (e.g., weather and market forces); however, there are clearly decisions that he or she controls (e.g., stocking rate and fertilizer rate). These choices—known as management practices, and their underlying technologies, together with land use decisions—have a dramatic influence on the total amount and ultimate fate of reactive nitrogen (N) in the environment.

Here we describe our on-going analysis of the practices and technical options producers use. The focus has been based on three questions distilled from the stakeholder listening sessions: (1) When were nitrogen recommendations established and are they relevant for today's cropping systems? (2) What is the most efficient cropping system in terms of N use? (3) Which practices are currently available to help producers manage N more efficiently and reduce nitrogen pollution? We present preliminary results and observations, and next steps where these results will be integrated with future N science, practice, and policy work.

#### **Question 1: When were nitrogen recommendations established, are they relevant for today's cropping systems, (and would they be useful for establishing a maximum rate of application)?**

N guidelines for most crops were originally established between the mid-1950s and mid-1980s. N guidelines for the commodities that account for the large majority of California's crop production have been updated in the last 15 years and reflect changes in technology, information, and plant genetics. For example, most guidelines account for drip irrigation. As expected, the amount of research on N fertility management and N guidelines appears to be related to the importance of the commodity to the agricultural economy as a whole—acreage, production, or value. *We therefore conclude that N guidelines for the majority of crops are current.*

The N rate guidelines established by the University of California and its affiliates are not the appropriate demarcation for establishing a maximum rate of application. In contrast to prescriptive N recommendations, N rate guidelines purposely vary widely to account for the diversity of production conditions under which a single crop is grown in California. Guideline ranges can vary from 30% to greater than 100% between minimum and maximum values. Determining the appropriate rate is subject to contextual production factors – such as soil type, climate, and cropping history. *More flexible strategies would need to be developed to account for the diversity of California cropping conditions if the goal is to establish a maximum rate of application.*

#### **Question 2: What is the most efficient cropping system in terms of N use?**

The efficiency of N applications ( $NUE^1 = N \text{ export} / N \text{ applied}$ ) and the amount of residual N are indicators of how well fertility is being managed and potential N losses, respectively. Therefore, information on N applications, NUE, and residual N in each cropping system is needed to direct targeted responses— in research, outreach, and

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<sup>1</sup> Agronomic nitrogen use efficiency (NUE) can be calculated in many ways. When using NUE as an indicator, it is important to be clear about the parameters used in its calculation. Here we use the most basic definition.  $NUE = N \text{ exported from the field in crop yield} / N \text{ applied}$ .

policy. We calculated the amount of total N applied, nitrogen use efficiency, and residual N for 38 commodities and present data from the plant commodities that rank among the top 20 commodities of economic value (CDFA 2008), except alfalfa (TABLE 1, below). We omitted alfalfa because it is a legume, fixes its own nitrogen, and in many cases does not receive supplemental N (see pg. 12 to understand the relative input of alfalfa to California N flows).

There is significant uncertainty in these calculations. All of the parameters used—N application rate, crop production, N content of crops, moisture content of crops, etc.—are averages or approximations and subject to considerable debate. For example, fertilizer application rates are not well-documented in general and these data are approximations from USDA survey data. To decrease this uncertainty, we are performing a survey of UCCE farm advisors and certified crop advisors to better characterize fertility management and application rates and plan to perform simulations to determine the sensitivity of the conclusions to variation in the parameters.

**Table 1. Total N, NUE, and residual nitrogen for the most economically significant commodities.**

Commodity	N applied <sup>2</sup> (lbs. per acre)	Area <sup>3</sup> (acres)	Total N applied (tons)	Total production (tons)	N export (tons)	NUE (%)	Total residual N (tons)	Residual N (lbs. per acre)
Almond	200	580000	58000	545780	17421	30	40579	140
Broccoli	135	123600	8343	920821	5356	64	2987	48
Carrot	180	71620	6446	1147352	2080	32	4366	122
Celery	344	25740	4427	917631	1212	27	3215	250
Cotton <sup>1</sup>	123	404000	24846	814262	18538	75	6308	31
Grapes (raisins)	58	240000	6960	2069760	2333	34	4627	39
Grapes (table)	47	83200	1955	776755	876	45	1080	26
Grapes (wine)	33	477800	7884	3198393	3605	46	4278	18
Lemons	200	45000	4500	782372	1514	34	2986	133
Lettuce	200	251400	25140	4080222	8084	32	17056	136
Oranges	85	183100	7782	2127407	3506	45	4276	47
Pistachio	200	102400	10240	138854	4572	45	5668	111
Rice	124	535800	33220	2119625	26063	78	7156	27
Strawberry	215	33680	3621	1020504	1116	31	2505	149
Tomato (proc)	178	279400	24867	10523322	16151	65	8715	62
Tomato (fresh)	243	39600	4811	582120	2134	44	2677	135
Walnut	200	215200	21520	335282	7666	36	13854	129

<sup>1</sup>Includes N in lint and seed (Nitrogen content data from USDA crop nutrient tool <http://npk.nrcs.usda.gov/>).

<sup>2</sup>Nitrogen application rate data are from the most recent USDA chemical usage reports except for nut crops. Almond, walnut, and pistachio application rate data are from UC Agricultural and Resource Economics Cost Studies.

<sup>3</sup>Area equals the average harvested acreage 2003-2007.

Total N applied varies between crops. Crops receiving the greatest amount of N were almonds, rice, and lettuce; the crop receiving the lowest amount was strawberries. Approximately 30% of N applied to these crops was on tree crops and 30% to vegetables and strawberries. Area was positively correlated with total N applied ( $R^2=0.64$ ), suggesting that area could function as a rough indicator of total N application for the purposes of directing future analysis, research, and responses.

NUE for these commodities was slightly less, on average, than the 50% global average (45%). Rice, cotton, broccoli, and processing tomato were the most agronomically efficient crops. Greater than 60% of the N applied in these crops was exported from the field in harvested yield, far above the global average. Cool season vegetables were the least agronomically efficient.

Significant amounts of nitrogen were unaccounted for in yield (residual N). Almond, lettuce, and walnut crops had the largest total residual nitrogen and celery and strawberry had the most residual N per acre.

**Next steps:** (1) “Group” crops based on the eight adopted system designations (data not shown) and draw conclusions across systems. (2) Perform simulations to examine the sensitivity of the conclusions and variations in the parameters. (3) Collaborate with D. Liptzin (the Fellow working on the N mass balance) to identify agricultural N “hotspots.” (4) Identify potential farm-level responses by targeting the analysis of practices and technological options (e.g., Question #3) at the commodities with greatest potential.

**Question 3: What effect do practices have on the fate of nitrogen? Which practices are feasible options to increase agronomic efficiency and decrease pollution?**

Management decisions affect the fate of nitrogen. In plant-based systems, the most important strategy is to synchronize the supply of N with the demand by the crop – but this is easier said than done. Applied N is bound to soil particles or dissolved in the soil solution. Ensuring that it is in the right place, at the right time, and in the right quantity is a significant challenge. Producers face substantial economic risk due to unfulfilled yield potential if N timing is suboptimal. The ability of producers to manage N is limited by technology, expense, and information. In animal systems, while some techniques (e.g., managing N through feed inventories) attempt to control the flow of N into the animal by manipulating the timing and quantity of supply, most management techniques attempt to control the rate of flow of N back to the environment after it has been excreted.

Our aim has been to review the literature and speak with experts, scientists and producers, to identify management options and challenges for implementation. We examined six facets of the movement of N—yield, agronomic efficiency, nitrate leaching and runoff, ammonia volatilization, and nitrous oxide emissions—and twenty-five practices. In total, we reviewed more than 150 articles on CA cropping systems to determine the level of agreement and amount of evidence in the literature. We present a preliminary assessment of the amount of evidence and agreement in the literature for five practices of twenty-five identified. Table 2 (next page) is best interpreted by examining individual grid cells with either many or few check marks (✓) or plus signs (+); each cell indicates where there is significant or little agreement or information, respectively, on the relationship between a particular practice and the fate of N. The symbols simply code assessment of the amount of evidence and agreement and do not convey the sign, positive or negative, of the relationship.

**Table 2:** Preliminary assessment of the amount of evidence and level of agreement in the literature for five practices of the twenty-five identified. This qualitative analysis represents our current thinking on the topic; this literature review and analysis is currently in progress.

Practice or technology	Gains		Loses			
	Yield	Agronomic NUE	Water		Air	
			Leaching	Runoff	NH <sub>3</sub> Volatilization	N <sub>2</sub> O Emissions
<b>Crop agriculture</b>						
Cover crops	√√+++	√√√+++	√√√+++	√√++	√+	√+
Controlled release fertilizers	√√√++	√√√++	√√√+	√+	√++	√√+
Tissue sampling	√+++	√√+++				
Genetic improvement	√++	√++				
<b>Animal agriculture</b>						
Integrated nutrient management plans			√+++	√√++		

**Legend for Table 2**

		Amount of evidence		
		Limited (+)	Medium (++)	High (+++)
Level of agreement	High (√√√)	Agreed but unproven (√√√+)	Agreed but incompletely documented (√√√++)	Well-established (√√√+++)
	Medium (√√)	Tentatively agreed by most (√√+)	Provisionally agreed by most (√√++)	Generally accepted (√√+++)
	Low (√)	Suggested but unproven (√+)	Speculative (√++)	Alternate explanations (√+++)

*adapted from Scholes et al. (in press)*

Practices have received unequal research treatment. For crop agriculture, the greatest amount of information is, as expected, related to how practices affect yield and agronomic efficiency (indicated in Table 2 by +++). Despite a significant amount of research, the effectiveness of some practices on the fate of N (e.g., tissue sampling—only one √) is uncertain. The relationship between management practices and N pollution has been studied far less (e.g., the effects of controlled release fertilizer on leaching—only one +). However, research dating back to the mid-1980s analyzes the effect of management practices, such as cover crops, on nitrate pollution of groundwater. Few studies quantify gaseous N loses under CA cropping conditions. A consensus on how cover crops and controlled release fertilizer affect these emissions has not emerged.

Research on N in animal agriculture focuses on manure management—developing nutrient management budgets and plans, manure lagoons, and irrigation techniques to deliver nutrients to surrounding crop fields. There has been a considerable amount of research on how these practices influence the movement of N. It appears that there is some disagreement about the effectiveness and feasibility of the prescribed practices under actual production conditions.

Preliminary observations for each practice:

- **Cover crops:** It is difficult to synchronize N mineralization of the green manure with crop demand. Cover crops can also interfere with other management practices (e.g., water allocation, pest management, and tillage) and are not cost effective in many production systems.
- **Controlled-release (CR) fertilizers:** Limited value under some California cropping systems. Fertigation (supplying water and fertilizer together) is widespread and operators control leaching because of the lack of rain during the growing season. These conditions suggest that the producer could have fairly precise control of the timing of fertilizer. CR may be useful as preplant fertilizers in some systems.
- **Tissue sampling:** Widely used by producers, but there are many questions about the accuracy, timing, and interpretation of the test for both annuals and perennials.
- **Genetic improvement:** A long-term goal, but one that is complicated by the diversity of crops and the length of time it takes to bring a new tree crop cultivar to market.
- **Integrated nutrient management plans and manure lagoons:** Practice lags far behind theory. The ability of the producer to implement the plan and effectively use lagoons seems to be limited by information and use of current technology.

**Next Steps:** (1) Turn this qualitative review into a quantitative measure (meta-analysis) of the potential effects of these practices on yield, efficiency, and losses. (2) Feed the most feasible technical options for increases in NUE into the analysis of policy options.

## D. SCENARIOS

*“Scenarios can be defined as plausible and often simplified descriptions of how the future may unfold based on a coherent and internally consistent set of assumptions about key driving forces, their relationships, and their implications for ecosystems.”* (Henrichs et al., in *Ecosystems and Human Well-being*, Ash et al.)

Scenarios can help stakeholders deal with controversy and complexity, and they are particularly useful in cases where there is a large amount of uncertainty, as is the case in this assessment. Since our outreach activities to date point to a wide range of beliefs and understandings among our stakeholders with regards to nitrogen, an objective of the assessment is to create a space where stakeholders are able to come together and discuss the problems and benefits of nitrogen in a respectful and productive environment. We aim to do this through holding stakeholder-driven scenario development exercises midway through and at the end of the assessment. Our stakeholder advisory board – the makeup of which is discussed in page 5 of the communications plan (see Appendix E) – will participate directly in the creation of these scenarios with the help of a professional facilitator we propose to hire to assist in this process.

We propose to use scenarios as a primary tool and outcome of this assessment. This will involve a reprogramming of our allocated dollars from Web tools, \$50,000, to putting most of these funds toward the scenario exercises. As we were able to accomplish much of our Web site redesign in house, and, based on our stakeholder consultations to date, we do not believe a Web-based calculator to be the best use of this money, (see Appendix I) we propose using scenarios as one of the primary products of the assessment and with agreement from the Packard Foundation, we would refocus on enabling stakeholders to participate in scenario building.

### **What Do Scenarios Do?**

Scenarios are useful tools for exploring options about the future. They allow individuals to communicate the “main assumptions” (Velarde 2005) on which they base their individual visions of the future – this is especially important with the CNA because of the wide range of interests represented by our stakeholder groups. Our scenarios will serve as a way to mediate across a variety of perspectives. We see several main goals emerging from the scenario exercise (adapted from Henrichs et al., in *Ecosystems and Human Well-being*, Ash et al.):

- communicate with stakeholders
- stimulate thinking about the future
- change ways of thinking about the future
- visualize the future to provide information for policy makers and input for models

Scenarios allow for this dialogue across groups in a structured way and are capable of being used as educational tools, strategic planning tools, and tools to support scientific exploration and research (Henrichs et al., in *Ecosystems and Human Well-being*, Ash et al.).

Scenarios are known for spurring “open discussion among different groups of people who might not otherwise interact” (Velarde 2005) – which is a valuable outcome for the CNA and also feeds into ASI’s broader institutional goals of serving as a convener of groups with varying perspectives.

**What Will Our Scenarios Do?**

An important role of the assessment is to gain stakeholder buy-in to the assessment, as the stakeholder groups that we interact with have different levels of understanding of nitrogen's benefits and its potentially negative effects – from its use in agriculture and the food system to its impacts on the environment and human health. Scenarios are a powerful tool that will help get our stakeholders engaged with one-another, and our intended outcome for the scenario process is to get most of the stakeholders to the point where they are all able to come to the table and discuss how we can increase nitrogen efficiency and reduce nitrogen pollution in California.

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## **E. RESPONSES/ INTERVENTIONS**

Building on the early stages of assessment results and observations, we can begin a policy analysis of alternative management practices and identify potential interventions for improving N use efficiency and reducing N pollution. This identification of interventions will integrate work from all of the fellows. Our management practices and technical options fellow will provide the most feasible technical options for increases in nitrogen use efficiency (NUE). Our biogeochemistry fellow will identify hot spots and map the stocks and flows of nitrogen across the state, while our communications and outreach fellows will coordinate the multi-stakeholder, participatory scenario exercises that will help identify practical response options.

Once the above information is integrated by our policy fellow, our analysis will involve a multidisciplinary approach that (i) identifies potential N management strategies, (ii) assesses the N management capability of various strategies, (iii) provides a cost-effectiveness analysis for the most promising strategies, (iv) assesses the incentives created for farmers, ranchers, and other key actors, (v) identifies the implementation potential within major airsheds/watersheds, (vi) identifies cost effective policy instruments that would promote adoption of strategies, and (vii) assesses the social acceptance and potential for adoption.

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## INTERDISCIPLINARY RESEARCH TEAMS

### Junior Faculty Award Program

A group of 8 junior faculty has met several times, facilitated by ASI senior faculty and staff, to brainstorm collaborative research ideas focused on nitrogen issues in California. As a result, members of the group developed a total of 6 project proposals, with two projects directly involving interdisciplinary collaboration. The projects range in cost from \$20,220 to \$78,996. On recommendation of the technical advisory committee, who provided feedback on each of the proposals, the initial sum of \$287,643 has been allocated from Packard funds (with an additional \$14,720 committed to one of the projects which would continue into 2011, pending approval of a no-cost extension from the Packard Foundation). The projects will focus on a range of nitrogen-related topics and will complement and enhance the output of the nitrogen assessment itself. The project titles are listed below:

- *California nitrosapes: an environmental, social, and economic evaluation of the fate and consequence of excess N* (A. Kendall, Civil and Env Engineering, B. Houlton, Land, Air and Water Resources, & M. Springborn, Env. Science and Policy)
- *Greenhouse gas emissions and energetics of Community Supported Agriculture production and distribution systems: a spatially explicit life-cycle assessment in Yolo County* (R. Galt, Human and Community Development & A. Kendall, Civil and Env. Engineering)
- *Impacts of management and environmental conditions on the roles of different plant species in altering nitrogen inputs, recycling and retention* (V. Eviner, Plant Sciences)
- *Inferring the effects of nitrogen management policies using a fully calibrated programming model in California agriculture* (P. Merel, Agric. & Resource Economics)
- *Investigating the influence of biochar on the soil N-cycle, C sequestration, and stabilization with soil minerals* (S. Parikh, Land, Air and Water Resources)
- *Application of the SEAMLESS-IF model to California agriculture* (K. Steenwerth, Viticulture and Enology)

A subgroup of the junior faculty and ASI staff is considering several options for formats to engage the whole group in dialogue and learning activities to bridge disciplinary divides and facilitate research collaboration. These activities would take advantage of the remaining funding available for the Jr. Faculty Award Program. Ideas currently in development include seminars on interdisciplinary research with guest speakers, cross-disciplinary learning workshops within the group, and/or a potential group project (such as production of a white paper or journal article) centered around a nitrogen-related topic. These ideas will be further developed and prioritized for implementation during the first quarter of 2010.

### Interdisciplinary Team Development and Mentoring

In October, ASI hosted the first speaker in our seminar series, Dr. Peter Vitousek from Stanford University, to give a seminar on global nitrogen use and associated environmental impacts. We also used the opportunity to hold an informal round table discussion with him and a group of junior and senior faculty to share research interests and brainstorm ideas for future research collaboration with Stanford. We are planning for additional guest speakers in 2010.

Future activities being planned for interdisciplinary team development include a UC Davis-hosted nitrogen science symposium to be held in summer 2010. Participants in this symposium will include all the funded junior faculty, the technical advisory committee members, core project team, other UC Davis researchers and selected internationally recognized scholars from other institutions working on nitrogen-related issues. The group will be kept small enough to allow close interaction between participants, and activities will include a mixture of formal

presentations and informal, one-on-one or small group discussion to maximize opportunities for relationship building that will pave the way for interdisciplinary collaboration.

Additional activities being planned for mid- to late-2010 include write-shops – one- or two-day retreats in which small groups of researchers get together for collaborative writing and feedback on research results and/or white papers. The core ASI team is also researching the options for hiring a consultant who specializes in "high impact team building" for a half-day or one-day workshop.

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## PROJECT EVALUATION

### Monitoring and Evaluation

The Academic Coordinator and Program Manager have had two extended face-to-face meetings with the Packard evaluation consultant, Andy Rowe, and several additional long-distance communications. The entire core project team also met with him for two half-day sessions. During these meetings, the group began to define a theory of change for the project and map project outcomes. Next steps include completion of outcome mapping, prioritization of key areas where monitoring will be essential, and development of a more detailed plan for team members to use in implementing meaningful monitoring protocols and addressing perceived barriers to achieving hoped-for outcomes.

### 2010-2011 IMPLEMENTATION PLAN SUMMARY

Appendix K depicts the projected timeline for major project activities and products in 2010-2011. Several key activities will anchor the project during this period and will provide a focal point for uniting different efforts across all areas of the project. These anchor activities include the nitrogen science symposium (summer 2010), the initial Stakeholder Advisory Board meeting (spring 2010), and the public nitrogen conference (spring 2011). The symposium will provide a venue for the Packard fellows and the junior faculty to present preliminary results from their assessment work and funded projects to other scientists for feedback, in addition to providing important networking opportunities for building interdisciplinary teams around nitrogen science and future topics. These activities will help to ensure that the scientific knowledge base being developed in the assessment has scientific credibility, and they will build the capacity of researchers at UC Davis to understand each other's work and to work collaboratively on nitrogen and other future issues that require an integrated, multi-disciplinary approach to effectively attain scientific and outreach goals.

The Stakeholder Advisory Board activities, including the initial meeting and follow-up interactions, will provide input on the course of the assessment and communications work by the Packard fellows, thereby ensuring relevance and legitimacy of the work to different stakeholder groups. It will also function as a way for the assessment team to reach out to broader constituencies in communicating results, thereby linking the scientific work to populations in California most likely to be affected by the results. These interactions and the people represented in them will provide important vehicles for communicating information relevant to responses and interventions (such as best management practices for farmers and policy alternatives for government), which constitute the final stage of the ecosystem assessment framework (and the implementation of which will likely occur beyond the 2-year scope of this project). They will also build key relationships with external stakeholders for future ASI work, enhancing the capacity for ASI to effect meaningful change on nitrogen and other agroecosystems issues. Finally, they will provide a forum in which stakeholder groups that do not necessarily communicate often with one another can develop an understanding of each other's perspectives, which may facilitate their working together in the future.

The Nitrogen Conference will provide a venue for the Stakeholder Advisory Board and any other external groups to learn about the scientific results of the assessment and discuss their implications for changes among their constituencies. It will also provide an additional venue for the junior and senior faculty associated with this project and with ASI to present and exchange scientific results and interact with one another across disciplines. Finally, it will provide a platform for demonstrating to external actors, including policy makers, NGO leaders, and other scientists, that ASI and UC Davis are the "go-to" sources for credible, useful and legitimate information about nitrogen issues in agriculture.

## ADMINISTRATIVE UPDATE

The core project team is now complete, as detailed below:

- Four Packard Fellows have been hired, including those for the mass balance assessment (Dan Liptzin), the technological and best practices assessment (Todd Rosenstock), and the two communications fellows (Stephanie Ogburn and Colin Bishop). The final Packard fellow (Antoine Champetier, policy assessment), was recruited in mid-2009 and is due to begin in January 2010, pending final approval of his doctoral dissertation.
- Administrative Assistant Karen Curley joined SAREP/ASI in August and is assisting in managing logistics for meetings with stakeholder groups, and other functions of the project.

The SAREP Academic Coordinator, Sonja Brodt, joined the project in July 2009 and is providing additional strategic oversight and project management. The SAREP/ASI Communications Coordinator, Ian Cahir, joined in October. In addition to his other duties for SAREP and ASI in general, he is working with the two Communications Fellows on the Web site development and providing guidance and advice on other CNA-related communications activities.

The Technical Advisory Committee is formed and had an initial meeting in September to discuss feedback on the Junior Faculty projects (see below), and the conceptual framework, and to get an overview of current project activities. In addition to the four Principal Investigators (Tomich, Dahlgren, Scow, and Sumner), the committee includes the following four faculty members:

Thomas Harter, Extension Specialist in Land, Air and Water Resources

Johan Six, Professor, Plant Sciences

Frank Mitloehner, Associate Professor and Air Quality Extension Specialist, Animal Science

Daniel Putnam, Extension Specialist, Plant Sciences

This group will meet on approximately a quarterly basis, and individual members are also available for informal consultation with core project team members as needed.

Finally, our graduate student seminar on "Integrated Ecosystem Assessment: Agriculture, Nitrogen, and Climate Change in California," just completed with the closing of the fall academic term, had 10 students enrolled, in addition to participation by the four current Packard Fellows and the faculty sponsors (Tomich and Scow) who are also PIs of this project. Several of the students completed individual projects that may feed directly into the final assessment report, potentially as "side-boxes" on specific topics or issues. The following are the project titles:

- *Nitrogen sleuthing: Identifying sources and tracking behavior of nitrogen in the environment*
- *Health effects of nitrates in groundwater*
- *Climate Change Policies: A New and Potentially Effective Way to Regulate Nitrogen*
- *Nitrogen deposition and its ecological effects in Southern California*
- *Genetic potential to raise nitrogen use efficiency in California's Specialty Crops*

Details on the project budget are provided in Appendix J: Budget Narrative and Budget Table.

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## APPENDICES

- A. Activities Table
- B. Stakeholder-generated Question Tree
- C. California Nitrogen Assessment Outreach Contacts Chart
- D. Map of Outreach Meetings
- E. California Nitrogen Assessment Draft Communications Plan
- F. Draft Conceptual Frameworks (1-5)
- G. Nitrogen Cycle Graphic
- H. Agricultural Sustainability Institute Web Site home page
- I. California Nitrogen Assessment Web Site Home page
- J. Budget Narrative and Budget Table
- K. Project Timeline
- L. Assessment Table of Contents Draft

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