FINAL REPORT
Fertilizer Research and Education Program
California Department of Food and Agriculture
Project 16-0621-SA

Understanding Influences on Grower Decision-Making and Adoption of Improved Nitrogen Management Practices

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Abstract

Adoption of nitrogen (N) management practices is paramount to meeting the demand of regulatory agencies to reduce N loading into surface and groundwater of California. This project quantified the current use of practices and characterized drivers of grower behavior in order to enhance future research, education and outreach, and tailor policy recommendations. Our approach included semi-structured interviews with growers and advisors and focus groups with interactive surveys, culminating in mail surveys distributed to the Colusa Glenn Subwatershed Program (CGSP), San Joaquin County & Delta Water Quality Coalition (SJDWQC) and the East San Joaquin Water Quality Coalition (ESJWQC). Overall, we sent the mail survey to 5,000 growers across these three regions and received responses from 377 growers in CGSP (31% response rate), 183 growers in ESJWQC (14% response rate), and 312 growers in SJDWQC (15% response rate), and 94 growers who did not specify their coalition, for a total of 966 mail survey responses.

Differences by coalition include higher overall adoption by ESJWQC compared to CGSP and SJDWQC, and across all coalitions, higher adoption of fertilizer practices compared to irrigation practices. Growers report higher adoption by perennial crops compared to annual crops and higher adoption by very large (>1000 acres) compared to small (<50 acres) farm sizes. Growers across all coalitions in our mail survey reported on farm information sources are the most used and a range of barriers impact practice adoption, including cost, uncertainty and technical knowledge. Farm priorities related to N management practices include crop yield, crop quality, soil fertility and farm profitability. Growers report water quality coalitions as effective at addressing water quality issues. The majority of growers report a greater sense of control over on farm N management such as water use efficiency and N losses from the farm, but feel less control over local water quality outcomes and associated N regulations.

The results of this project include the following recommendations including: 1) the gap between irrigation and N management needs to be better researched and communicated in grower outreach;

2) there should be a greater focus on N management outreach and education programs for PCAs and CCAs, as the most trusted and used information sources; 3) there is a need for improved articulation of goals of the ILRP in a way relevant to growers and; 4) improved communication is needed to reduce uncertainty with respect to how the practices effect crop yield and farm profitability. The primary impact of this work includes providing a basis of information for the evolution of policy decisions related to the development of the ILRP and on-going outreach and education by a large network of agriculture extension actors. The results from this work point to clear trends and consistent themes regarding the need to make policy, outreach and future research decisions within the context of farmer behavior and the needs of farm operations.

Objectives

1) To develop an understanding of barriers to adoption of N management practices in the regions represented by the CGSP, SJDWQC and the ESJWQC;

2) To distribute, collect and aggregate survey data from growers in these regions;

3) To analyze both qualitative and quantitative response data to determine key motivations and barriers to adoption of N management practices;

4) To communicate these findings directly with the grower communities as well as academic and regulatory bodies;

5) To outline and recommend potential incentives targeted at different segments of the grower population in order to design more effective programs.

Introduction

Adoption of N management practices by California growers is a required step in reducing N movement into surface and groundwater maintaining economically viable cropping systems, while satisfying the Irrigated Lands Regulatory Program (ILRP) requirements. Research over the past decade has identified many promising practices that can improve N management. These practices include the use of N budgets to balance N inputs and outputs for individual field units; implementation of the "4R's" (right rate, time, place, and source) to guide fertilization strategy; the use of leaf and soil N sampling for verification of crop nutrient status and residual soil N; appropriate integration of fertilizers with irrigation; enhancing soil health to improve nutrient retention; and careful deployment and management of micro-irrigation systems for efficient water use. Despite progress in the development of improved N management practices, there is insufficient understanding regarding the current rate and barriers to practice adoption.

Recent research has suggested a number of possible factors influence grower decision-making, including perceptions of risk, economic and labor constraints, social norms, sources of trusted information, social capital and networks, farm characteristics including size and income, and participation in local policy forums. However, we do not have a robust understanding how these factors relate to adoption rates of N management practices across the diverse geographies and grower demographics of the Central Valley. This includes the role of different types of policy tools and outreach strategies for influencing farmer behavior.

The general orders for the Irrigated Lands Regulatory Program require development of Management Practices Evaluation Plans (MPEPs) to evaluate and measure progress toward adoption of improved practices and reduced flow of N to surface and groundwater. Inherent in these MPEPs is the requirement to identify beneficial practices, to adapt these practices to specific site/crop/grower characteristics and to provide a strategy to measure progress toward achieving these goals. However, we do not currently have good strategies to determine rate of adoption of N management practices or to identify the constraints to adapting practices for given site or grower contexts. Furthermore, we do not currently have a baseline against which to measure progress.

This project aims (i) to develop an understanding of the current status of grower adoption of N management practices, (ii) to determine the key influences on grower decision-making, and (iii) to identify the key incentives and barriers to enhanced adoption of N management practices. Our general approach is a combination of grower focus groups, interviews and regional scale mail surveys. The information developed will inform stakeholder groups including regional Water Quality Coalitions, UC Extension, private consultants, State Water Boards, commodity groups and others to inform policy-making and improve N management.

Work Description

Objective 1: Qualitative understanding of adoption of N management practices

Task 1.1: We conducted ~20 semi-structured interviews with growers in the SJDWQC and ESJWQC regions to better understand their use of N management practices and the social, political, and economic factors influencing adoption of practices.

Task 1.2: At SJDWQC and ESJWQC meetings, we hosted voluntary grower focus groups with real-time surveys (i.e. participants respond anonymously using "clickers") and roundtable discussions. We quantified which practices are most in use in each region and why, perceived costs and benefits of each used and unused practice, greatest challenges to adopting new practices, additional soil health practices that appeal for multi-benefit purposes, sources of information most important in each region and their opinions on effective N management practices.

Task 1.3: We conducted ~10 semi-structured interviews with farm advisors and Water Quality Coalition representatives identified by growers as trusted and influential sources of information on N management issues. We discussed their roles in regional N management; perceptions on the ILRP program, improved N management and soil health practices, and the role of the water quality coalitions; the biggest challenges their growers face when adopting N management practices.

Objective 2: Survey growers in CGSP, SJDWQC and ESJWQC regions to identify adoption of N management practices and key decision-making influences

Task 2.1: We designed a survey instrument based on Task 1, to assess social, political and economic factors influencing decision-making and adoption of N management practices. The survey included questions regarding different levels of N management practice implementation, participation in available policy initiatives and outreach/extension programs, communication with agricultural stakeholders (e.g. government agencies, non-governmental organizations, crop/pest control advisors, producer associations, and other farmers), attitudes towards N management

issues, and basic operator/operation characteristics. We assembled a Survey Advisory Committee (SAC) of nearly 20 representatives of key stakeholder groups (i.e. growers, industry groups, extension, farm advisors, environmental groups, coalition directors, etc.).

Task 2.2: Our SAC reviewed the draft version of the survey tool, and we made revisions based on their input. We piloted a second draft of survey instrument with a small group of growers to test the efficacy of the question design and structure and to elicit desired information.

Task 2.3: We developed a strategy for identifying the appropriate grower sample, survey distribution method (i.e. mail) and outreach activities in each region, coordinating with Water Coalitions and/or other advisory groups (i.e. Cooperative Extension, RCDs, Farm Bureau).

Task 2.4: Deliver survey to growers within CGSP, SJDWQC and ESJWQC using best available membership lists identified in Task 2.3

Objective 3: Analyze survey responses to inform outreach, education and incentive programs

Task 3.1: We developed descriptive analysis of compiled results and emerging trends from interview, focus group and survey data, leading to multiple peer-reviewed papers in progress.

Task 3.2: We used multi-level hierarchical modeling with random effects and factor analysis on survey response data to determine key variables influencing grower decision-making and adoption of N management practices in each region,

Task 3.3: Using unidentified grower information, correlate survey responses on practice adoption with submitted farm N management plans and regional MPEPs.

Task 3.4: We developed policy briefs to address key factors influencing grower participation in N management programs and advise actions to overcome barriers to adoption.

Objective 4: *Outreach and education activities*

Task 4.1: We organized and conducted multiple outreach activities, including workshops to present trends of adoption of N management practices, comparison of perceived costs/ benefits of practices, and introduce resources (i.e. technical advisory services and financial incentive programs) to assist in adapting management practices. Workshops hosted in collaboration with Water Quality Coalitions and Cooperative Extension during regular Coalition meetings.

Objective 5: Outline and recommend potential incentives for adoption

Task 5.1: We developed policy briefs that will address barriers to adoption for subsets of the grower population. We will use our results to identify key variables that could be used to target by different types of outreach programs and policy incentives.

Results and Discussion

Successful execution of our work plan led to a variety of results with corresponding discussion points. Results are organized based on the response to our mail survey for all regions and include discussion of 1) Practice adoption, 2) Information sources, barriers and priorities; 3) Water Quality Coalitions participation and perceptions and; 4) Research and Policy recommendations.

Practice adoption

Practice adoption by coalition are reported for split application, leaf and soil testing, fertigation, foliar applications, moisture probe, irrigation N testing, evapotranspiration testing, cover crops, pressure bomb and variable rate GPS. Differences by coalition include higher overall adoption by ESJWQC compared to CGSP and SJDWQC (Fig. 1). Despite the higher adoption by ESJWQC, their grower membership showed the lowest response of 181 eligible surveys completed, compared to 324 and 273 eligible survey responses completed for CGSP and SJDWQC, respectively.

Practice adoption for all regions for the same set of practices is also reported. Across all coalitions, there was higher adoption of fertilizer practices such as split application, leaf testing and fertigation compared to irrigation practices such as use of a moisture probe, irrigation N testing and ET scheduling (Fig. 2). Soil management practices such as soil testing were high compared to cover crops. This result suggests practices with a direct connection to fertilizer N management are more readily adopted by growers. Irrigation practices impact leaching but, a greater cognitive disconnect in the relationship with N management outcomes may contribute to lower adoption.

Across all coalitions, there was higher adoption by perennial crops compared to annual crops (Fig. 3) and higher adoption by very large (>1000 acres) compared to small (<50 acres) farms (Fig. 4). These effects may be the result of higher crop values from perennial crops such as fruits and nuts, compared to agronomic crops, which affords greater capacity to invest in new technologies. Furthermore, the longer-term nature of perennial crop production yield greater returns on investments realized over time. Similarly, higher adoption by larger farms suggests the role of economies of scale on practice adoption, where the costs associated with practice adoption can be more readily distributed over larger farm sizes.

Information sources, barriers and priorities

Growers across all coalitions in our mail survey reported information sources, barriers and priorities associated with N management practice adoption. In general, on-farm information sources are the most used, including grower's own past experience, PCAs, CCAs and other growers (Fig. 5). However, in preliminary surveys with PCA/CCAs, we found UC cooperative extension, NRCS and CDFA FREP are the primary information for these technical advisors of growers, elucidating an important information chain from more central information sources to on-farm, individual consultants. A range of barriers impact adoption such as cost, uncertainty and technical knowledge (Fig. 6); on-farm priorities such crop yield, crop quality, soil fertility and profitability of the farm are the major focus for growers related to decision making for practice adoption (Fig. 7). These results collectively suggest efforts to increase grower adoption of N management practices most consider both the barriers and priorities experienced by growers and cater outreach and technical assistance to addressing these needs.

Water quality coalitions and membership

Our survey also inquired into grower perceptions concerning the efficacy of Water Quality Coalitions, the sources contributing to water quality impacts, and their perceived control over their own potential water quality impact. Growers report Water Quality Coalitions as effective at addressing water quality issues, despite lack of perceived benefits relative to costs growers and challenges with the coalitions adequately articulating the rationale for regulations (Fig. 8). Furthermore, when we asked growers to report on a range of sources that impact water quality, growers identified urban sources, livestock operations and historic agricultural management as the most significant sources, more significant than current agricultural practices (Fig. 9). Despite the impact of agriculture on water quality, growers report a greater sense of control over on-farm N management, such as N and water use efficiency and N losses from the farm (Fig. 10). At the same time grower report less control over local water quality and the associated regulations.

Recommendations

The results of this project include the following recommendations:

1) Gap between irrigation and N management needs to be better understood;
2) Focus N management outreach and education programs on PCA/CCAs;
3) Articulate goals of the regulatory program in a way relevant to growers;
4) Reduce uncertainty with respect to how the practices affect yield and profitability.

Project Impacts

The primary impact of this work includes providing a basis of information for the evolution of policy decisions related to the development of the ILRP and on-going outreach and education by a large network of agriculture extension actors. The results from this work point to clear trends and consistent themes regarding the need to make policy, outreach and future research decisions within the context of farmer behavior and the needs of farm operations. Simple examples include practice adoption being impacted by different crop types and farm sizes. However, more impactful examples include the need to consider on-farm information sources, barriers related to farmers' goals and farm operations, and to conduct outreach on management practices within the context of addressing on-farm priorities such as crop yield, quality and profitability. Furthermore, Water Quality Coalitions play an effective role in administering the requirements of the ILRP yet, more can get done to communicate the rationale for regulations and the ability for growers to control the agricultural outcomes that impact water quality.

Other examples of the impact of this work include 1) supporting the premise that irrigation management is an important outreach point for coalitions as related to the new INMP; 2) stimulating additional coalitions to participate in survey efforts as well as other information sources such as WRCCA and CAPCA; and 3) and greater appreciation for grower control over management outcomes leading to higher rates of self-certification. While we deny any active role or take any credit related to these impacts defined above, we wish to point out the results from the work provide a more comprehensive and data-driven support for these impacts moving forward.

Figures

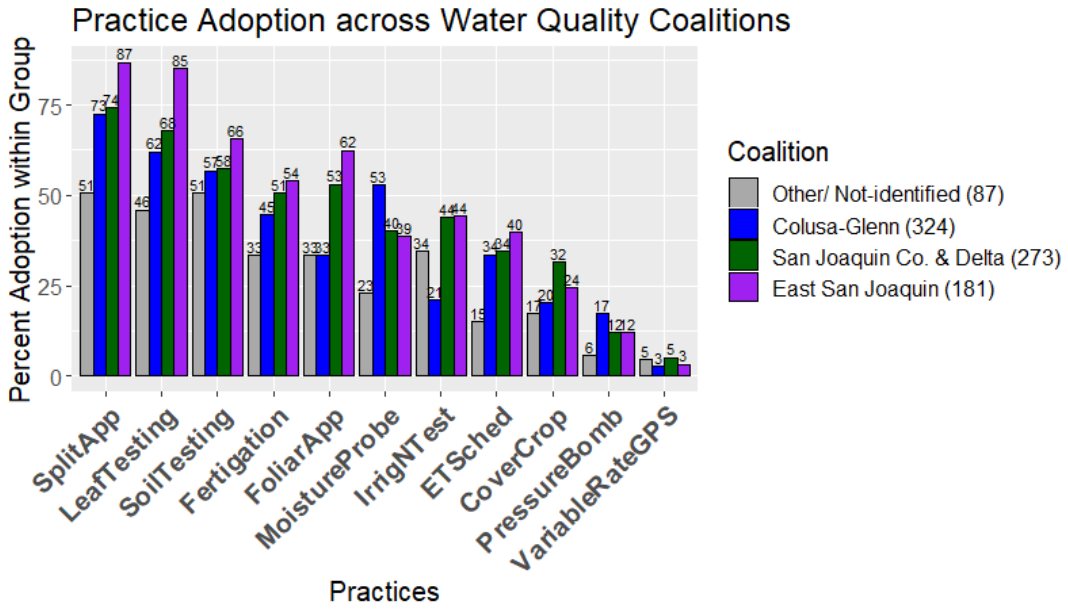

Figure 1. Practice adoption for CGSP, SJCDWQC and ESJWQC. Practices include (left to right) split application, leaf and soil testing, fertigation, foliar applications, moisture probe, irrigation N testing, evapotranspiration testing, cover crops, pressure bomb and variable rate GPS. Differences by coalition include higher overall adoption by ESJWQC compared to CGSP and SJDWQC.

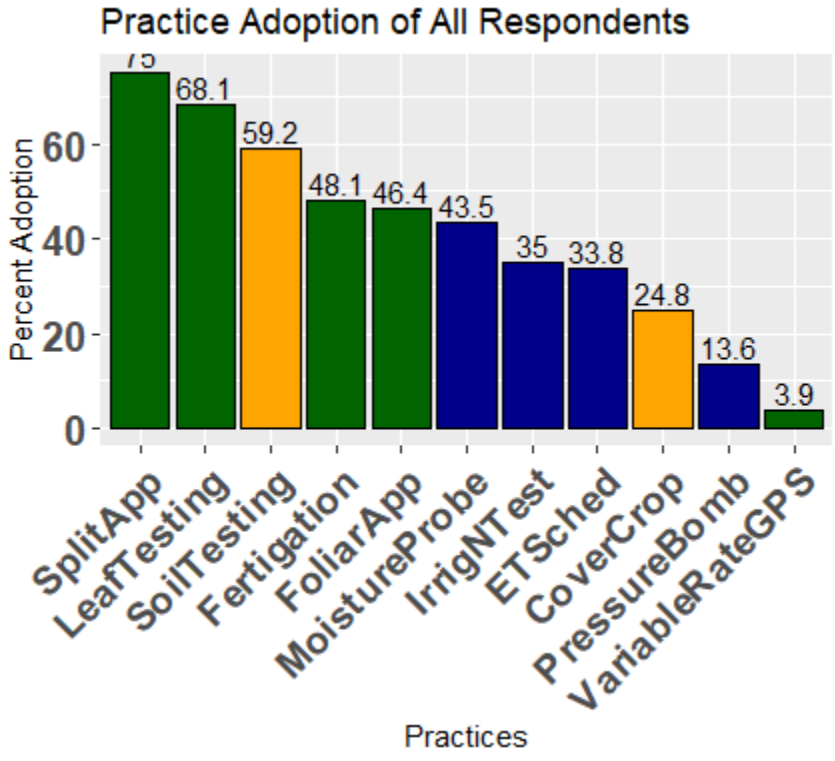

Figure 2. Practice adoption for all regions Practices include (left to right) split application, leaf and soil testing, fertigation, foliar applications, moisture probe, irrigation N testing, evapotranspiration testing, cover crops, pressure bomb and variable rate GPS. Across coalitions, there was higher adoption of fertilizer (green bars) compared to irrigation (blue bars) practices.

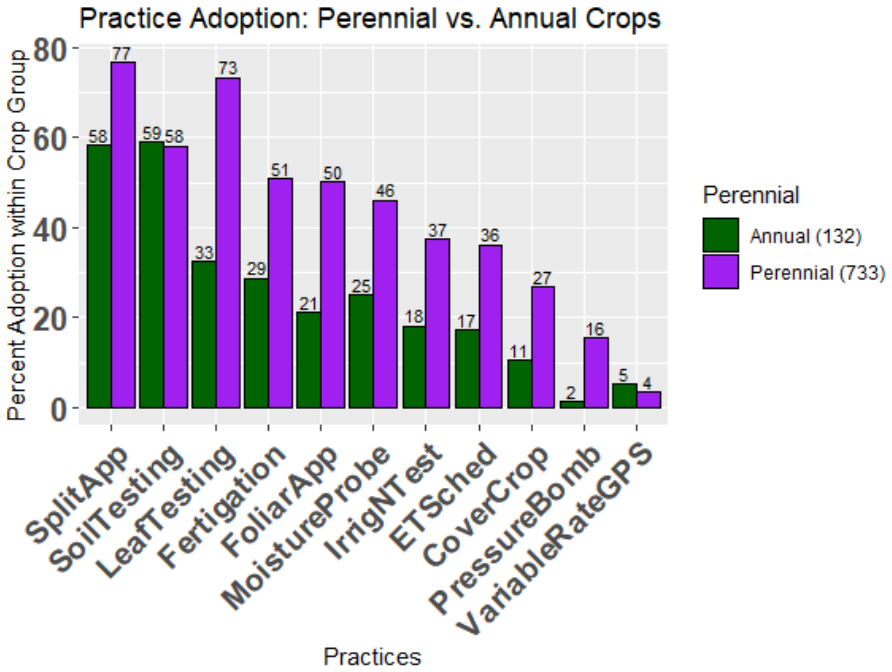

Figure 3. Practice adoption for annual and perennial crops. Practices include (left to right) split application, leaf and soil testing, fertigation, foliar applications, moisture probe, irrigation N testing, evapotranspiration testing, cover crops, pressure bomb and variable rate GPS. Across coalitions, there was higher adoption by perennial crops compared to annual crops.

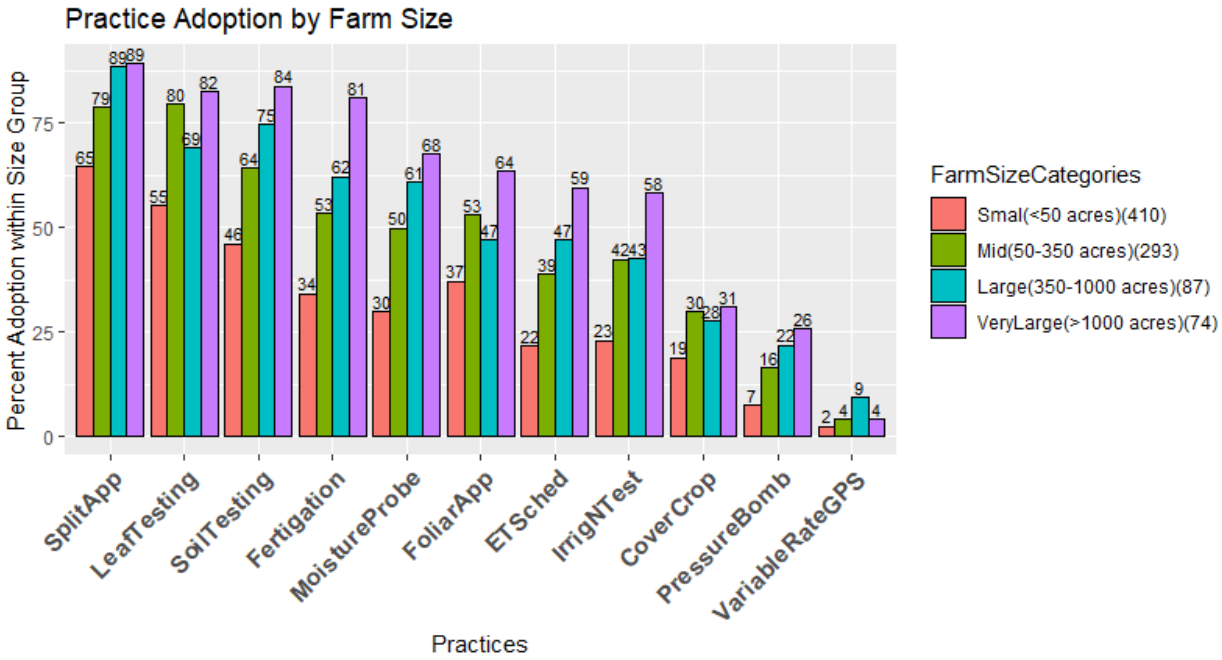

Figure 4. Practice adoption by farm size. Practices include (left to right) split application, leaf and soil testing, fertigation, foliar applications, moisture probe, irrigation N testing, evapotranspiration testing, cover crops, pressure bomb and variable rate GPS. Across coalitions, there was higher adoption by very large (>1000 acres) compared to small (<50 acres) farm sizes.

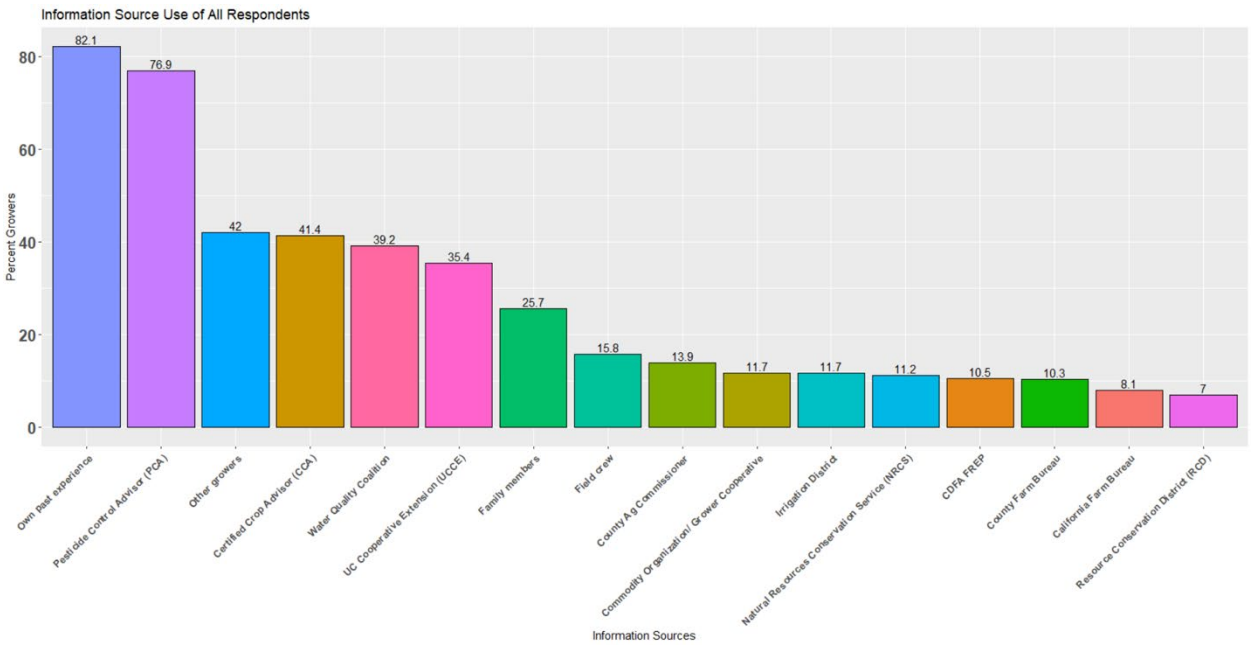

Figure 5. Percentage of growers using different information sources. On farm information sources are the most used including grower past experience, PCA, CCA and other growers.

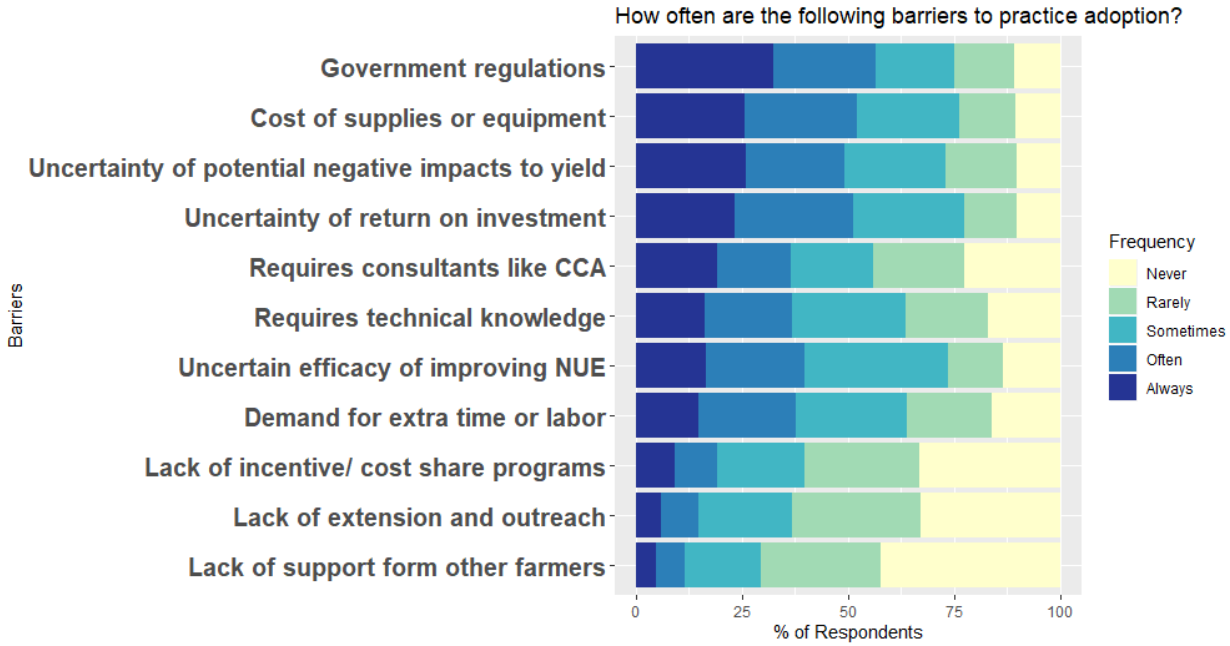

Figure 6. Frequency of barriers for N management practices by growers across all regions. A range of barriers impact adoption such as cost, uncertainty and technical knowledge.

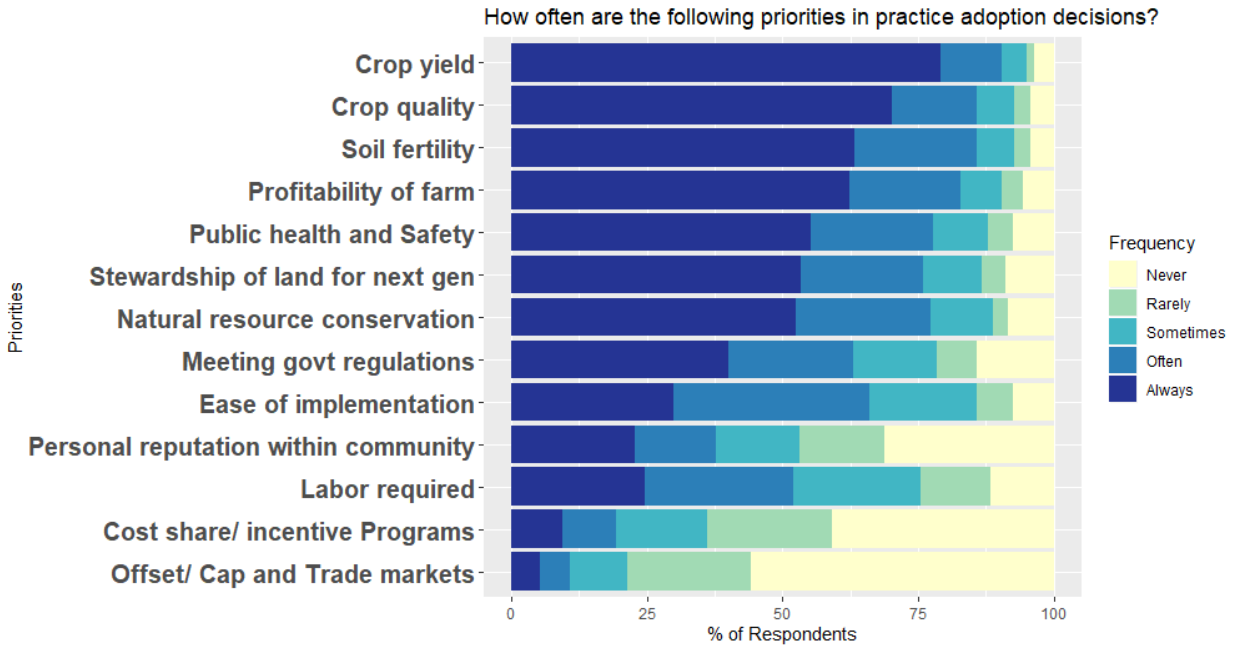

Figure 7. Frequency of priorities for N management practices by growers across all regions. On farm priorities such crop yield, quality, soil fertility and profitability of the farm are the major focus for growers related to decision making for practice adoption.

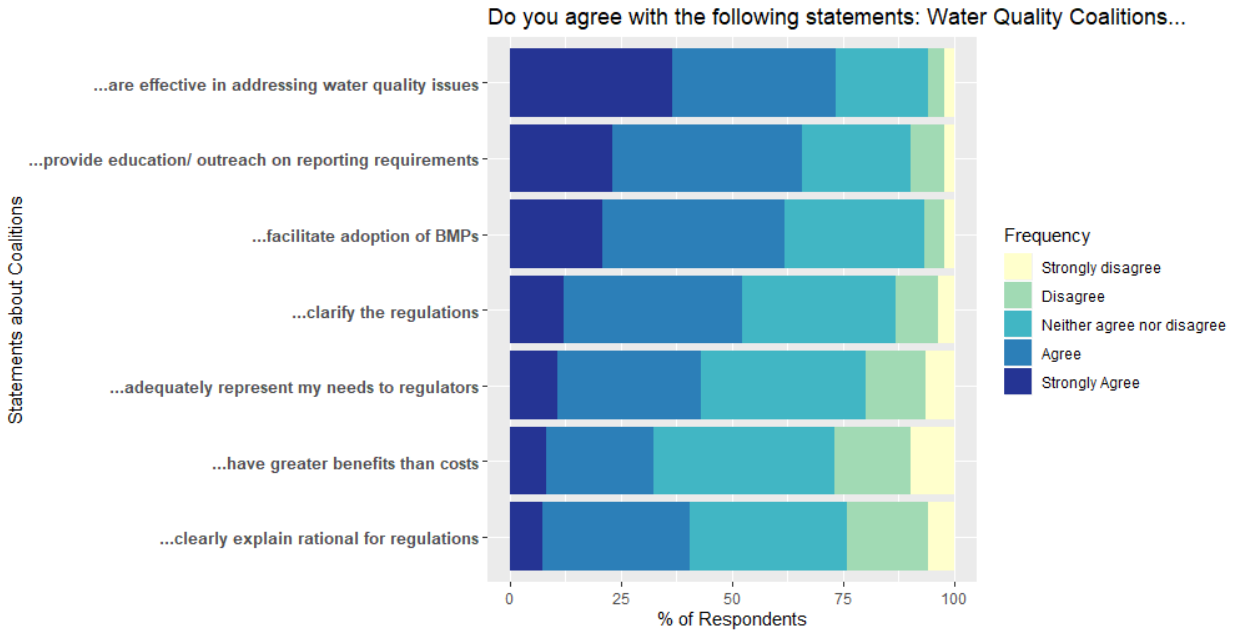

Figure 8. Frequency of statements about coalitions by growers across all regions. Water quality coalitions are perceived as effective at addressing water quality issues despite lack of perceived benefits relative to costs and challenges with articulating the rationale for regulations.

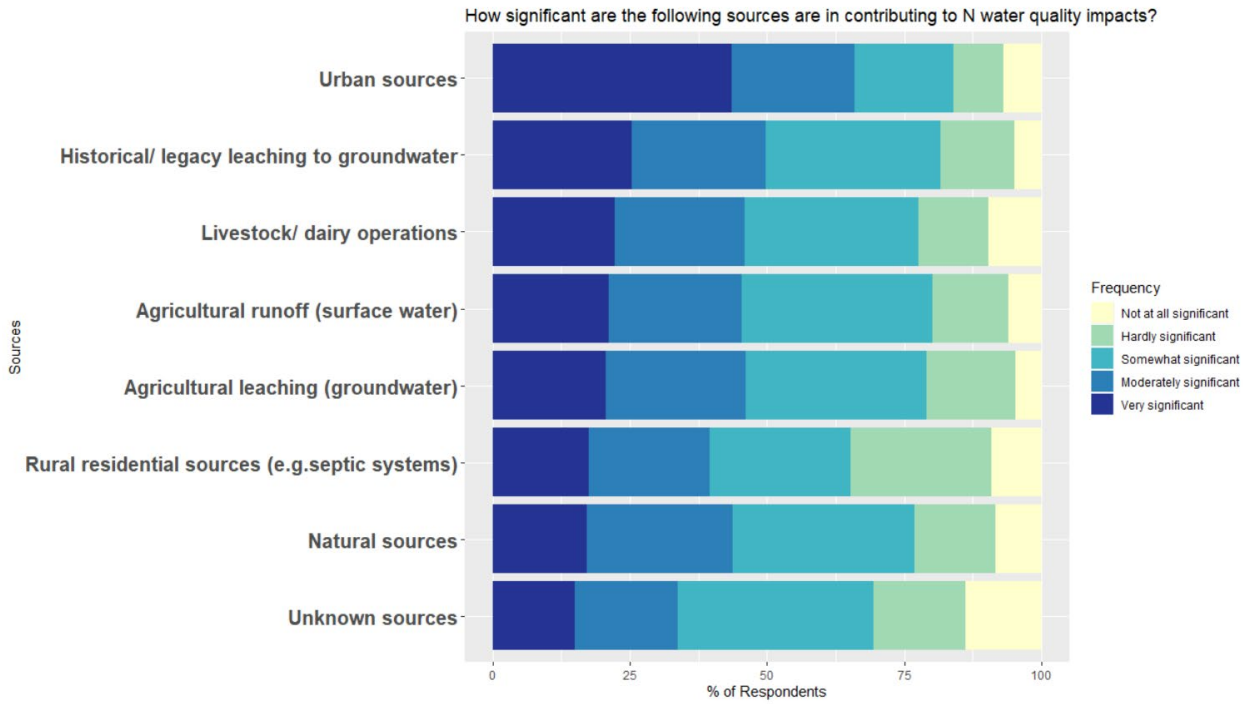

Figure 9. Frequency of sources for N management impacts by growers across all regions. Growers perceive water quality impacts from a range of sources including urban, livestock operations and historic agricultural management.

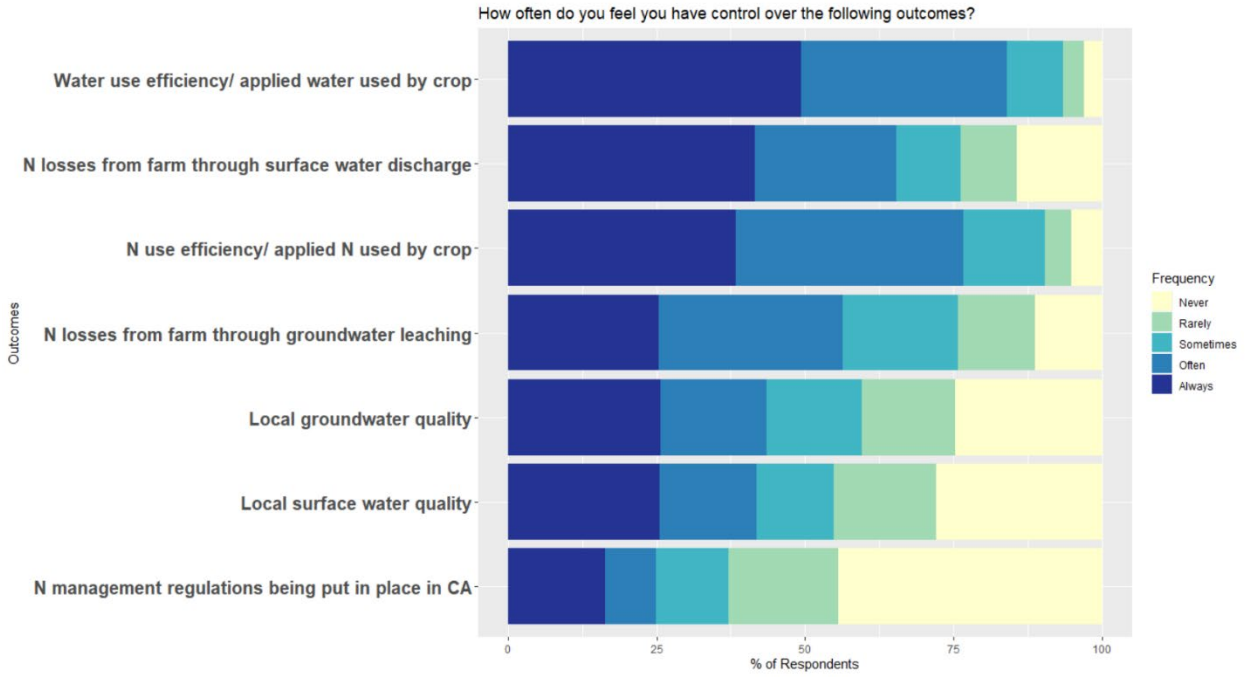

Figure 10. Frequency of control for N management outcomes by growers across all regions. Growers report greater sense of control over N management such as water use efficiency and N losses from the farm compared to local water quality outcomes and regulations.

Outreach Activities Summary

- Annual Water Quality Coalition grower education meetings
  - 4 meetings at San Joaquin County and Delta Water Quality Coalition, Jan-March 2017; ~300 grower attendees; conducted clicker surveys with ~40% response rate
  - 4 meetings at East San Joaquin Water Quality Coalition, Feb- March 2017; ~1200 grower attendees; conducted clicker surveys with ~30% response rate
  - 1 meeting at Colusa Glenn Subwatershed Program, December 2018; ~75 attendees; shared preliminary results from mail survey in form or research brief and 15-minute presentation
- Board meetings
- IRLP stakeholder meetings
  - 8 ILRP quarterly stakeholder meetings, 2018-2019; ~30 attendees from Water Quality Coalitions across the Central Valley and interested stakeholders; attend as an observing researcher to hear updates on ILRP programs; presented preliminary results after Grower Meeting Surveys were completed
- Research briefs
  - Used in field days and outreach with Water Quality Coalitions
- Water Quality Coalition steering committee meetings
  - 6 San Joaquin County and Delta Water Quality Coalition monthly Steering Committee meetings, Jan – Dec 2017; give project updates and hear about ongoing activities of the Coalition and interested stakeholders
- Conferences
  - 2018 Plant and soil conference, Fresno, CA
  - 2018 FREP conference, Seaside, CA
  - 2019 American Geophysical Union Annual Conference, San Francisco, CA
- UCCE field days: **See poster & presentations attached
  - San Joaquin and Delta Field Day: January 2018, ~75 growers in attendance; presented preliminary results from clicker surveys and discussed ongoing research activities around barriers to adoption, including large mail survey effort.
  - Nickels Field Lab: March 2018, ~75 growers in attendance; presented preliminary results from clicker surveys and discussed ongoing research activities around barriers to adoption, including large mail survey effort.
  - Kern County Nitrogen Management Practices Field Day: March 2018, ~75 growers in attendance; presented preliminary results and ongoing research activities.
  - Merced County field day on whole-system nitrogen field experiment: July 2018, College of Agriculture and Environmental Sciences covered as interdisciplinary sciences and outreach project news article: https://caes.ucdavis.edu/news/nitrogen-efficiency
  - Almond field days in Fresno, Salida and Chico during February and March 2019
- Radio interview on Cal Ag Radio with Patrick Cavenaugh: Jan 2018; 10 minute discussion on project, early findings and announcing upcoming delivery of mail survey; https://californiaagtoday.com/survey-coming-gauge-nitrogen-fertilizer-use/
- USDA Brown Bag Seminar presentation on December 10th, 2018; 30 attendees from USDA NRCS, California state government, UC Davis researchers, USDA Climate Hubs, and Water Coalitions; 1.5-hour presentation to share our project, early findings, and anticipated future directions in analysis; **presentation attached.

Factsheet Template

Understanding Influences on Grower Decision-Making and Adoption of Improved Nitrogen Management Practices

Project 16-0621-SA
2017/2019

Mark Lubell, Jessica Rudnick, Sat Darshan Khalsa & Patrick Brown

Location
Colusa Glenn Subwatershed Program
San Joaquin County & Delta Water Quality Coalition
East San Joaquin Water Quality Coalition
Colusa, Glenn, Contra Costa, San Joaquin, Stanislaus, Merced and Madera Counties

Highlights
- Higher adoption of N practices by perennial crops and larger farms
- On-farm priorities and information sources are most trusted and used by growers
- A range of barriers impact adoption such as cost, uncertainty and technical knowledge
- Growers perceive coalitions as effective, except for articulating rationale for regulations

Introduction
Adoption of N management practices by California growers is a required step in reducing N movement into surface and groundwater maintaining economically viable cropping systems, while satisfying the Irrigated Lands Regulatory Program (ILRP) requirements. This project aims (i) to develop an understanding of the current status of grower adoption of N management practices, (ii) to determine the key influences on grower decision-making, and (iii) to identify the key incentives and barriers to enhanced adoption of N management practices.

Methods
Our general approach is a combination of grower focus groups, interviews and regional scale mail surveys in the Colusa Glenn Subwatershed Program, San Joaquin County & Delta Water Quality Coalition and the East San Joaquin Water Quality Coalition.

Recommendations
The results of this project include the following recommendations:

1) Gap between irrigation and N management needs to be better understood
2) Focus N management outreach and education programs on PCA/CCAs
3) Articulate goals of the regulatory program in a way relevant to farmers and growers
4) Reduce uncertainty with respect to how the practices effect yield and profitability

The primary impact of this work includes providing a basis of information for the evolution of policy decisions related to the development of the ILRP and outreach by a large network of agriculture extension actors. The results from this work point to clear trends and consistent themes regarding the need to make policy, outreach and future research decisions within the context of farmer behavior and the needs of farm operations.

Products

All research projects are posted on the research website of Prof. Lubell:
https://environmentalpolicy.ucdavis.edu/project/agricultural-nutrient-management-decision-making

List of products

- Cover Crops Research Brief Final.pdf
- Grower Surveys Research Brief March 2018.pdf
- Research Brief (handout): San Joaquin & Delta Water Quality Coalition early results
- Research Brief (handout): East San Joaquin Water Quality Coalition early results
- Research Brief (handout): Colusa Glenn Subwatershed Program early results
- Research Brief (slides): San Joaquin County & Delta Water Quality Coalition Mail Survey Full Results
- Research Brief (slides): East San Joaquin Water Quality Coalition Mail Survey Full Results
- Research Brief (slides): Colusa-Glenn Subwatershed Program Mail Survey Full Results

Manuscripts in preparation

Khalsa, SDS et al. (*In prep*) Adoption of N management practices by permanent crop growers in the San Joaquin Valley U.S.A.

Rudnick, J. et al. *(In Prep)* A portfolio approach to sustainable nitrogen management: understanding farmer adoption of multiple best management practices in California.

Rudnick, J. et al. *(In Prep)* Understanding causes and implications of uncertainty in farmer decision-making on nitrogen management.

Completed works

Tatge, S. (2019) Potential spatial accessibility as a proxy for self-reported accessibility in Californian agricultural knowledge and information systems. M.S. Thesis in International Agricultural Development U.C. Davis; 88 pages.