INCREASING IMPLEMENTATION OF CONSERVATION PRACTICES TO PROTECT GROUNDWATER QUALITY

Southern San Joaquin Valley

NRCS CONSERVATION INNOVATION GRANT

Final Report

Grantee Entity Name	Kings River Water Quality Coalition (KRWQC)
Project Title	Increasing Implementation of Conservation Practices to Protect Groundwater Quality
Agreement Number	69-3A75-17-25
Project Director	Ms. Charlotte Gallock
Contact Phone Number	(559) 237-5567 x 105 E
Contact eMail Address	cgallock@krcd.org
Project Period	September 30, 2016, through September 30, 2019

This Final Report describes implementation of the project *Increasing Implementation of Conservation Practices to Protect Groundwater Quality*.[1] The following sections provide a project summary, the project background, and the assessments and outreach activities conducted to increase the implementation of conservation practices to protect groundwater quality. Challenges and potential next steps are also described. Note that multiple hyperlinks are included throughout the report to provide additional information.

1 SUMMARY AND KEY MESSAGES

During recent decades, groundwater wells in California's Central Valley have a) expanded in number and depth, notably during the 2011-2015 drought, and b) exceeded drinking water nitrate standards with increasing frequency. With the advent of regulatory programs to address these problems, our use of water and fertilizer to grow crops is under increasing scrutiny, prompting the formation of groups like the Southern San Joaquin Valley (SSJV) Management Practices Evaluation Program (MPEP) Committee (Committee), in which growers have joined forces to improve understanding and performance of their cropping systems to alleviate these problems. As a longtime conservation partner to growers, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has been instrumental by providing human, information, and financial resources that enabled far more rapid expansion and impact of the SSJV MPEP than would otherwise have been feasible for such a young organization. It has also allowed the Committee to attract other collaborators, including the California Department of Food and Agriculture (CDFA) Fertilizer Research and Education Program (FREP), the University of California (UC), California State University Fresno's (CSUF) Center for Irrigation Technology

[1] https://agmpep.com/mpep-projects/increasing-implementation/

(CIT), multiple commodities groups and grower/packer/shippers, and other water quality coalitions. Each of these provides valuable input and/or in-kind efforts that support the Committee's and NRCS' goals. For example, our broad grower and partner base enabled the Committee to generate over $7.6M in non-federal match during the project.

The MPEP and project activities fell into three broad categories: assessment, focused studies, and outreach. The assessment sought to develop an application of USDA's Soil and Water Assessment Tool (SWAT) to the entire, Central Valley, irrigated lands domain. This fills a massive knowledge gap, since percolation of water and leaching of nitrate below irrigated cropland root zones is very difficult to measure directly, and therefore seldom quantified. We became beta testers and partners with USDA modeling teams in the further development of a digital soils database that significantly improves percolation and leaching predictions by SWAT. The realization of the Central Valley SWAT domains, with newly calibrated crop models adapted to this highly productive zone, is now a key component of the Conservation Effects Assessment Project's (CEAP) Central Valley effort with Thomas Harter (UC Davis). Results of initial runs illustrate the influence of efficient water and fertilizer management on recovery of applied water and nitrogen (N) fertilizer. A web application allows growers to look at how this plays out on specific mapping units in each one of their fields, so that they can understand the environmental as well as production implications of management decisions.

The focused studies, all still in progress, have furnished a better understanding of how and why growers select among management options, so that we can better tailor outreach programs. Early results point to the importance of solutions that simultaneously address other priorities, such as levels of production and labor efficiency, and the key role of pest control advisors in helping with nutrient management decisions. Grower uncertainty about these decisions is substantial. Another study provides growers a better picture of crop N demands and field N balances so that they make more informed fertilization decisions. A third study provides detailed field measurements and alternative modeling assessments that ground truth and inform the broad-scale SWAT assessment, and the interdependence between management and water use/quality outcomes.

Drawing on and adding to information generated by assessment and focused studies, the outreach program combines new (online and offline) tools, presented and explained to many hundreds of growers and advisors who attend compulsory and voluntary outreach events. Newly available information on growers' actual use and recovery of irrigation water and N has been built into more online tools and presentations. In the case of water use, the new tools, like the SWAT results, are very site-specific, avoiding the generalities that sometimes hamper applicability of information to individual fields.

The Committee endeavors to harness the momentum that these initiatives have generated to sustain and expand the effort to capture more of the N and water our growers apply, and thus, over time, to reduce negative water quality impacts, and to inform and reinforce our growers' water conservation efforts.

2 BACKGROUND

This project was initiated by the Committee, a group of grower-led water quality coalitions in the Central Valley, California. These coalitions formed in response to the Irrigated Lands Regulatory Program (ILRP). The ILRP issues irrigators state water quality orders that contain requirements and conditions with which they must comply. One of the requirements is to develop and implement an MPEP. A major component of the MPEP is evaluation of the influence of management practices on water quality. This includes assessing the recovery and leaching loss of applied N fertilizer, under a range of irrigation and N management regimes. The MPEP also includes study, extension, and implementation of practices that minimize N leaching. Many of these depend on planning and control of irrigation. Additional detail about the MPEP is at agmpep.com, including the MPEP Workplan.[2]

In addition to the NRCS Conservation Innovation Grant (CIG), funding for the MPEP is provided by members/growers and FREP. As mentioned previously, these entities, as well as other partners (UC, CIT, commodities groups, and other water quality coalitions) also contribute in-kind.

3 ASSESSMENTS AND FOCUSED STUDIES

Assessments conducted as a part of the CIG include the following:

- Development of SWAT for a landscape-scale performance assessment of Central Valley agriculture.
- Agronomic assessment of Nitrogen Management Plan (NMP) data.
- Focused study of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Crops (Yield to N Removed, or Y-to-R Study).
- Focused study of Almond and Orange Irrigation and Fertilization by Combining Grower Operational Records, Actual Evapotranspiration, Soil, and Plant Tissue Data (Irrigation/Fertilization Assessment Study).
- Understanding Influences on Grower Decision-Making and Adoption of Nitrogen Management Practices in the South San Joaquin Valley (Barriers to Adoption Study).

Each is described below.

3.1 LANDSCAPE-SCALE PERFORMANCE ASSESSMENT

A major component of the project was development of a Central-Valley-wide set of SWAT domains to understand how changes in fertilizer and irrigation management affect leaching across the landscape. SWAT is a globally-recognized, physically-based spatial model that operates on a daily timestep. It

[2] https://agmpep.com/mpep/wp-content/uploads/20170914_Final_SSJV_MPEP_Workplan.pdf

considers climatic, edaphic, topographic, and management information for each location simulated. The simulation runs with a daily time step on discrete land units called hydrologic response units (HRUs). HRUs are comprised of unique combinations of soil, crop, climate, and topography. The SWAT model built for this application has 104,649 unique HRUs across Central Valley (Region 5). Furthermore, the model is executed for a 25-year time period (1990 through 2014) to capture the influences of a fluctuating climate.

The SWAT model has been used to describe water and nutrient flows in a wide variety of crops growing in many different landscapes around the world. As such, it contains more than 130 crop models that can be adapted to describe specific, local conditions. However, the existing crop-specific parameters describing crop management, growth, and productivity have often been developed in production environments that are quite different from, and often less productive than California. This is particularly the case with horticultural crops. This necessitated considerable modification of these parameters to represent typical California field conditions, management practices and yield levels. Over 30 crop models were calibrated to represent more than 90% of the farmed acreage.

Four management scenarios were developed for each crop to represent a range of fertilizer and water use efficiency. All scenarios were informed by grower reports, University of California Cooperative Extension recommendations, other scientific literature, and expert opinion. The scenarios reflect “common” practices and “normal” levels of production. Scenario 1 represents practices considered to be reasonably efficient, based on current knowledge. In Scenario 1, the annual N application rate is near the reported industry mean, with N application timing in accordance with current UC recommendations. Irrigation rates are based on ETcrop and actual ET (ETa) data; irrigation volume was adjusted for an assumed distribution uniformity of 85-90%, where low-volume irrigation (drip or microsprinkler) was modeled, and 75-80% for other methods. The remaining scenarios depicted greater N application (Scenario 2), greater irrigation depth (Scenario 3), or greater N rate and greater irrigation depth (Scenario 4). Amounts of N and irrigation water applied were increased 15-20% above the levels used in Scenario 1. Based on grower-reported N application data, the higher N rates used in Scenarios 2 and 4 are within the mainstream of current industry practices.

Results for a grower’s set of fields can be viewed through an interactive web application (available through some coalition websites). As with most models, SWAT results reflect relative differences reasonably well, with absolute quantities being less certain. However, the most valuable information for growers is in the comparison of results among different management approaches. Users can choose specific fields and select from available crop types, and then view separate results for each soil mapped within the field. Results are presented as an average across all years and within different year-types (i.e., “wet,” “dry,” and “normal”). The field’s performance and management response can be assessed relative to all soil types with the same crop within the domain. This tool informs users of how their fields may perform with more and less efficient N and irrigation management regimes. It also shows how differences in soil type and climate may influence outcomes in terms of percolation and nitrate leaching. By understanding these relative differences, growers can better balance benefits and risks associated with additional inputs in a given field, and the sensitivity to shifts in management.

Deliverables

- Methodology Report, including the major crop model inputs, management practice parameters, and graphical summary of output for the three Central Valley planning domains (i.e., SSJV, San Joaquin Valley, Sacramento Valley).
- SWAT files for each of the three Central Valley planning domains.
- Multiple related outreach events (see Section 4.4).

3.2 AGRONOMIC ASSESSMENT OF NMP DATA

The Water Board requires growers to report NMP data to their water quality coalition, including crop type, acreage, N applied, yield, and N removed. An agronomic assessment of the 2016 and 2017 NMP data was completed to understand the distributions of yield, N applied to the crops, and the N balance (N applied minus N removed). Crops analyzed included almonds, pistachios, tomatoes, walnuts, wine grapes, table grapes, oranges, cotton, corn silage, wheat silage, raisin grapes, and potatoes. Results are being shared with commodity groups and growers so that they can incorporate the information and lessons learned into outreach, research, and annual N management planning.

Subsequent NMP datasets will be similarly analyzed to understand shifts in N balances in agricultural fields, to inform modeling / monitoring of potential long-term groundwater quality trends, and to develop awareness among commodity groups, researchers, ag advisors, and the growers that they serve.

Deliverables

- A technical memorandum summarizing the 2016 and 2017 NMP data analysis is enclosed as Attachment 1.
- Multiple related outreach events (see Section 4.4).

3.3 YIELD TO N REMOVED STUDIES

The Water Board now requires growers to document the effectiveness of management practices to minimize nitrate leaching by providing, among other things, information on field N balances. In addition, the Agricultural Expert Panel convened by the State Water Resources Control Board recommended metrics composed of N applied (A) and N removed (R) to gauge program progress in reducing the mass of leachable N (Burt et al., 2014[3]). This approach was incorporated into ILRP Orders by the Water Board. To comply with this new reporting requirement, growers and their coalitions need reliable data about N removed from fields in harvested crop materials, so that reported yields can be accurately converted into N removal rates. Also, growers can use rates of N removal in crops to help plan nutrient management programs that reasonably minimize N at risk of leaching below the root zone.

On behalf of the Central Valley water quality coalitions, including those that comprise the SSJV MPEP Committee, Kings River Conservation District contracted and worked with Dr. Daniel Geisseler of UC

[3] Burt, C., et al. 2014. Agricultural Expert Panel. Recommendations to the State Water Resources Control Board

Davis to complete and publish usable, literature-based yield-to-N-removed conversion factors for 72 crops, representing more than 98% of Central Valley irrigated lands. *Nitrogen Concentrations in Harvested Plant Parts - A Literature Overview* (N-concentrations Report)[4] was prepared by Dr. Geisseler (2016). The N-concentrations Report noted that some of the conversion factors are based on datasets that were small, more than 20 years old, or from outside the Central Valley, and / or reflected cultivars, yields, cropping systems, and soil types other than those common under contemporary Central Valley conditions. The N-concentrations Report showed that well-established coefficients are available for only 10 of the 72 crops, accounting for approximately 12 percent of irrigated lands in the Central Valley. Further, there are even fewer data on the amount of N sequestered into perennial crop biomass, which growers need to know when planning N fertilizer programs for younger orchards, groves, and vineyards during rapid early growth of perennial tissues. To refine currently available coefficients for the remaining 62 crops from the N-concentrations Report, additional data need to be obtained from analysis of recent crop samples from Central Valley fields over several years. Approximately $220k in funding for this work was awarded from CDFA FREP.

During 2017, the MPEP Team initiated a study (funded by this CIG) to pilot an innovative, efficient approach to procuring representative harvest samples and processing them to determine N content and rates of N removal from fields. The MPEP Team worked with the California Fresh Fruit Association and a major grower/packer/shipper to sample numerous peach fields, and used partner laboratories to process and analyze samples to determine N content. Detailed cultural information was collected from the cooperating grower/packer/shipper, and results were related to these factors to determine how and why N removal rates vary among orchards. Results were presented to and discussed with colleagues at the 2017 FREP conference, and the full-scale, FREP-funded study commenced in 2018.

In 2018, the methodology piloted during 2017 was applied to many more crops. Conversion factors for 25 crops are being updated as part of the full-scale Y-to-R Study. For some crops, information is coming from other research projects. For others, the MPEP Team is coordinating harvest sampling with commodity groups, marketing order organizations, and grower/processor/shipper/packer partners. Dr. Geisseler's group is processing and analyzing the collected samples. Representative samples of harvested carrots, corn [grain and silage], peaches, pistachio, plums, pomegranates, raisins, safflower, sunflower, sorghum [grain and silage], and processing tomatoes are being obtained and processed, awaiting analysis later in 2018. By partnering with commodity groups, marketing order organizations, and grower/processor/shipper/packer partners, it has been possible to procure hundreds of samples that represent a range of varieties and growing environments for each crop. In most cases, substantial information about source fields, such as age of perennial crops, crop management, variety, yield, quality, and dates of bloom or planting, are acquired and related to results. In this way, some of the factors that affect harvest N content of each crop can be investigated and explained. Results of Y-to-R research will be incorporated into updates of Geisseler (2016). In addition, the existing Y-to-R calculator (http://agmpep.com/calc-y2r/) will be revised to reflect findings, and the results will be used to update the assessment and planning tools available to growers, grower advisors, and coalitions. An annual

[4] https://agmpep.com/calc-y2r/data/Geisseler_Report_2016_12_02.pdf

report summarizing work completed in 2018 is provided in Appendix F. Additional N removal information for cotton, almonds, walnuts, grapes, prunes, oranges, and mandarins, and for N sequestration in perennial tissues of almonds, walnuts, pistachio, prunes, oranges, and mandarins, are being procured from collaborating researchers. Also, another phase of the work is being planned for Central Valley crops, and we are collaborating with colleagues on the Central Coast as they design a similar project for vegetable crops grown there.

Deliverables

- Information about this study, including 2018 and 2019 Interim Reports for the FREP grant, is available here: https://agmpep.com/mpep-projects/harvest-and-sequestered-nitrogen-assessment/.
- Multiple related outreach events (see Section 4.4).

3.4 Irrigation / Fertilization Assessment Study

Nitrate leaching and salinity distribution in the root zone are strongly affected by irrigation scheduling; fertigation timing; the extent to which irrigation events are adjusted based on soil moisture or climatic conditions; and the extent to which fertilizer amount and timing are matched to crop demand and uptake patterns. Irrigation and fertigation decisions, in turn, depend on growers' a) knowledge of site conditions, and b) ability to control the infrastructure. Therefore, the proportion of applied nitrogen N used by the plant (N-use efficiency [NUE]) depends on system operation, which in turn depends on the design of the monitoring, irrigation, and fertigation components of the system. Adding urgency to management questions is the increased risk of leaching root-zone nitrate from increased groundwater recharge by heavy, dormant-season irrigation of highly permeable soils, a key strategy triggered by the 2014 Sustainable Groundwater Management Act (SGMA).

High-frequency, low-rate (HFLR, i.e., drip and microspray) irrigation systems are increasingly common in California, particularly (but not exclusively) for permanent crops. They are often cited as a management practice to increase both irrigation efficiency and NUE. Increases to NUE are partly due to greater control of irrigation water that carries nitrate, which allows the crop, over the course of a growing season, to recover a greater proportion of applied N. Certain operational modes facilitate irrigation and fertigation that deliver applied N more precisely into root zones, in times and locations that better match crop N demand. Indeed, the very high yields achieved with some of these systems indirectly attest to the efficacy of these modes of delivering N and water to crops.

The study is located on a medium-size fruit and nut production field near Fresno, California on the Kings River fan, on a site that encompasses 47 acres, with 29 acres devoted to relatively shallow-rooted oranges and 18 acres to relatively deep-rooted almonds. Situated on highly permeable, moderately coarse-textured soils with occasional gravel stringers, the fields' surface lie approximately 18-20 feet above the regional shallow groundwater. These conditions result in relatively rapid movement of nitrate out of the root zone to the underlying groundwater, which flows from the east-northeast to west-southwest.

Study objectives are to 1) quantify the yield, quality, WUE, and NUE benefits of converting from a non-automated irrigation system (operated weekly) to widely available, replicable systems that provide more frequent and precisely timed irrigation and fertigation through automation and SMM feedback; 2) relate these management changes to reductions in the amount of nitrate transiting to groundwater, and 3) work with growers, commodities groups, and the NRCS to develop an initiative that would facilitate cost-share funding of these types of system upgrades, encouraging and enabling their broader adoption.

The study has demonstrated that detailed information about the fate of water and N in the root zone, as determined by crop and soil measurements that growers can make, can be used to infer the amount of nitrate moving into groundwater, and that even in a well-managed, HFLR (drip or microspray) irrigated orchard, environmental performance can sometimes be significantly improved by modest shifts in management. This study has also demonstrated strategies that extend N residence time in and uptake from the root zone, even as other salts continue to move outward to avoid damaging levels of salinity.

This study is linked to three, separately funded, intensively monitored, N fate and transport study sites that have been, or that will be developed and managed by our project partners at UC Davis, with our program as a major collaborator. The crops and sites include:

- Almonds at Bowman Ranch near Modesto (ongoing).
- Tomatoes in Yolo County (beginning in 2020).
- Citrus on the east side of the Southern San Joaquin Valley (start date to be determined).

Deliverables

- Multiple related outreach events (see Section 4.4).

3.5 BARRIERS TO ADOPTION

Adoption of improved N management practices is paramount to reducing N loading into surface and groundwater. However, there is inadequate information on the current rate of adoption and little understanding of barriers to more complete adoption. The SSJV MPEP Committee contracted with project partners at UC Davis to quantify the current use of practices and characterize drivers of grower behavior. The overall objective of this effort was to expand on current work by the project team by extending the study into the SSJV and to focus that work on crops that are locally important in that region, so that SSJV coalitions and the MPEP might enhance existing education and outreach programs. The specific study objectives were 1) to develop a quantitative understanding of key influences and barriers to adoption of N management practices for citrus and raisin grape growers in the regions represented by the SSJV water quality coalitions; 2) to distribute, collect and aggregate survey data from growers during focus groups and; 3) to analyze response data to determine key motivations and barriers to grower adoption of N management practices. Results will be used to understand the status of adoption of N management practices; determine the challenges and benefits on grower decision-making; and identify the key incentives and barriers to enhanced adoption of improved management practices.

Initial work was funded through the CIG. Thanks to that initial support and extensive, supportive letters from SSJV ag groups (coordinated by the MPEP), the UC Davis team was additionally awarded a 2018 CDFA FREP grant to expand this study to further understand key incentives and barriers to adoption of improved management practices throughout the SSJV MPEP area. Additional information about the project is available here.[5]

Deliverables

- Understanding Decision-Making of Citrus and Raisin Grape Growers and Adoption of Nitrogen Management Practices[6], Final Report Southern San Joaquin Valley Management Practices Evaluation Program Committee (September 2019).
- Multiple related outreach events (see Section 4.4).

4 OUTREACH

Outreach activities included development and publication of a website; development and publication of a learning events calendar, information sheets, and tools and calculators for growers and grower advisors; presentations at conferences and grower meetings; outreach to growers through their commodity organizations; and other outreach activities. Most are posted at agmpep.com.

4.1 SSJV MPEP WEBSITE

The SSJV MPEP website, http://agmpep.com, was developed and published in early 2017. The site provides a number of resources for growers and advisers, including an interactive calendar of outreach events[7] related to nutrient management, which was developed in collaboration with FREP. Events are organized by field days, crop-specific seminars, profession association meetings, and other events. Users may search for events by crop, location, event type, and other criteria. The website also includes a directory[8] of publicly available agricultural management practice tools and resources. At a single, grower-owned location, it brings together links to management practice information and resources from experts throughout agriculture in academia, industry, government, and crop advisers. The website continues to be improved and refined with more and more tools and links for use by growers and grower advisors.

4.2 N MANAGEMENT TOOLS AND CALCULATORS

Tools and calculators for growers and grower advisors include the following:

- **Irrigation N Calculator**. The N supply in irrigation water is a crucial component of N management. This calculator allows users to calculate N supply from inches of applied water and N (nitrate and/or ammonium) content from surface and/or groundwater (accommodating two different water supplies to the same field). This peer-reviewed calculator is published at https://agmpep.com/calc-

[5] https://agmpep.com/mpep-projects/barriers-to-adoption/
[6] https://agmpep.com/mpep/wp-content/uploads/Barriers-SSJV-Final-Report.pdf
[7] https://agmpep.com/events/
[8] https://agmpep.com/other-resources/

irrn/. As an alternative to the online calculator, users may also download an offline Excel calculator, a single-page calculation guide (for those making their own calculations), and a printable lookup table that does not require use of a computer or calculator. Growers who do not customarily work in inches of applied water have the option to begin the calculation with pump run time or water volume readings from flow meters.

- **Y to R Calculator**. The Crop Yield to Nitrogen Removed Calculator (also known as the Y-to-R Calculator) was developed based on conversion factors developed by Geisseler (2016). The calculator can be used by growers and advisers to use anticipated or actual yield data to estimate N removed (R) and the ratio of N applied (A) to N removed (A/R). Results can be calculated on inputs for a single crop or for multiple crops. This peer-reviewed calculator is published at https://agmpep.com/calc-y2r/. Recent updates include clarification on reporting units and plant parts, as well as plant parts in which N removal is considered. Additional updates will be incorporated as results from the Y to R Project (Section 3.3) become available.
- **Actual Evapotranspiration (ETa) Variability Viewer**. Management is often discussed at the field or block level, even though we know that individual fields or blocks may contain very distinct units due to soil, topographic, or management variation. Precision agriculture increasingly provides options to manage this variation, but a first step is to determine how much variation exists within a given area, and how it is patterned. This online mapping tool allows the user to zoom into specific fields, complete with field boundaries and reference maps and imagery, and view evapotranspiration variability (5 pixels/acre, or 400 on an 80-acre field) within each field. Data are aggregated over an irrigation season (May to October) and for July. The tool also quantifies variability in terms of distribution uniformity of the ETa pixels within each field, as a way to assess the degree and importance of variability in one field relative to others. Growers can access the Evapotranspiration Variability Viewer online through a portal on their coalition's website. The portal restricts the view to the grower's own fields. *Currently available through some coalition websites, with more to be added as coalitions add this feature.*
- **Field Water Use Tool**. This tool is similar to the ETa Variability Viewer, but allows growers to view a 1) histogram of the Statewide ETa distribution for a selected crop and 2) annual total ETa, ETa95, and ETc. The portal is under development and will restrict the view to the grower's own fields. *Currently available through some coalition websites, with more to be added as coalitions add this feature.*
- **SWAT Viewer**. This viewer allows growers to evaluate N and water balance outcomes of a range of management options for each soil mapping unit in a specific field, as influenced by site-specific climatic, topographic, and agronomic factors. *Currently available through some coalition websites, with more to be added as coalitions add this feature.*

4.3 MANAGEMENT PRACTICE FLIERS

Three management practice fliers were developed for use at grower outreach meetings. One flier describes how to calculate irrigation water nitrogen content and two fliers summarize key information on how to avoid polluting groundwater via wells. Spanish versions are also available.

- Calculation of irrigation water nitrogen content[9]
- Abandoned wells and inactive wells[10]
- Wellhead protection and well maintenance[11]

4.4 Outreach Events

Outreach events where the MPEP Team presented (including poster presentations) material related to the activities described herein are included in Appendix A. The number of presentations given each year is shown in Table 1. Specific outreach events are in Attachment 2. Select presentations are posted at https://agmpep.com/presentations/.

Table 1. Summary of Presentations During the Initial MPEP Period

Year	Number of Outreach Presentations
2016	1
2017	15
2018	20
2019	27
Total	**63**

5 Implementation

A number of management practices (e.g., irrigation scheduling, sprinkler design, timely application of appropriate rates of nitrogen) have potential to increase nitrogen fertilizer efficiency and reduce the amount of residual soil nitrate at risk of leaching beyond the root zone. This section provides a conservative assessment of implementation of nutrient management practices by producers in 2017 based on management practice data reported by producers. For this assessment, nutrient management practices are focused on those similar to the Nutrient Management 590 (NM 590) practice standard, including the following:

- Receiving assistance in developing a nutrient management plan from a credible source (e.g., certified crop advisor, a technical service provider that is certified by NRCS, professional agronomist, etc.),
- Soil N testing,
- Irrigation water N testing,
- Split fertilizer applications and/or variable rate applications using GPS, and

[9] https://agmpep.com/mpep/wp-content/uploads/Irrigation_Calculator_V15.pdf
[10] https://agmpep.com/mpep/wp-content/uploads/abandoned_wells_V9.pdf
[11] https://agmpep.com/mpep/wp-content/uploads/Wellhead_Protection_V9.pdf

- Some measure of irrigation water use efficiency (e.g., use of evapotranspiration [ET] estimate or measurement to schedule irrigation).

Farm Evaluation data reported by producers were assessed to identify the areas where producers implement this entire suite of practices. Results are summarized in Table 2.

TABLE 2. 2017 IMPLEMENTATION OF THE NUTRIENT MANAGEMENT 590 SUITE OF PRACTICES

Sub-region/Coalition Name	2017 Area (acres)
Southern San Joaquin Valley	
Buena Vista Coalition	11,681
Cawelo Water District Coalition	10,609
Kaweah Basin Water Quality Association	64,085
Kern River Watershed Coalition Authority	285,357
Kings River Water Quality Coalition	449,982
Tule Basin Water Quality Coalition	113,090
Westside Water Quality Coalition	18,138
San Joaquin Valley	
East San Joaquin Water Quality Coalition	406,768
San Joaquin County and Delta Water Quality Coalition	157,415
Westside San Joaquin River Watershed Coalition	113,369
Westlands Water Quality Coalition	77,369
Sacramento Valley	
Sacramento Valley Water Quality Coalition	235,715
Total	**1,943,578**

6 CHALLENGES AND NEXT STEPS

Activities undertaken under this CIG were extensive and substantial, moving a significant portion of the Central Valley acreage closer to the type of production and environmental performance that will be needed to recover as much applied N fertilizer as possible, and to minimize the mass of leaching nitrate. However, there are challenges to recognize, and more work to be done.

The initial, four Central Valley SWAT model runs lay the foundation for exploration of more suites of management practices' influence on percolation and nitrate leaching. This larger library of management practices and outcomes can be incorporated into the Grower SWAT Results Viewer developed under this project, allowing growers for the first time to study environmental outcomes of management options without costly research and monitoring.

Our partnership with CEAP means that this new assessment tool meets a need that would otherwise have remained a large challenge to understand conservation effects in the region. The model is also being adapted to assess sources and fate of salinity at a regional scale, as well as nitrate leaching as driven by reported management practices in smaller areas.

Extending practices that adequately control movement of N through root zones across most of the farmed acreage in the Central Valley will occur when millions of individual decisions by tens of thousands of irrigators are effectively informed by accurate estimates of crop needs for N and water through time. This is a monumental technical and educational task. Motivation to succeed is substantial on the production side, since yield, crop quality, and plant disease resistance can all be improved, even as the needs for irrigation and fertilizer inputs are stabilized or reduced. On the environmental side, regulatory pressure to protect groundwater quality increases over time, and households and communities in which growers live often drink this groundwater.

For these reasons, the SSJV MPEP Committee plans to continue to work with multiple partners who share similar goals and mandates, and whose resources and expertise complement the member water quality coalitions and MPEP Team.

Research and assessment components of the program will continue on their current paths. However, the outreach program is at a bit of a crossroads. We now have many partners and expanding materials to share with growers. However, relying 100% on in-person presentations is costly and perhaps unsustainable. An updated approach would be to work with partners to bolster available online video content. This could also be a more efficient way for growers to access information they need. Also, it might enable improvement/enrichment of visual content, and inclusion of the observations and experience by knowledgeable growers in actual field situations. Grower-to-grower communications are much more powerful than expert-to-grower delivery of information, especially when the presenting growers have faced and resolved similar issues as the participant. Whatever our approaches, it is imperative to inform and empower technical service providers, including federal and state agency personnel and private, Certified Crop Advisors and Pest Control Advisors, as well as commodity group experts. All of these resources need to be brought to bear to extend the reach of management practices that adequately protect water quality as swiftly as possible.

Attachment 1 – NMP Methodology Memo

TECHNICAL MEMORANDUM

AGRONOMIC ASSESSMENT OF 2016/17 NITROGEN MANAGEMENT PLAN DATA FOR 8 WATER COALITIONS IN THE CENTRAL VALLEY

PREPARED FOR:	Southern San Joaquin Valley Management Practices Evaluation Program (SSJV MPEP) Committee
PREPARED BY:	SSJV MPEP Team
DATE:	June 2019

1 INTRODUCTION

Irrigated Lands Regulatory Program (ILRP) orders require Central Valley irrigators to complete Nitrogen Management Plans (NMPs) for each crop. For high-vulnerability groundwater acreage (where groundwater nitrate is identified as especially vulnerable to irrigated agricultural practices), NMP data are reported to growers' water quality coalitions, who in turn summarize them in reports to the Central Valley Regional Water Quality Control Board (CVRWQCB 2014). NMP data include crop type, acreage, total nitrogen (N) applied, crop yield, and N removed via crop harvest. As a part of the Southern San Joaquin Valley Management Practices Evaluation Program (SSJV MPEP), 2016 and 2017 NMP anonymized data from 8 water quality coalitions were analyzed from an agronomic perspective to examine the yield growers attained across a range of N application rates. These data also illustrate commonly, occasionally, and rarely reported ranges of N application rates. A map of the water quality coalitions is shown in Figure 1.

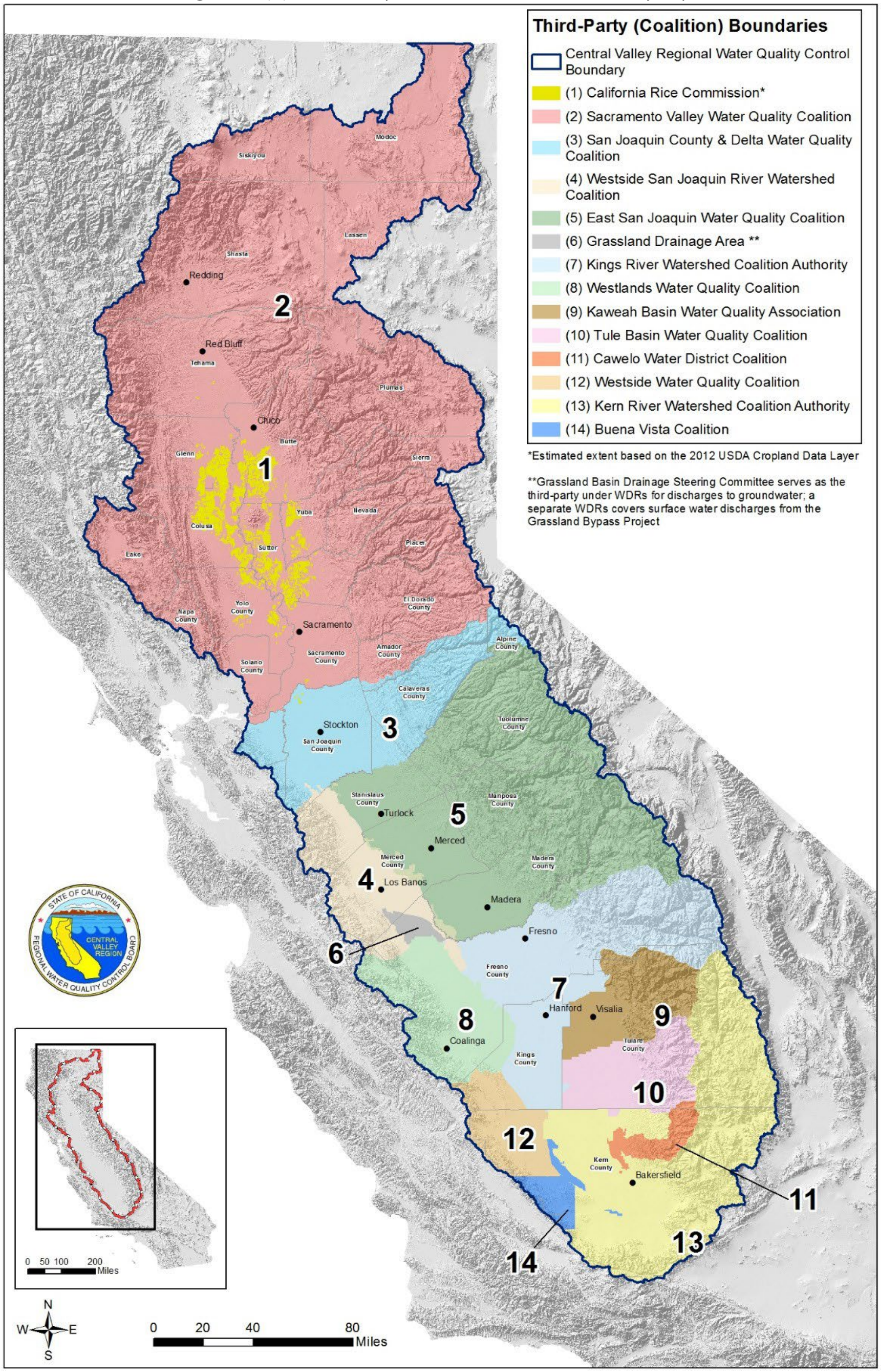
Reports for 924,000 and 1.38 million acres of irrigated land were available for 2016 and 2017 NMP data, respectively, but this analysis focuses on the largest 15 crop classes, and another small percentage for these crops was not considered (e.g., zero-yielding fields or those deemed to represent young perennials or crop failure). The results represent information drawn from NMP reports for over 700,000 and 1 million acres of the 15 crops occupying the largest, highly vulnerable total land area.

This memorandum describes the analysis methodology, an overview of the results, limitations of the dataset, and recommendations for future NMP data collection. Results from this analysis may inform discussion about how to improve NMP data collection methods, and perhaps about how best to balance profitability and environmental risk associated with N fertilization. Detailed results are reported in separate memoranda for the following crops:

Almonds	Carrot	Corn Silage	Cotton	Mandarins
Oranges	Peaches	Pistachios	Potatoes	Raisin Grapes
Table Grapes	Tomatoes	Walnuts	Wheat Silage	Wine Grapes

FIGURE 1. WATER QUALITY COALITIONS IN THE CENTRAL VALLEY

The 2016/17 NMP dataset includes anonymized NMP data from 8 of the 14 coalitions. The California Rice Commission (1) and the Grassland Drainage Area (6) are not required to submit NMP Summary Reports.



2 2016/17 NMP DATASET

Anonymized NMP data were provided by 8 water quality coalitions. NMP data include crop type, acreage, total N applied, and crop yield. N removed via crop harvest was calculated from crop yield and the fraction of N in the harvested materials as reported by Geisseler (2016). A summary of NMP data provided by the coalitions for 2016 and 2017 is shown in Table 1.

TABLE 1. SUMMARY OF 2016 AND 2017 NMP DATA PROVIDED BY 8 WATER QUALITY COALITIONS

	2016				2017		
Crop Variety*	No. of NMP Records	Total Acreage	% of NMP Reporting Acreage		No. of NMP Records	Total Acreage	% of NMP Reporting Acreage
Almonds	2,772	263,689	28.5		5,067	371,084	26.8
Pistachios	876	90,805	9.8		1,485	136,587	9.9
Oranges	2,456	78,741	8.5		4,644	121,265	8.8
Table Grapes	1,555	87,477	9.5		2,360	115,197	8.3
Cotton	616	45,844	5.0		1,148	87,180	6.3
Walnuts	778	33,580	3.6		1,607	55,753	4.0
Wine Grapes	255	30,607	3.3		601	51,499	3.7
Raisin Grapes	352	15,177	1.6		1,552	51,398	3.7
Corn Silage	471	28,704	3.1		719	37,765	2.7
Tomatoes	369	31,846	3.4		330	33,242	2.4
Alfalfa	657	47,843	5.2		509	32,525	2.4
Wheat Silage	320	17,780	1.9		452	30,859	2.2
Peaches	14**	1,159**	0.1**		1,146	29,969	2.2
Carrots	320	16,480	1.8		308	24,862	1.8
Mandarins	211	16,365	1.8		352	20,017	1.4
Potatoes	222	12,491	1.4		238	18,650	1.3
Pomegranates	54	11,463	1.2		123	14,851	1.1
Mixed Veg	**	**	-		254	13,706	1.0
Nectarines	345	10,831	1.2		625	12,228	0.9
All Other Citrus	368	12,312	1.3		488	11,916	0.9
Tangerines	15	253	0.0		438	10,871	0.8
Plums	191	3,990	0.4		521	10,471	0.8

*Crops are sorted by 2017 acreage.
** Data limited or unavailable for 2016.

3 METHODOLOGY

The data were used to 1) develop summary tables of average yield, N applied, N removed, and N balance, 2) identify yield response to N application to understand the upper end of the N applied range that seems to reliably augment yield, 3) identify the relationship between N balance (N applied minus N removed in harvested materials) and N applied, and 4) develop acreage distributions of N applied for each crop.

3.1 DATASET REFINEMENTS

As shown in Table 1, the original 2016 and 2017 datasets included 14,432 and 27,308 NMP records, covering a total of 924,291 and 1,383,702 acres in the Central Valley, respectively. Refinements to the original NMP dataset include the following:

- Crop classes reported by different coalitions varied and were grouped into one consistent set of crop classes, to the extent feasible.
- Reports relatively low or zero yields were removed from the dataset. Thus, perennial crops that are non-bearing or low yielding (young perennials) as well as annual crops experiencing failure were not considered in this analysis.
- In the original datasets, all types of corn and wheat (e.g., silage, grain) were aggregated and reported as only corn and wheat. However, N management for silage and grain crops differs. For this analysis, corn and wheat were divided between crops harvested for silage and grain based on yield data. Corn fields with yield greater than 8,000 lb/ac were designated corn silage, while those less than 8,000 lb/ac were designated corn grain. Similarly, a threshold of 6,000 lb/ac was used for wheat.
- For cotton, the mean reported yield was 1,862 and 1547 lb (3.5 bales) for 2016 and 2017, respectively. This value is comparable to the reported average yields of 3.2 bales for Pima cotton, and 3.43 bale Acala cotton for 2016 in Kings County (County of Kings 2017). We conclude that only lint is being reported. However, in Geisseler (2016), the N removed value includes both lint and seed. Hence, the yield data were recalculated for cotton lint with seed, assuming the lint fraction to be 36% of the harvested weight (Geisseler 2016).

After these refinements, for 2016 and 2017 respectively, we retained for analysis 11,587 and 22,009 NMP records representing 770,745 and 1,185,327 acres of the 15 crops with the highest acreage (excluding alfalfa, which receives little or no N fertilizer).

3.2 DATA ANALYSIS

Initially, data were analyzed in the classic manner—plotting yield against rate of applied N and evaluating the statistical strength of the relationship—to understand the response of yield to N applied. Considering the range of sites in this dataset and yield variability due to other factors (e.g., soil type, climate, and management), yield was likely influenced by many factors other than application of N fertilizer. As a result, the statistical relationship between N applied and yield was weak and not informative, so additional approaches were employed.

Ultimately, data analysis included removing potentially erroneous data, screening data likely representing young perennials and crop failure, creating and filling data bins (or subdivisions of the range of the observed N rates into discrete intervals), determining outliers, and creating summary tables. Each is described below.

3.2.1 REMOVING ERRONEOUS DATA

Data points likely representing input error were removed from the dataset. This was done by using threshold values for applied N and yield. These thresholds have been developed iteratively by members of the MPEP team and are informed by communication with growers, NMP reports, and industry experts. While subject to further refinement, these values represent the upper limits for N application rates and yields likely observed in reality. Table 2 shows threshold values for the 15 major crops.

TABLE 2. LIST OF THRESHOLDS FOR 15 MAJOR CROPS USED TO SCREEN POTENTIALLY ERRONEOUS DATA

	Upper Threshold for Realistic Observations (lb/ac)	
Crop	**Applied N**	**Yield**
Almond	700	7,000
Carrots	700	120,000
Corn Silage	700	70,000
Cotton	700	7,000
Mandarins	700	85,000
Oranges	700	85,000
Peaches	700	60,000
Pistachios	700	7,000
Potatoes	700	80,000
Raisin Grapes	400	40,000
Table Grapes	400	50,000
Tomatoes	700	160,000
Walnuts	700	10,000
Wheat Silage	700	60,000
Wine Grapes	400	50,000

After these observations were removed, the NMP data records were trimmed from 11,587 to 11,322 and from 22,009 to 21,036 for the top 15 crops, representing final areas of 770,523 and 1,135,065 acres for 2016 and 2017, respectively.

3.2.2 REMOVING YOUNG PERENNIALS AND FAILED ANNUAL CROPS

Data for young perennials and failed annual crops can represent relatively low nitrogen application rates and yields. For the purposes of this analysis (i.e. understanding valley-wide agronomic trends in well-established, productive systems), it is desirable to remove these observations. However, reported NMP data do not always provide contextual information in this regard. As a result, employed was a method for determining young perennials and failed annual crops by first calculating the area-weighted average (AWA) yield and nitrogen applied for crops for individual years based on the screened data. For perennial crops, yields or N application rates less than 30% of their respective AWA values were deemed to represent young plantings and were screened, with the exception of grape classes where only yield was considered. For annuals, N application rates were not considered, but rather only yield, where values less than 20% of the AWA were removed.

After these observations were removed, the NMP data records were trimmed from 11,322 to 10,692 and from 21,036 to 18,495 for the top 15 crops, representing final areas of 713,283 and 1,038,210 acres for 2016 and 2017, respectively (Table 3). This final dataset has the following information for each NMP record: crop type, acreage, pounds of N applied per acre, pounds of harvested yield per acre, and pounds of N removed per acre. The latter was re-calculated from the reported yield and the removal coefficient (Geisseler 2016) to ensure consistency. Once N removed was known, a two-part N balance (N applied minus N removed in the harvest) was calculated for each record.

TABLE 3. NMP DATA USED FOR AGRONOMIC ASSESSMENT

	2016		2017	
Crop Variety*	**Reports**	**Acres**	**Reports**	**Acres**
Almonds	2,516	238,908	4,358	321,371
Pistachios	779	81,599	1,268	121,112
Oranges	2,300	74,607	3,944	105,426
Table Grapes	1,356	78,298	1,742	94,744
Cotton	612	45,654	1,049	81,667
Walnuts	726	31,853	1,364	48,585
Wine Grapes	240	29,982	504	44,513
Raisin Grapes	312	13,766	1,059	36,706
Corn Silage	453	28,058	688	36,455
Tomatoes	358	31,234	303	31,235
Wheat Silage	317	17,573	433	30,111
Peaches**	1,160	14	957	26,267
Carrot	289	13,238	303	24,590
Mandarins	199	16,083	307	18,919
Potatoes	221	12,416	216	16,509
Totals	**11,838**	**713,283**	**18,495**	**1,038,210**

*Crops are sorted by 2017 acreage.
** Data limited for 2016. Agronomic assessment only conducted on 2017 data.

3.2.3 DETERMINING OUTLIERS

Outliers were determined based on N balance. Outliers are observations that are unusually high or low compared to the bulk of the dataset. To identify these outliers, the interquartile technique (Tukey 1977) was used. In the interquartile technique, outliers are defined as any point that is 1.5 times the interquartile range below the first quartile, or 1.5 times the interquartile range above the third quartile. Outliers were not removed from the dataset, but rather identified to understand high N balance values relative to the sample population.

3.2.4 CREATING DATA BINS

To facilitate further analysis, data were binned (grouped into a sequence of 20 intervals along the range of N applied). The minimum N application rate defines the lower limit of bin 1. The following equation was used to define the upper bound of each bin:

Min + (Max-Min) * (x/20), where x is the bin number, Min is the lowest N application rate, and Max is the highest.

A moving average of three bins was used to smooth plots of yield and N balance, so that relationships of these important outcomes to N application rate can be more readily discerned. This method dampens variation among bins by including more observations in each average, but retains the relationship of the bin position along the N applied axis to the middle of the range represented by the bin. Figure 2 shows an example of data bins and moving average of data in each sequence of three bins for a hypothetical crop.

For each bin, the total acreage, total N applied, total yield, and total N removed were calculated. Acreage in each bin was plotted in a histogram. The AWA yield and N balance (N applied minus N removed) w calculated within each sequential group of three bins (see Figure 2). These rolling AWA values for yield and N balance were then plotted as functions of N applied.

3.2.5 NMP DATA SUMMARY TABLES

Summary tables show average yield, N applied, N removed, and N balance (summary tables are included in separate memoranda). Nitrogen balance is the difference between nitrogen applied to the crop (in irrigation water and fertilizer) and removed from the field in harvested material. It is an important indicator of the amount of nitrogen that may be stored and recycled in future crops, incorporated into perennial tissues, microbial tissues, or soil organic matter, or that may leave the field in gaseous form, runoff, or leachate. For most crops, the N balance grows steadily as N application increases.

FIGURE 2. EXAMPLE OF DATA BINS AND MOVING AVERAGE BINS FOR A HYPOTHETICAL CROP

The red, double-ended arrows at the top indicate the intervals (or bins) into which the data range was subdivided. From there, moving averages were created by averaging three adjacent bins as shown by the green, double-ended arrows. Acres in each bin were plotted onto a histogram for each crop. The green arrows indicate intervals across which moving, area-weighted averages were calculated for yield and N balance, and then plotted against N applied. The black circles indicate the raw data points, record-by-record.

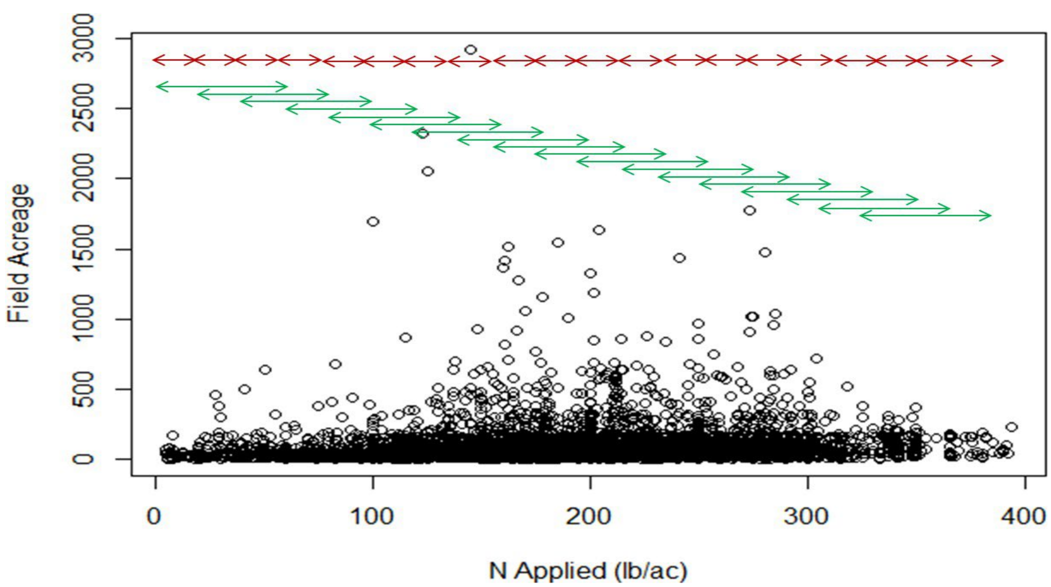
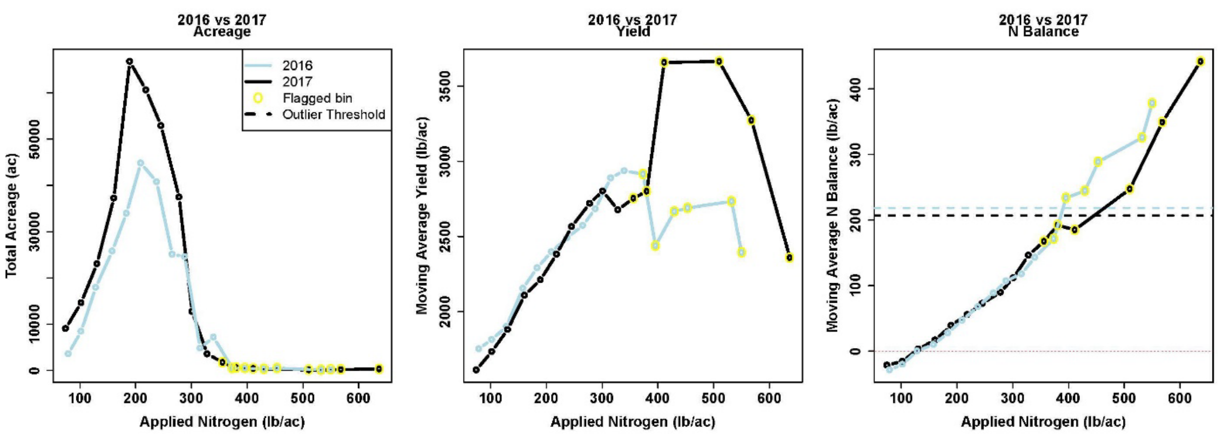


FIGURE 3. EXAMPLE OF OUTLIER THRESHOLD: DISTRIBUTION OF APPLIED N BY ACREAGE FOR A HYPOTHETICAL CROP



The N balance outlier thresholds are marked by the horizontal dashed lines for each year. Total acreage for each bin is represented by points shown. Yellow-flagged bins represent N application classes comprised of fewer than 3 reports or 1% of the total crop acreage.

3.2.6 SCREENING POINTS FOR MINIMUM ACREAGE AND RECORD THRESHOLDS

It is apparent from Figure 3 that for this example, certain portions of the range of applied N rates represent only a few reports and/or small acreage. Results for these portions of the range need to be interpreted with greater caution. As a convenience to the reader, points for bins containing less than 1% of the total NMP reported acreage or fewer than three reports for a given crop are marked with yellow circles.

4 DISCUSSION

Results for the 15 crops with the greatest reported acreage are summarized in separate memoranda, one for each of these crops. These memoranda report acreage for the crop, acreage distribution of N applied, and the AWA yield and N balance as a function of N applied. This depiction of production and environmental outcomes (averaged over large areas) should be useful to commodity communities (e.g., growers, commodity groups, research boards, crop advisors, and research and extension staff) to assess recent use of N in production of their commodity. As future years of NMP data are obtained and analyzed, our understanding of how N use and outcomes change over time will grow.

Armed with this greatly improved information about N use and outcomes, commodity communities should be better able to formulate and test opportunities to a) recover a greater proportion of applied N into the crop, b) improve production and environmental outcomes where their commodity is grown, and c) demonstrate progress in diminishing the mass of N applied to their crop that is subject to loss.

Results also help the MPEP Team to perform required assessments with the Soil & Water Assessment Tool (SWAT), providing a realistic basis for N rates in operational management scenarios for SWAT runs. More information on the use of SWAT is available at agmpep.com.

Patterns of N application and resulting yield furnish clues about possible opportunities to recover a larger fraction of applied N. In general, crop yield increases with N rate, but this response is irregular due to the many factors that influence yield levels and fate of N after application. For example, at low N rates, N may be a key limiting factor, so yield steadily increases as N increases. As N rates continue to increase, the crop yield response may be limited by other factors, such as availability of water, light, and other nutrients. Depending on the crop, elevated N rates can reduce yield and/or crop quality, due to various factors. For example:

- Increased disease (e.g., almond hull rot), insects, or weed pressure
- Delayed maturity (cotton), blanking (rice), and lodging (small grains, rice)
- Excessive vegetative growth that limits reproductive growth needed for yield (many crops)
- Reduced quality (e.g., low sugar content in sugar beet, low solids in tomatoes, less character in wine grapes)

N balance, on the other hand, generally grows steadily with increasing N rate. This balance may be stored and recycled into future crops, incorporated into perennial tissues, microbial tissue, or soil organic matter, or leached to groundwater. For some crops, growers who apply N rates in the upper end of the reported range might reduce relative risk of N leaching to the groundwater by reducing rates of applied N. However, the highest average yields are sometimes beyond the identified N threshold. For other crops, the reported data suggest that N application at the thresholds might be possible without much, if any, reduction in crop yield. Note that crop quality is not considered in this analysis but as mentioned can sometimes decline at higher N application rates, further reducing net returns.

5 LIMITATIONS OF NMP DATA

It is impossible to unravel how production and environmental risk are affected by N management based on grower-reported N application and yield data alone. This is because yield and environmental outcomes are affected by many factors, including seasonal variations in the crop's growing environment, root system morphology, annual and episodic precipitation (e.g., drought), soil conditions, N transformations in soil, depth of groundwater, crop and irrigation management, and so on. In addition, many non-fertilizer factors affect reported N and yield. For example:

- Permanent crop acreage is rapidly expanding, and young vines and orchards yield zero or relatively small yields (compared to mature orchards).
- Some crops (e.g., pistachio) are alternate bearing, resulting in erratic yield levels.
- N applied to permanent crops contributes to perennial structures (roots, trunks, branches), and indirectly to future-years' production, an effect that is masked when considering individual years.
- N applied to annual crops and not taken up during the current year may be recovered in subsequent years, especially by deeper rooted annuals.
- During drought years like 2016, crop yields were affected by limited water, salinity, and specific ions (boron, sodium, and chloride), all resulting from prolonged drought.
- Pest pressure varies from year to year. For example, 2017 was a brutal year for lygus in cotton.
- Early bloom (e.g., 2018 almonds in some areas) can result in tree-crop vulnerability to spring storms.
- Crops are occasionally lost (e.g., left in the field, or not packed for shipment after harvest) due to damage or poor market conditions.
- Neither the chemical form of applied N nor the timing and mode of its application are specified. These factors can influence the ultimate fate of fertilizer N by affecting what portion is available and taken up by the crop. This is true for both conventionally and organically managed systems.
- Some sources of N (e.g., N carryover, cover crops) are not collected as part of NMP summary reports, so that their effects cannot be appreciated by an analysis of these data.

The NMP data do not control for these sources of variability, or by themselves inform how any particular field has been managed. Nevertheless, when these limitations are borne in mind, the data are useful in understanding the general N productivity and environmental risk relationships in fields managed throughout the Central Valley. Specifically, observing the distributions of acreage, crop yield, and N balances provides clues about instances where efficient N use might maintain production and profitability. For this purpose, crop-specific analyses of these results are documented in separate memoranda for study and consideration by growers, commodity communities, and their advisors.

6 RECOMMENDATIONS FOR FUTURE NMP DATA COLLECTION

Data will improve as coalitions work continuously with growers to facilitate and improve reporting. Several improvements that are currently underway include a clearer definition of perennial crops' age and of harvested materials (e.g., with wheat and corn, clarity as to whether the harvest was as grain or silage).

Future NMP datasets will be analyzed with similar methods, so that patterns of N use, and in outcomes (yields and N balances), can be increasingly understood. This understanding will inform future N management, so that environmental risk can be brought down while maintaining crop yields. Additional years' data will improve data quality and interpretations.

7 BIBLIOGRAPHY

County of Kings. 2017. 2016 Agricultural Crop Report. Accessed February 5, 2019. https://www.countyofkings.com/home/showdocument?id=16141.

CVRWQCB (Central Valley Regional Water Quality Control Board). 2014. Nitrogen Management Plan Worksheet. Template for the Nitrogen Management Plan Summary of Regulatory Requirements. For Compliance with the General Orders for the Irrigated Lands Regulatory Program, Approved December 23.

Geisseler, Daniel. 2016. Nitrogen Concentrations in Harvested Plant Parts – A Literature Overview. December 2.

MPEP Team (Southern San Joaquin Valley Management Practices Evaluation Program Committee). 2018. Site-specific Irrigation Information PowerPoint Presentation. March 27.

Tukey, John W. 1977. Exploratory Data Analysis. Addison-Wesley, Reading, Massachusetts. ISBN-10: 0201076160.

University of California. Nitrogen Management Training for Grower Nitrogen Management Plan Self-Certification. A Training Program Developed in Cooperation with California Department of Food and Agriculture – Fertilizer Research and Education Program and University of California.

Attachment 2 – Outreach Presentations / Conferences

Table B-1. Summary of Southern San Joaquin Valley (SSJV) Management Practices Evaluation Program (MPEP) Outreach Activities (activities listed by topic area, then chronological date). Select presentations are posted at https://agmpep.com/presentations/.

No.	Outreach Presentations and Materials, by Theme	Venue	Date
	Events related to landscape-scale performance assessment:		
1	Assessing N fate at the landscape scale	CA N Assessment Workshop	02/24/17
2	How performance will be assessed in the MPEP	California Cotton Ginners and Growers	06/02/17
3	California's approach to preventing and managing nitrate pollution of groundwater	Korean nitrate study group at FREP	08/16/17
4	Use of SWAT for assessment and outreach in the ILRP	NZ delegation on GW quality management	10/05/17
5	Quantifying Nitrate Leaching from Central Valley Irrigated Lands Using the Soil & Water Assessment Tool (SWAT)	California Plant and Soils Conference	02/06/18
6	The role of soil survey information in running SWAT	National Cooperative Soil Survey Planning Meeting	03/01/18
7	Briefing on modeling effort, underlying model & data, structure of analysis, nature of outputs, and schedule	UC and Northern Coalition partners, Sacramento	08/30/18
8	Quantifying Nitrate Leaching from Central Valley Irrigated Lands with the Soil & Water Assessment Tool (SWAT)	Western Groundwater Congress, Sacramento	09/25/18
9	Quantifying Nitrate Leaching with the Soil and Water Assessment Tool (SWAT)	Annual Conference of the Fertilizer Research and Education Program / Western Plant Health Association	11/22/18
10	Grower Responses to the Central Valley Irrigated Lands Program	EES 266 (Natural and Agricultural Uses of Water, CSU Fresno Water Resource Management MS Program)	03/20/19
11	Update on SWAT model work completed to date	ILRP Coalitions, Modesto	04/02/19
12	Update on the SSJV MPEP.	ILRP Stakeholder Workshop, Modesto	04/10/19
13	Quantifying Nitrate Leaching from Central Valley Irrigated Lands with the Soil & Water Assessment Tool (SWAT)	"Land Use and Water Quality" conference in Aarhus, Denmark	06/04/19
14	SWAT Modeling Forum	At NRCS, Davis, CA, with Water Quality Coalition, UC, NRCS, and CDFA partners	06/20/19
15	SWAT Assessment Update	CEAP Planning Meeting, Davis CA	06/20/19

16	Quantification of nitrate leaching from almond fields in Central Valley of California using SWAT	2019 ASABE Annual International Meeting, Boston	07/08/19
17	Use of SWAT to assess the effects of management practices on leaching nitrate from irrigated lands	Workshop at the Central Valley Regional Water Quality Control Board	07/23/19
18	Overview. of SWAT modeling, monitoring, indices, and other tools' use in the MPEP	Sac Valley Water Quality Coalition	07/29/19
19	Soil Physics at the Groundwater-Agriculture Interface	2019 SSSA Meetings	11/11/19
20	Site-Specific Management Effects on Nitrate Leaching	Annual Conference of the Fertilizer Research and Education Program / Western Plant Health Association	11/28/19
21	Discussion of use of SWAT in the ILRP	Kings WQ Coalition Board	12/17/19
	Events related to agronomic assessment of NMP data:		
22	Review N and irrigation management study results	California Citrus Mutual	08/16/17
23	Reminders from Our Nitrogen Management Planning Reports	Grower Re-Certification Course, Kearney Ag Research & Extension Center	03/29/18
24	The South San Joaquin Valley Management Practices Evaluation Program – New Tools & Outlook for CCAs & Growers	CAPCA meeting at Tulare Ag Center	08/09/18
25	Agronomic Overview of Citrus NMP Results	California Citrus Conference of the Citrus Research Board	11/10/18
26	Nitrogen Management Information from Growers	Kings River Water Quality Coalition Meetings, Kerman	01/29/19
27	Management Practices Evaluation Program as it Affects Processing Tomato Growers	California Tomato Research Institute	02/27/19
28	SSJV Management Practices Evaluation Program	NRCS CIG Partner. NRCS/Davis	04/25/19
29	Practical limitations and opportunities related to collecting, managing, analyzing, and reporting NMP information in other geographies (mainly the American Midwest)	Environmental Defense Fund	05/24/19
30	Nitrogen Balance as an Indicator of Nitrate Leaching Risk	Annual Conference of the Fertilizer Research and Education Program / Western Plant Health Association	10/28/19
31	Current Status of Nitrogen Use Efficiency, Prospects for Improvement	Tulare Kings CAPCA CE Meeting	11/07/19
32	Improving N efficiency. Kern River Watershed Coalition Authority	Grower Workshop, Kern Ag Pavilion	11/08/19
33	Efficient Nitrogen Management in the south San Joaquin Valley	Kern River Watershed Coalition Authority, Grower Workshop, Kern Ag Pavilion	11/08/19

34	Recovering more water and N into crops to improve production and protect water quality	Center for Irrigation Technology, California State University Fresno	11/15/19
	Events related to Irrigation / Fertilization Assessment Study:		
35	Field tour and presentation of irrigation and N management demonstration	NRCS local, state, and national nutrient management personnel	09/07/17
36	MPEP irrigation tools and Almond Board's irrigation continuum	Almond Board of California	10/11/17
37	Assessment of Almond and Orange Irrigation and Fertilization by Combining Grower Operational Records and Actual Evapotranspiration Estimates with Soil and Plant Tissue Sampling	2017 Conference of the Fertilizer Research and Education Program / Western Plant Health Association	11/01/17
38	Key Components to Preventing Nitrogen Contamination of Groundwater	Mid Valley Nut Show, Modesto	11/03/17
39	The South San Joaquin Valley Management Practices Evaluation: Potential Applicability to Pesticides and Available Tools	Tulare Chapter of CAPCA	11/09/17
40	Some tools for understanding where your N is going, and why	Fall UCCE San Joaquin Valley Citrus Meeting, Kearney Ag Center	11/29/17
41	Connection Between Nitrate in Root Zone and Groundwater as Affected by Crop and Soil Management	California Plant and Soils Conference	02/05/18
42	Irrigation effects on nitrogen efficiency	Grower Re-Certification Course, Kearney Ag Research & Extension Center	03/29/18
43	Site-specific Irrigation Information	Grower Re-Certification Course, Kearney Ag Research & Extension Center	03/29/18
44	Site-specific ET information for irrigation decision making as part of session on "The Big Picture: Airborne Remote Sensing Survey and Applications"	UC-ANR, Pistachio Field Day & Pistachio ET & Irrigation Workshop	05/30/18
45	Reviewed multiple irrigation and N management practice potential areas of collaboration	Almond Board of California	09/20/18
46	Presentation on MPEP & tools for growers to manage water and nitrogen more precisely	Producing Healthy Forage Systems, 2018 California Alfalfa & Forage Symposium & Soil Health and Fertility Workshop, Reno, NV	11/27/18
47	Demonstrating how Frequent Applications Boost N Recovery by Oranges with Grower Operational Records, Actual Evapotranspiration, Soil, and Plant Tissue Data	2019 Plant & Soil Conference of the American Society of Agronomy	02/05/19
48	Update on efforts to retain and use applied N	Advances in Citrus Water Use Workshop & Field Day	03/26/19
49	MPEP Program Update with Water Board representatives	Fresno area	11/07/19

	Events related to yield to N removed studies:		
50	Proposal to work together on N removed study	California Cotton Ginners and Growers	03/14/17
51	Proposal to work together on N removed study	California Fresh Fruit	05/11/17
52	Online Nitrogen Management Tools, and Nitrogen and Dry Matter Accumulation in Peaches	2017 Conference of the Fertilizer Research and Education Program / Western Plant Health Association	11/01/17
53	Some Tools for Understanding Where Your N is Going, and Why	Fall UCCE San Joaquin Valley Citrus Meeting, November 29, 2017	11/29/17
54	N removed flier distributed to growers.	2018 Plant & Soil Conference of the American Society of Agronomy	01/29/18
55	Assessment of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Perennial Crops	2019 Plant & Soil Conference of the American Society of Agronomy	01/29/18
56	Online Irrigation and Nitrogen Management Tools	2020 Plant & Soil Conference of the American Society of Agronomy	01/29/18
57	Nitrogen Management Tools for Growers & Advisors. Kings River Water Quality Coalition	Grower Re-Certification Course, Kearney Ag Research & Extension Center	03/29/18
58	Briefing on N removed studies	Northern Coalitions	07/24/18
59	Working with Industry Partners to Procure Crop Samples and Assess Harvest N Content	Annual Conference of the Fertilizer Research and Education Program / Western Plant Health Association	10/22/18
60	Working with Industry Partners to Procure Crop Samples and Assess Harvest N Content	2019 Plant & Soil Conference of the American Society of Agronomy	02/05/19
61	Tools for Site-Specific Crop Management to Maximize Recovery of Applied Nitrogen Fertilizer	Annual Conference of the Fertilizer Research and Education Program / Western Plant Health Association	10/28/19
62	Update on N removed studies and planning Phase 2	Northern Coalitions	12/02/19
	Events related to barriers to adoption:		
63	Our cooperators at UC Davis have presented on this work at multiple grower and grower advisor meetings.	Various	Various