

FINAL REPORT

Fertilizer Research and Education Program
California Department of Food and Agriculture
Project 19-0591

Next Generation N Management Training for Certified Crop Advisors

Project Team

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Abstract

The Certified Crop Advisor (CCA) Nitrogen Specialty Training Program and Exam was developed to enhance nitrogen management expertise among CCAs, equipping them with the skills necessary to support growers in optimizing nitrogen use efficiency and complying with regulatory requirements. A team of subject matter experts from UC Davis, UC ANR, and the American Society of Agronomy (ASA) established key competency areas to structure the training, ensuring alignment between educational content, certification standards, and real-world application. The asynchronous, online course was designed to be accessible and provided continuing education units (CEUs) to participants. Since 2021, the program has trained more than 200 individuals enrolled, including 130 CCAs and over 70 additional agricultural professionals, UC advisors, and students through online courses. This highlights the program's broader impact beyond its initial target audience.

The program also included development of a certification example. The certification exam was developed through collaboration with assessment specialists and validated using Angoff Analysis to ensure fairness, consistency, and relevance to industry needs. Over four years, 138 CCAs have taken the exam, with 116 achieving certification, resulting in an 84% pass rate. This increase in certified professionals has strengthened the industry's ability to implement data-driven nitrogen management plans in alignment with water quality regulations. While the exam remains self-sustaining, the future of the online course is uncertain due to funding limitations, despite its demonstrated success in expanding the number of trained professionals. The program serves as a model for competency-based training in California agriculture, bridging the gap between scientific knowledge, regulatory requirements, and field application. Continued investment in structured, high-quality educational programs like this will be essential for ensuring the long-term sustainability of management expertise within our industry.

Introduction

The use of nitrogen (N) fertilizer on major California crops has contributed to the degradation of water quality due to nitrate leaching into groundwater. This issue stems from past nitrogen management practices, including uniform N fertilizer applications across heterogeneous soil types, misaligned seasonal application rates, and excessive irrigation when soil N levels exceed crop uptake capacity. Such practices reduce nitrogen use efficiency (NUE) and increase the risk of nitrate leaching, particularly when irrigation surpasses crop water demand. As trusted advisors, CCAs play a critical role in reversing these trends by guiding growers toward more efficient and sustainable nitrogen management practices. With the right knowledge and tools, CCAs can help reduce environmental impacts while ensuring agricultural productivity, positioning themselves as leaders in regulatory compliance and responsible stewardship of nitrogen resources.

The Irrigated Lands Regulatory Program (ILRP) now mandates grower reporting of nitrogen use efficiency (applied N from all sources / N removed in the harvested crop) and requires reductions in nitrate leaching to groundwater. Compliance with these regulations presents challenges for farming communities, as growers must optimize N use while maintaining productivity. Current ILRP rules require growers to develop an annual N management plan with input from a Certified Crop Advisor (CCA) at the start of the growing season and later report actual N use. As ILRP requirements expand, the role of trained and informed CCAs becomes increasingly critical in ensuring compliance and promoting efficient N management. The success of this initiative depends on the development of clear, streamlined study materials and training programs that maintain program integrity and support regulatory agencies such as the California Department of Food and Agriculture (CDFA) and the State and Regional Water Quality Control Boards (Water Boards).

To effectively prepare CCAs for this responsibility, the program incorporates learner-centered and experiential education, strategies shown to be highly effective in adult learning. Mezirow (1991) describes adult learning as a process of critical reflection in which individuals expand their perspectives and adopt new frameworks for decision-making. Effective learning occurs when participants actively engage in real-world applications rather than passively receiving information (Sams and Bergmann, 2013). This program was designed to facilitate knowledge transformation by providing interactive, problem-solving approaches tailored to CCAs. By integrating these adult learning strategies, CCAs will have the knowledge and skills necessary to improve nitrogen management recommendations, ensuring both regulatory compliance and sustainable agricultural outcomes. Through interactive workshops, case studies, and exam-preparation materials, this initiative empowered CCAs to support grower adoption of efficient nitrogen management practices, while enhancing environmental quality and crop productivity.

Objectives

Through this project, we:

1. Delivered an in-person CCA workshop.
2. Organized key information sources into structured learning objectives.
3. Curated study materials into an asynchronous online course.
4. Developed exam questions in collaboration with our expert team.
5. Analyzed exam responses and updated study and exam materials accordingly.
6. Delivered the online course on a bi-annual basis to the general public.

Methods

Our project consisted of four distinct phases: CCA Workshop, Learning Objectives Development, Online Course Implementation and Feedback, and Specialty Exam Deployment.

Phase 1: CCA Workshop

In March 2020, we conducted a two-day CCA Nitrogen Certification Workshop in Fresno, CA, following a structured agenda developed by our project team. This in-person event provided CCAs with a valuable opportunity to participate in specialized, interactive training designed to enhance their expertise in nitrogen management. Unlike remote learning formats, the workshop facilitated real-time engagement with subject matter experts, enabling participants to ask questions, discuss region-specific challenges, and explore practical solutions tailored to California's diverse agricultural landscapes. The training was designed to maximize peer-to-peer interactions, allowing CCAs to exchange knowledge, share experiences, and refine their approaches.

Beyond formal instruction, the workshop incorporated specialty breakout sessions, where participants engaged with advanced topics relevant to their specific areas of work. The presence of regulatory representatives and experienced agronomists further enriched discussions by providing insights into both technical best practices and compliance requirements. To assess participant engagement and learning outcomes, the workshop included informal discussions, Q&A opportunities, and evaluations of satisfaction and knowledge gains. These assessments allowed attendees to reflect on the training content, identify areas for further emphasis, and provide valuable feedback for future programming. By convening in a collaborative, community-focused setting, the workshop strengthened technical expertise and reinforced professional networks among CCAs.

The first day of the workshop covered core nitrogen management topics through structured modules, including nitrogen cycle basics, nitrogen sources, irrigation management, nitrogen budgeting, and available tools and resources. A presentation from the Water Boards was also included to provide CCAs with essential regulatory context and compliance considerations related to nitrogen management. The second day featured breakout sessions tailored to the specific nitrogen management challenges of annual and permanent crops. CCAs selected the track that best aligned with their expertise and client needs. The annual crop session addressed the seasonal variability of nitrogen demand, shorter cropping cycles and rotations, and the importance of

precise in-season applications. In contrast, the permanent crop session focused on tree versus crop nutrient management strategies, including perennial nutrient storage, timing of remobilization, and multi-year and in-season fertilization adjustments based on yield expectations. By structuring the second day around these crop-specific challenges, the workshop allowed CCAs to refine their nitrogen management recommendations for growers in their respective sectors.

Phase 2: Learning Objectives and Curriculum Development

By early 2020, we completed the development of learning objectives, a critical step in structuring the CCA Nitrogen Specialty training program. This process began with a coordinated effort among subject matter experts from UC Davis, UC ANR and certification specialists at the American Society of Agronomy (ASA). Together, we outlined key knowledge areas that CCAs would be expected to master before engaging in course materials or attempting the specialty exam. This structured approach ensured that the training program was built upon a clear framework of competencies, aligning with both scientific best practices and regulatory needs.

Once the learning objectives were established (see the *Products* section below for the output), we proceeded with consolidating existing training modules and study materials that had been previously developed by our team. This effort allowed us to integrate proven resources into a cohesive curriculum, ensuring that course materials directly supported the defined competencies. At this stage, we also began outlining an online course structure that aligned with the learning objectives, ensuring that the curriculum would effectively prepare CCAs for both practical field applications and regulatory compliance expectations.

Another key outcome of this phase was the development of exam question categories based on the finalized learning objectives. These categories defined the areas of knowledge that the exam would assess, ensuring a direct link between training content and certification standards. Additionally, we established levels of difficulty for exam questions, a necessary step for ensuring a balanced assessment that accurately measured varying degrees of expertise among CCAs.

This stage of developing learning objectives and the curriculum stage was essential for the subsequent phases of the project. It laid the groundwork for Phase 3 by structuring a training program that aligned with professional competency needs, and informed Phase 4 ensuring that the exam served as a valid and comprehensive assessment of the knowledge gained. By structuring the program in this way, we ensured that CCAs would receive targeted, practical education, allowing them to translate complex nitrogen management principles into actionable recommendations.

Phase 3: Online Course Implementation and Feedback

Starting in 2020, adapting through 2022, and carrying through 2024, we developed, implemented, and expanded an asynchronous, low-cost online training program for CCAs seeking the California Nitrogen Specialty certification. This phase built directly upon the learning objectives and competency areas established in Phase 2, ensuring

that the training content was aligned with key knowledge domains and real-world application needs. The same subject matter experts who contributed to the learning objectives were engaged in developing the online course modules, allowing for consistency between training content and certification expectations. The core curriculum development began in 2020, when we collected, refined, and adapted previous training materials into PowerPoint presentations with voice-over video lectures. These materials were structured into concise, digestible modules, each lasting 10 to 15 minutes, to support learner engagement and retention. The selection of a learning management system (LMS) was a key part of this development phase, ensuring that students could onboard efficiently, engage with course materials, and receive structured follow-ups throughout the learning process.

Each of the online course modules directly mirrored the seven competency areas established in Phase 2, reinforcing the core knowledge areas required for certification. The modules included:

1. Environmental Impacts of Nitrogen Loss
2. Nitrogen Cycling – Soil Transformations
3. Nitrogen Uptake – Plant Utilization
4. Nitrogen Sources
5. Nitrogen Budgeting
6. Irrigation and Nitrogen Management
7. California Cropping Systems

Each module was designed to address the key knowledge and skills expected of CCAs, ensuring alignment with both scientific best practices and regulatory requirements. To meet the requirements for continuing education units (CEUs) in a specialty area, each module was assigned a corresponding competency area. Our team determined that Modules 1, 2, and 6 best fit the Soil and Water Management specialty, while Modules 3, 4, 5, and 7 aligned with the Nutrient Management specialty. This structured categorization ensured that CCAs received targeted training in their respective areas while fulfilling CEU requirements for certification renewal. In addition to the required modules, we developed an optional “Barriers to Adoption” module, which provided CCAs with insights into the economic, behavioral, and logistical challenges that growers face when implementing nitrogen management strategies. While this module was not part of the competency-based certification exam, it served as a valuable resource for CCAs seeking to support growers in overcoming obstacles to nitrogen best management practices.

In addition to video lectures, each module included reflective prompts designed to help learners critically engage with the material and connect new knowledge with their existing understanding. The reflective prompts encouraged students to complete statements such as:

- I used to think/feel _____, but now I think/feel _____.
- I used to think/feel _____, and I still think/feel _____.
- I knew that _____, but it was surprising to learn/realize that _____.
- I didn’t know/realize that _____, and I want to know more about _____.

These reflections were open-ended, but learners were encouraged to use the provided prompts to articulate their knowledge shifts and areas where they sought further clarification or application.

Since its launch, the online course has attracted a diverse group of participants beyond CCAs, demonstrating its value as a publicly available resource. While the course was initially designed for Certified Crop Advisors, enrollment data shows that it successfully reached a broader audience, including university students, UC advisors, agricultural specialists, and individuals with a general interest in nitrogen management. Over four years, 201 students enrolled in the course, with 130 participants (65%) identifying as CCAs, our primary target audience.

The percentage of CCAs within the course grew steadily each year, starting at 58% in 2021 and increasing to 80% by 2024 (Table 1). This trend suggests that as awareness of the certification grew, the course became an increasingly targeted resource for those seeking formal accreditation. However, the participation of non-CCA learners was also important, highlighting the course's impact across the wider agricultural community. By making this training publicly accessible, we were able to extend knowledge beyond the initial target audience, supporting the broader adoption of nitrogen management principles across different initiatives in the agricultural sector.

To evaluate the effectiveness of the online course, we conducted a qualitative analysis of the reflective responses collected from five iterations of the online course. Learner responses were anonymized and uploaded into NVivo, a qualitative analysis software, where they were coded using an inductive thematic approach. The first pass of coding identified broad themes, which were refined during a second pass to extract more detailed insights into learner experiences and challenges. A third round of coding is ongoing to further refine these themes and analyze them in relation to adult learning theory. Responses were only included from those who provided informed consent during enrollment of the course. All consents and data handling protocols were approved by the UC Davis Institutional Review Board (IRB) for Human Subjects Research, ensuring compliance with ethical standards and participant confidentiality requirements. Preliminary findings suggest that most learners were highly satisfied with the course, reporting increased confidence in nitrogen management principles. Some participants indicated a preference for more interactive elements, such as embedded quizzes or interactive exercises, similar to other professional training they had received. Others suggested the inclusion of worksheets or problem sets to practice nitrogen budgeting and application strategies before completing the final exam.

In addition to the qualitative assessment, we conducted a quantitative self-assessment where students ranked their pre-course and post-course knowledge levels across each module topic. By calculating the delta difference between these rankings, we were able to measure learning gains across the entire course (Fig 1). This mixed-method approach allowed us to triangulate the effectiveness of the online training, ensuring that both perceived knowledge gains and self-reported confidence improvements were documented as key outcomes.

The online course officially launched in October 2020 for the 2021 testing season, with continuous enrollment over multiple years. Enrollment trends over time reflected strong early engagement, with 78 students enrolling in 2021, 64 in 2022, and a gradual decline in participation in subsequent years, including 39 students in 2023 and 20 in 2024. As the grant reached its conclusion, we recognize that while the course has successfully served over 130 CCAs and more than 70 additional participants, its long-term sustainability remains uncertain without additional support.

Phase 4: Specialty Exam Deployment

The final version of the Certified Crop Advisor (CCA) Nitrogen Specialty Exam, consisting of more than 60 questions, was developed by our team of subject matter experts, many of whom had also contributed to the learning objectives and curriculum development in earlier phases. This continuity ensured that the exam questions directly aligned with the seven competency areas, providing a rigorous assessment of the knowledge and skills CCAs needed to support growers in nitrogen management and regulatory compliance. Additional colleagues with expertise in certification and assessment design were brought in to refine the question development process, ensuring that the exam met professional standards for validity, fairness, and consistency.

The exam was first deployed in February 2021, with 48 CCAs sitting for the exam that year, and an initial pass rate of 96%. Given this high success rate, certification specialists at the American Society of Agronomy (ASA) recommended conducting an Angoff Analysis to establish a statistically validated cut score. This process involved a panel of subject matter experts who independently evaluated the difficulty of each question, followed by a collaborative discussion to refine scoring criteria. The final pass/no-pass threshold was determined through psychometric analysis, ensuring that the exam remained rigorous yet fair. Psychometric analysis refers to the scientific process of measuring knowledge, skills, abilities, and other attributes in a reliable and valid manner, often used in the development and evaluation of exams and assessments. Select questions were returned for updates to increase their complexity and maintain an appropriate difficulty level for certification.

From 2021 to 2024, a total of 138 CCAs took the exam, with 116 passing, resulting in an overall pass rate of 84% (Table 2). While the number of test takers has gradually declined each year, the pass rate has remained relatively stable, except for lower pass rates in 2022 and 2023 before rebounding in 2024. This pattern suggests that as the initial wave of CCAs seeking certification tapered off, those continuing to take the exam may have had varying levels of preparation or access to training resources. Additionally, while course enrollment has declined (see above), the number of individuals taking the exam has not decreased as sharply, suggesting that some CCAs may be entering the space without enrolling in the online course.

Despite these fluctuations, the program has successfully expanded the number of certified CCAs, with 116 more professionals now qualified to assist growers with

nitrogen management planning. Given that regulatory requirements have remained in place, this increase in trained CCAs represents a valuable contribution to meeting ongoing industry and environmental demands. The exam itself remains financially self-sustaining, with fees paid by test takers to the American Society of Agronomy covering administrative costs and ensuring its continued availability.

Team Self-Assessment

The deployment of the exam has been smooth, with no significant communication issues reported between certifying bodies, subject matter experts, and the CCA organizations promoting the specialty. This seamless process reflects the strong collaboration and coordination among all stakeholders involved, from the initial learning objectives development to the final assessment process. The success of this initiative is a testament to the dedication of the team, the rigor of the certification process, and the commitment of CCAs to advancing best practices in nitrogen management. Moving forward, the team remains available for any necessary updates to the exam to ensure it continues to meet industry needs and regulatory standards.

Results

Table 1. Enrollment in the online CCA Nitrogen Course from 2021 to 2024, including the total number of students, the number of Certified Crop Advisors (CCAs), and the percentage of enrollees who were CCAs. While the course was designed for CCAs, enrollment data indicate that a significant number of additional participants engaged with the course, broadening its impact.

Year	Students	# CCA	% CCA
2021	78	45	58%
2022	64	43	67%
2023	39	26	67%
2024	20	16	80%
Total	201	130	65%

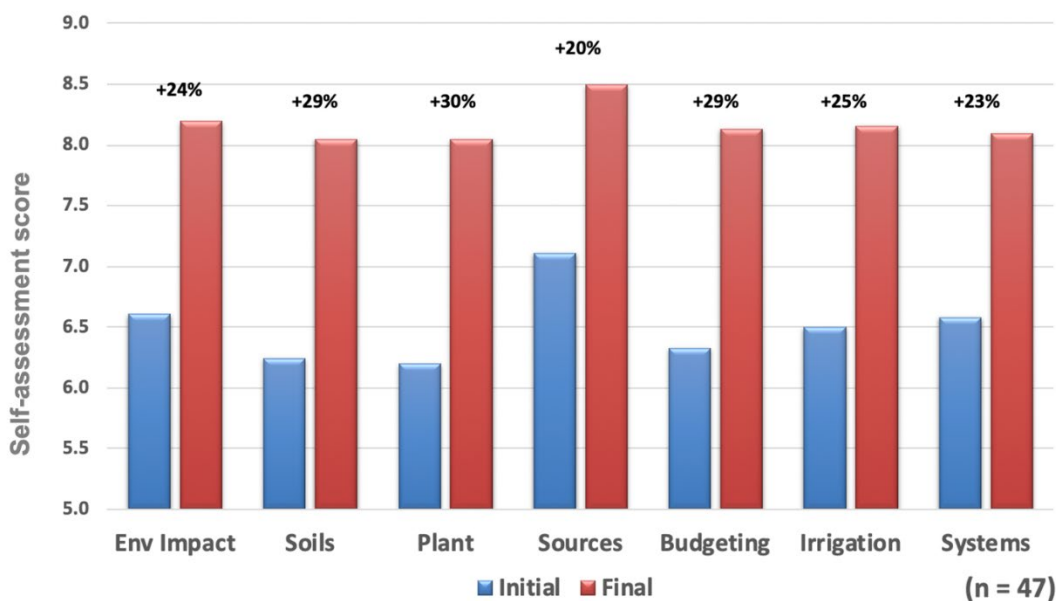


Figure 1. Student knowledge self-assessment for performance objectives aligned with each course module before starting the course and after completing the course.

Table 2. Number of Certified Crop Advisors (CCAs) who took the Nitrogen Specialty Exam from 2021 to 2024, including total test takers, number of passing candidates, and pass rates.

Year	Test Takers	# Pass	% Pass
2021	48	46	96%
2022	35	25	71%
2023	34	26	76%
2024	21	19	90%
Total	138	116	84%

Discussion

Our CCA Nitrogen Specialty Training Program and Exam was a multi-phase, collaborative effort that successfully aligned educational content, competency-based assessments, and certification requirements. Beginning with the establishment of clear learning objectives, our team worked closely with subject matter experts to define the core knowledge areas that CCAs needed to master. These objectives informed the design of structured training modules, ensuring a strong connection between the educational content and the exam itself. The online course, launched in Fall 2020 provided CCAs with specialized nitrogen management education. The certification exam, deployed in February 2021, was rigorously evaluated through Angoff Analysis, ensuring that it remained a fair, valid, and competency-driven assessment. Exam results demonstrated that 116 CCAs have successfully earned certification, strengthening the capacity to support science-based nitrogen management in compliance with regulatory demand.

Looking ahead, the impact of this program is evident in the increased number of certified professionals now equipped to guide growers in making data-driven, environmentally responsible nitrogen management decisions. However, while the exam remains financially sustainable, the future of the online course is uncertain due to the completion of grant funding and the challenges of maintaining ongoing administrative support. Despite this, the program has fulfilled its initial mission, successfully training and certifying CCAs at a time when nitrogen management continues to be a critical regulatory and agronomic issue. The strong collaboration among educators, industry experts, and certifying bodies has resulted in a well-structured, impactful educational program that remains available for potential expansion or adaptation in the future. Moving forward, sustaining the course in a lean format would require new support but could be done efficiently given that the core materials and assessments are fully developed. The success of this initiative highlights the value of structured, competency-based continuing education for CCAs, reinforcing the importance of continued investment in professional training programs that bridge science, policy, and practice.

The development of the CCA Nitrogen Specialty Training Program and Exam was primarily funded through grant support, which enabled the creation of learning objectives, curriculum development, online course implementation, and exam deployment. While the exam itself is financially self-sustaining through fees collected by the American Society of Agronomy (ASA), the online course did not generate sufficient revenue to cover ongoing administration and maintenance. A sustainable fiscal model for the program would require either external funding support, increased course fees, or a restructuring of the course into a modular format that could generate revenue through continuing education units (CEUs) or specialized exam preparation resources. Exploring strategic partnerships, institutional sponsorships, or a tiered access model could also provide pathways to long-term sustainability while maintaining accessibility for CCAs.



Figure 2. Fresno in person training in March 2020 include lectures, discussion and specialties.



Figure 3. Online UC nitrogen course developed by program
<http://ucanr.edu/nitrogencourse>

Challenges

While the project was largely successful in achieving its objectives, several challenges emerged throughout the development and implementation process. One of the primary challenges was ensuring sustained engagement with the online course over multiple years, particularly as initial demand from early adopters tapered off and newer CCAs entered the space without awareness of the training. Additionally, securing long-term support for course administration proved difficult, as the course fees were not sufficient to maintain ongoing oversight without external funding. The Angoff Analysis and cut score refinement introduced a critical step in the exam deployment phase, requiring additional coordination among subject matter experts and certification specialists to ensure the exam remained rigorous yet fair. Another challenge was finding the right depth of technical content, necessitating careful curriculum design and iterative refinements based on learner feedback. Despite these challenges, strong collaboration between universities, industry experts, and certifying bodies enabled the program to adapt effectively, ensuring that both the training and certification process met professional standards and industry needs.

Project Impacts

The CCA Nitrogen Specialty Training Program and Exam has had a significant impact on nitrogen management education and certification, strengthening the knowledge base and technical expertise of professionals responsible for guiding growers in regulatory compliance and best management practices. Over 200 participants engaged in the online course, including 130 CCAs who directly benefited from targeted nitrogen management training, and an additional 70+ agricultural professionals, UC advisors, and students, demonstrating the broader value of the course beyond its intended audience. The certification exam has further contributed to this impact, with 116 CCAs now certified, adding a critical workforce to support the implementation of data-driven nitrogen management strategies.

This program directly supports California's regulatory goals by increasing the number of trained professionals available to assist with nitrogen management planning and compliance reporting. Furthermore, the structured learning approach, integration of competency-based education, and rigorous exam validation process provide a model for future professional training programs, ensuring that CCAs are equipped with the skills necessary to drive sustainable nitrogen use and environmental stewardship in California agriculture.

Outreach Activities

Event 1: Nitrogen Training for Certified Crop Advisors

- Presentation Title: Nitrogen Training and Crop System Specialty
- Location and Date: Fresno, CA, March 3-4, 2020
- CCA/Grower Continuing Education Units (CEUs): 11.0
- Number of Participants: 65

Event 2: Western Region CCA Board Meeting

- Presentation Title: Update on CCA N Training Program
- Location and Date: Webinar, March 17, 2020
- Number of Participants: 10

Event 3: UC Nitrogen Course

- Presentation Title: UC Nitrogen Course
- Location and Date: Online (<http://ucanr.edu/nitrogencourse>) Fall 2020 to current
- CCA/Grower Continuing Education Units (CEUs): 12
- Number of Participants: 201

Event 4: FREP and ASA Annual Conferences 2021 and 2022

- Presentation Title: Nitrogen Management and CCAs
- Location and Date: San Luis Obispo and Salt Lake City
- Number of Participants: 100+

Event 5: WRCCA Educational Webinar Series

- Presentation Title: Nitrogen Management and CCAs
- Location and Date: Online webinar, November 30, 2021
- CCA/Grower Continuing Education Units (CEUs): 4
- Number of Participants: 22

Event 6: Fertilizer Research and Education Conference

- Presentation Title: Nitrogen Training Project Update
- Location and Date: Visalia, October 27th, 2022
- Number of Participants: 70

References

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Factsheet

Project title: Next Generation N Management Training for Certified Crop Advisors

FREP grant number: 19-0591

Project leaders: Sat Darshan Khalsa, University of California Davis

Erik Porse, California Institute for Water Resources

Marina Vergara, University of California Davis

Amanda Crump, University of California Davis

Time covered by the grant period: 2020-2024

Location: In-person CCA training held in Fresno, CA. Online training for statewide audience

County: Statewide

Highlights:

- This project developed a comprehensive online training course and a competency-based certification exam to assess knowledge and application of nitrogen management strategies.
- The low-cost, asynchronous training program covers seven key competency areas in nitrogen management:
 - Environmental impacts of nitrogen loss
 - Nitrogen cycling – soil transformations
 - Nitrogen uptake – plant utilization
 - Nitrogen sources
 - Nitrogen budgeting
 - Irrigation and nitrogen management
 - California cropping systems
- Over 200 participants engaged in the online course, including 130 CCAs who directly benefited from targeted nitrogen management training, and an additional 70+ agricultural professionals, UC advisors, and students, demonstrating the broader value of the course beyond its intended audience.

- The training course has expanded knowledge and training opportunities for CCAs and industry professionals, strengthened industry compliance with nitrogen management regulations and developed a sustainable certification process through the American Society of Agronomy.

Introduction: Use of nitrogen (N) fertilizer on major California crops has led to the degradation of water quality from nitrate leaching to groundwater. This outcome is the result of a combination of historic management practices including uniform rates of N fertilizer applied to land of heterogeneous soil types; poor timing, poor placement, or incorrect quantities of seasonal N applications; and irrigation in excess of crop water demand when abundant soil N is available. Where excess irrigation is applied when soil N concentrations exceed uptake capacity, N efficiency is reduced and leads to a greater risk of nitrate leaching. The overall goal of the CCA Nitrogen Specialty Training Program is to provide CCAs with advanced knowledge in nitrogen management to support growers in meeting regulatory requirements while optimizing nitrogen use efficiency, thereby improving both environmental quality and crop productivity.

Methods/Management: Our project consisted of distinct phases.

- *CCA workshop:* In March 2020, we hosted a CCA Training workshop in Fresno, CA attended by 65 CCAs following the 2-day agenda developed by our project team.
- *Learning objectives and curriculum development:* In early 2020, we completed the study curriculum including 1) consolidation of training modules and study materials already developed by our team; 2) drafting of exam question categories and outlining levels of difficulty; and 3) organization of workshop slides to be developed into video content.
- *Online course implementation and feedback:* Starting in 2020, adapting through 2022, and offering through 2024, we developed, implemented, and expanded an asynchronous, low-cost online training program for CCAs seeking the California Nitrogen Specialty (CA-NSp) certification. The project recruited content experts to record a total of 17 videos in 2020 and expanded the course to include a 'Barriers to Adoption' module in 2021. In addition to video lectures, each module included reflective prompts designed to help learners critically engage with the material and connect new knowledge with their existing understanding.
- *Specialty exam deployment:* The final version of the CCA Nitrogen Specialty Exam, which consisted of more than 60 questions, launched in October 2021. It was developed by a team of subject matter experts and has been validated using psychometric analysis.

Findings: The CCA Nitrogen Specialty Training Program and Exam has had a significant impact on nitrogen management education and certification, strengthening the knowledge base and technical expertise of professionals responsible for guiding growers in regulatory compliance and best management practices. The online course recruited 78 students in 2021, 64 students in 2022, 39 students in 2023, and 20 students in 2024.

From 2021 to 2024, a total of 138 CCAs took the CA N-Specialty exam, with 116 passing, resulting in an overall pass rate of 84%. While the number of test takers has

gradually declined each year, the pass rate has remained relatively stable, except for lower pass rates in 2022 and 2023 before rebounding in 2024. This pattern suggests that as the initial wave of CCAs seeking certification tapered off, those continuing to take the exam may have had varying levels of preparation or access to training resources.

To evaluate the effectiveness of the online course, we conducted a qualitative analysis of the reflective responses collected from five iterations of the online course. Preliminary findings suggest that most learners were highly satisfied with the course, reporting increased confidence in nitrogen management principles. In addition, a quantitative self-assessment, where students ranked their pre-course and post-course knowledge levels across each module topic, was also done to measure learning gains across the entire course. Overall, students reported a gain in knowledge scores between 20 and 30%. This evidence suggests that the online course delivers valuable knowledge gains for the targeted population.

While the exam remains financially sustainable, the online course requires support to continue operations. Future efforts will focus on maintaining the training program, refining exam content, and assessing ongoing industry demand.

Work Products

Nitrogen Specialty Exam Learning Objectives

Competency Area 1. Environmental Impacts of Nitrogen Loss

- A. Identify the impact of nonpoint source N pollution on human health
- B. Recognize sources of surface runoff and describe the effect on water quality
- C. Describe how N leaching influences groundwater and drinking water quality
- D. Understand the role of certified crop advisors in promoting efficient N use

Competency Area 2. Nitrogen Cycling - Soil Transformations

- A. Describe the process of mineralization including N sources and products, types of microbes and what factors affect mineralization rates like moisture, temperature, and C:N ratios
- B. Describe the process of immobilization including sources, energy requirements, types of products and impact of C:N ratios
- C. Explain the process of nitrification including the necessary reactants, products, types of microbes and how rates are impacted by temperature
- D. Explain the process of denitrification including reactants, products, and the effect of soil conditions like soil moisture and soil texture
- E. Define volatilization and how soil pH plays an important role along with what practices create significant losses

Competency Area 3. Nitrogen Uptake - Plant Utilization

- A. Compare the differences in root N uptake of ammonium and nitrate profile and understand uptake rates by plants at different growth stages

- B. Understand the process of assimilation of inorganic N into organic N compounds in plants
- C. Identify important times in the growing season for N uptake and utilization for annual and permanent crops

Competency Area 4. Nitrogen Sources

- A. Outline the contribution of various N sources to soil by different forms of fertilizers (organic/synthetic/foliar/controlled release/inhibitors)
- B. Identify organic matter amendments and crop residues and how their availability is impacted by C:N ratios
- C. Identify and calculate the availability of nitrate in irrigation water
- D. Describe the residual soil nitrate as a N source during crop rotations
- E. Recognize the contribution of soil organic matter as a source of N via mineralization

Competency Area 5. Nitrogen Budgeting

- A. Define different terminologies of N requirement, N uptake and N removal
- B. Understand how to account for N credits from irrigation water, residual nitrate and organic matter amendments
- C. Calculate the N sink and source terms to develop a balanced N budget
- D. Express the N removed over input ratio to determine crop N use efficiency using the partial nutrient balance method

Competency Area 6. Irrigation and Nitrogen Management

- A. Understand how irrigation practices can lead to N leaching below the root zone due to nitrate mobility in soils
- B. Identify efficient fertigation methods by surface and pressurized irrigation systems
- C. Identify the role of evapotranspiration in irrigation scheduling and how timing irrigation scheduling relative to fertigation can influence nitrate leaching
- D. Understand how the practice of leaching excess salt under saline or sodic conditions may increase the risk of N leaching below the root zone
- E. Determine how distribution uniformity by irrigation systems influences N use efficiency

Competency Area 7. California Cropping systems

- A. Describe how to minimize N losses during annual crop rotations and what factors to consider like residual soil nitrate, crop residues and rooting depth
- B. Discuss storage and remobilization of stored N in woody biomass of permanent crops and what role N storage plays in early season N demand

Qualitative Analysis

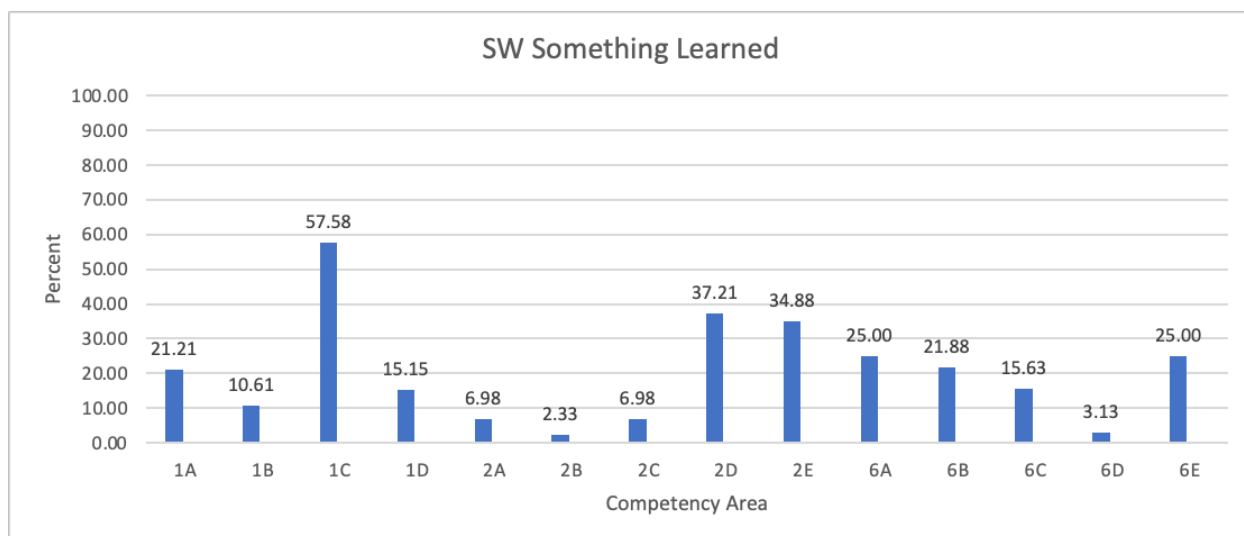


Figure 2. Percentage of student professionals identifying something learned for the soil and water (SW) modules/competency areas (1,2 and 6) and learning objectives (A-E). See additional information below to cross-reference the results.

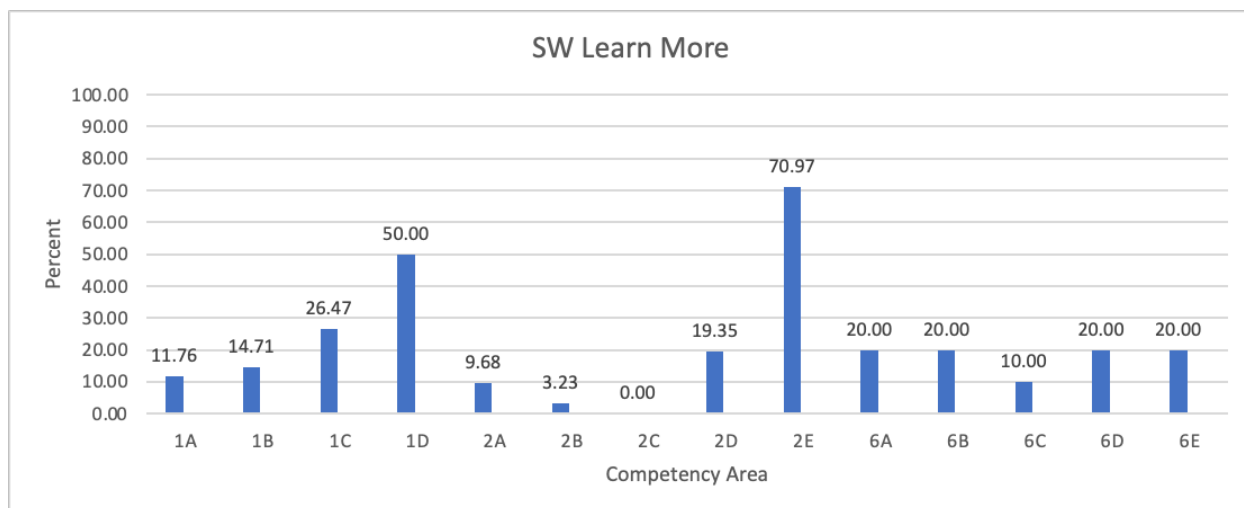


Figure 3. Percentage of student professionals identifying a desire to learn more for the soil and water (SW) modules/competency areas (1,2 and 6) and learning objectives (A-E). See additional information below to cross-reference the results.

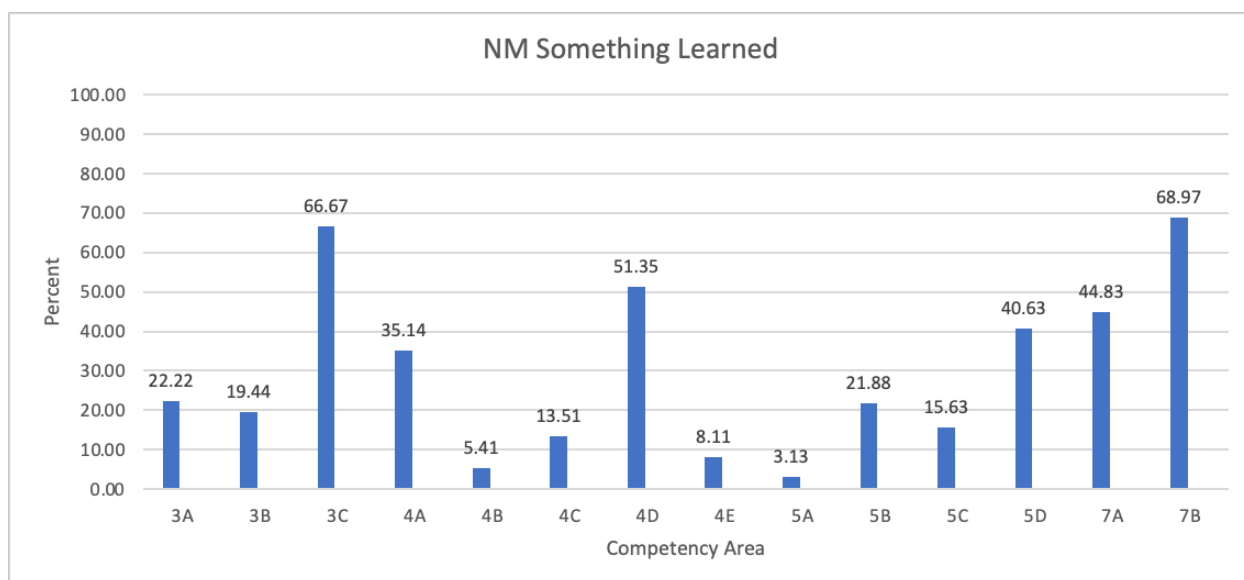


Figure 4. Percentage of student professionals identifying something learned for the nutrient management (NM) modules/competency areas (3, 4, 5 and 7) and learning objectives (A-E). See additional information below to cross-reference the results.

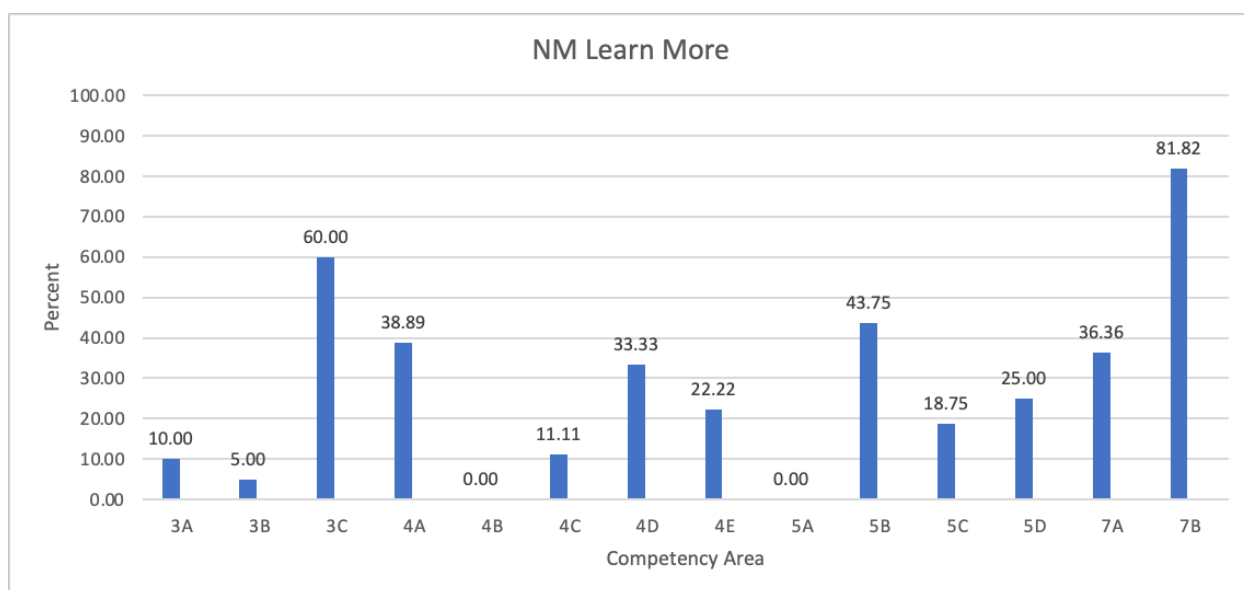


Figure 5. Percentage of student professionals identifying desire to learn more for the nutrient management (NM) modules/competency areas (3, 4, 5 and 7) and learning objectives (A-E). See additional information below to cross-reference the results.