Optimizing the Use of Groundwater Nitrogen (NO_3^-): Efficacy of the Pump and Fertilize Approach for Almond

Project No: **12-PREC6-Smart**

Project Leader: David R. Smart
Associate Professor
Department of Viticulture and Enology
UC Davis
One Shields Avenue
Davis, CA 95616
530.754.7143
drsmart@ucdavis.edu

Project Cooperators and Personnel:
Thomas Harter and Jan Hopmans, Dept of Land, Air & Water Resources, UC Davis
Patrick Brown and Francisco Valenzuela, Department of Plant Sciences, UC Davis
Christine Stockert and Matt Read, Dept of Viticulture and Enology UC Davis

Objectives:

The objectives being pursued under this project contribute to a multidisciplinary investigation funded by the California Department of Food and Agriculture (CDFA) Fertilizer Research and Education Program (FREP) that will answer a number of questions relevant to the “pump and fertilize” (P&F) approach to groundwater NO_3^- management. Pump and fertilize consists of the hypothesis that a unit mass of NO_3-N in groundwater is equivalent to a unit mass of properly managed synthetic N fertilizer. P&F has been projected to diminish leached NO_3^- while sustaining economic production to improve nitrogen use efficiency (NUE) of crops (Harter et al. 2012). The P&F approach will be contrasted with Advanced Grower Practice (AGP) that consists of 4 to 6 fertilizer N applications of 30 to 75 lbs N per acre and targeted to tree N demand. Further, there is a need for development of N monitoring technologies that are practical and provide real time feedback to growers as to the potential for NO_3^- leaching. For regulatory purposes data correlating grower practices with information on nitrate levels from long-term groundwater monitoring wells is needed to better be able to correlate practices with real impacts on ground water quality. The overall objectives being pursued under this agreement include:

1) Establish research and demonstration orchards for “Advanced Grower Practice” and “Pump and Fertilize” nitrogen management in pistachio and almond within “Hydrogeologically Vulnerable Areas” (HVAs).
2) Utilize and validate recent developments in yield and nutrient budget N management, early season sampling, and yield estimation to describe best management practices (BMPs) and contrast those practices with ‘Pump and Fertilize’ N management treatments.

3) Characterize key biological and physical parameters relevant to P&F concept (concentration dependent uptake, root distribution and activity, phenology of uptake, seasonal plant-soil N balance, soil NO_3^- movement, etc.).
4) Establish proof of concept for use of stable isotopes of $15NO_3^-$ in N tracing under P&F practices.
5) Develop and ground validate decision support models (including HYDRUS) to assist growers with optimal management of groundwater nitrogen (NO_3^-).
6) Demonstrate and proactively extend developed results, technologies relevant to on-site self-assessment and BMPs to growers.

Interpretive Summary of Work for 2012 - 2013:

The goals of this project are to test the pump and fertilize concept (P&F) as a realistic alternative/supplement to the use of synthetic fertilizers like CAN and UAN. Our primary objective during 2012-13 was to identify appropriate locations for the proposed experiments with a focus on finding knowledgeable and cooperative grower's orchards with modern and modifiable irrigation systems in a region of the Central Valley classified as a hydrogeologically vulnerable area (HVA: DWR, 2000). Appropriate sites consist of those with soil type and water table levels indicative of 'high risk' NO_3^- leaching scenarios. We were successful in this endeavor. Using ground water depth information taken from the California Department of Water Resources and Madera Irrigation District databases, candidate orchards were mapped onto satellite imagery and we were successful in establishing orchard sites for our proposed experiments. Soil pits were excavated at the candidate sites which were sampled and analyzed for soil texture to determine which orchards had relatively uniform particle size distribution (texture) and no horizons such as clay layers or hardpans that would impede the downward movement of water and, presumably, nitrate. For the two most likely candidate sites chosen, soil pits of 3 meter depth where excavated to determine rooting depth so that we could begin building instrumentation to suit each particular site. Consultation was done with all four of the Primary Investigators (PIs) during each step in order to assure that the sites would satisfy the demands of each element of the experimental design. We anticipate finishing construction of hardware (tensiometers and lysimeters) for intensive root zone and ground water monitoring during the next quarter.

Materials and Methods:

Work carried out during 2012-13 consisted of two comprehensive (2-week) tours and assessments of a region between the Madera Water Bank (North) and the San Joaquin River (South), the municipality of Madera (East) and the San Joaquin River (West). Bob Klein of the California Pistachio Research Board conducted one of these tours while Matt Andrew of ATB Growers in Madera conducted the second tour. ATB Growers is a cooperative that encompasses more than 2,100 acres of almond (and a lesser acreage of pistachio). Using ground water depth information taken from Department of Water Resource and Madera Irrigation District databases, we mapped onto satellite imagery gathered from ArcGIS and GoogleEarth databases. We established which orchards were likely candidates for experimental sites based on this preliminary survey, grower interviews, and interaction with stakeholders concerning the proposed objectives of the experiments.

The candidate sites were then sampled using a grid of bore holes of varying depths in order to determine which candidate orchards had relatively uniform sandy loam/loamy sand textures and no structures (such as clay layers or hardpans) that would impede the downward movement of water and, presumably, nitrate). An assessment of the position and size of the proposed orchards with respect to the groundwater monitoring objectives were also discussed among PIs. Over 230 borehole samples were analyzed for particle size distribution according to the hygrometer settling rate approach. Finally, two sites were chosen and 3, 3 meter deep soil pits where excavated to determine rooting depth, Ksat (saturated hydraulic conductivity), bulk density. and to review horizonation of the soil profiles so that we could begin building instrumentation to suit each particular site. One new graduate student in the Soils and Biogeochemistry Graduate Group and one in the Horticulture and Agronomy Graduate Group were recruited to participate in this exercise and conduct future research on the project. Consultation was done with all four of the Primary Investigators between each step in order to assure that the sites would satisfy the demands of each element of the experimental design.

Polyvinyl chloride (PVC) pipe, ceramic cups, tensiometer electronics, data loggers, pressure transducers and wiring were purchased, and an intensive review of instrumentation for intensively monitored tree root zones is now ongoing. The design of the tensiometers and lysimeters was reviewed and improved by Mr. Matt Read who is now overseeing or directly conducting construction of the apparatus needed for the proposed intensively monitored trees. The anticipated timeline of installation for the intensively monitored trees will be Fall 2013 and we are on schedule to meet that objective deadline.

Results and Discussion:

It was determined that the north-western orchards, outlined in red in the middle left side in **Figure 1** below, were situated in an area with too deep of a ground water table to be suitable for assessing movement of NO_3^- in water table monitoring. Other orchards closer to the Southern reach of the San Joaquin River were deemed to be more appropriate for the focus of the project (**Figure 1**). The selection of these sites underwent intensive scrutiny by all four PIs on the project. The conclusion was that ideal sites do not exist for monitoring potential leachable NO_3^- and to follow it through to first encounter with the ground water table. Nonetheless the demonstration of this hypothesis is critically important to stakeholders and regulatory organizations like the Central Valley Regional Water Board in moving forward with a program to develop best management practices for nitrogen fertilizer management and monitoring. The orchards we have selected for future P&F work, in our opinion, are the most suitable for this endeavor. For example we encountered no less that 50% sand content (e.g. very high infiltration capacity) and up to 91% sand content (HVA) in the candidate orchards selected for the project. Furthermore, the irrigation systems, size and numbers of rows in the individual orchards ensures the best chance for success in achieving the overarching goals of the project. One highly desirable aspect of the selected orchards is a grower community that is highly amenable to instituting the treatments needed to successfully test the proposed hypotheses (P&F) and assisting us in achieving those goals.

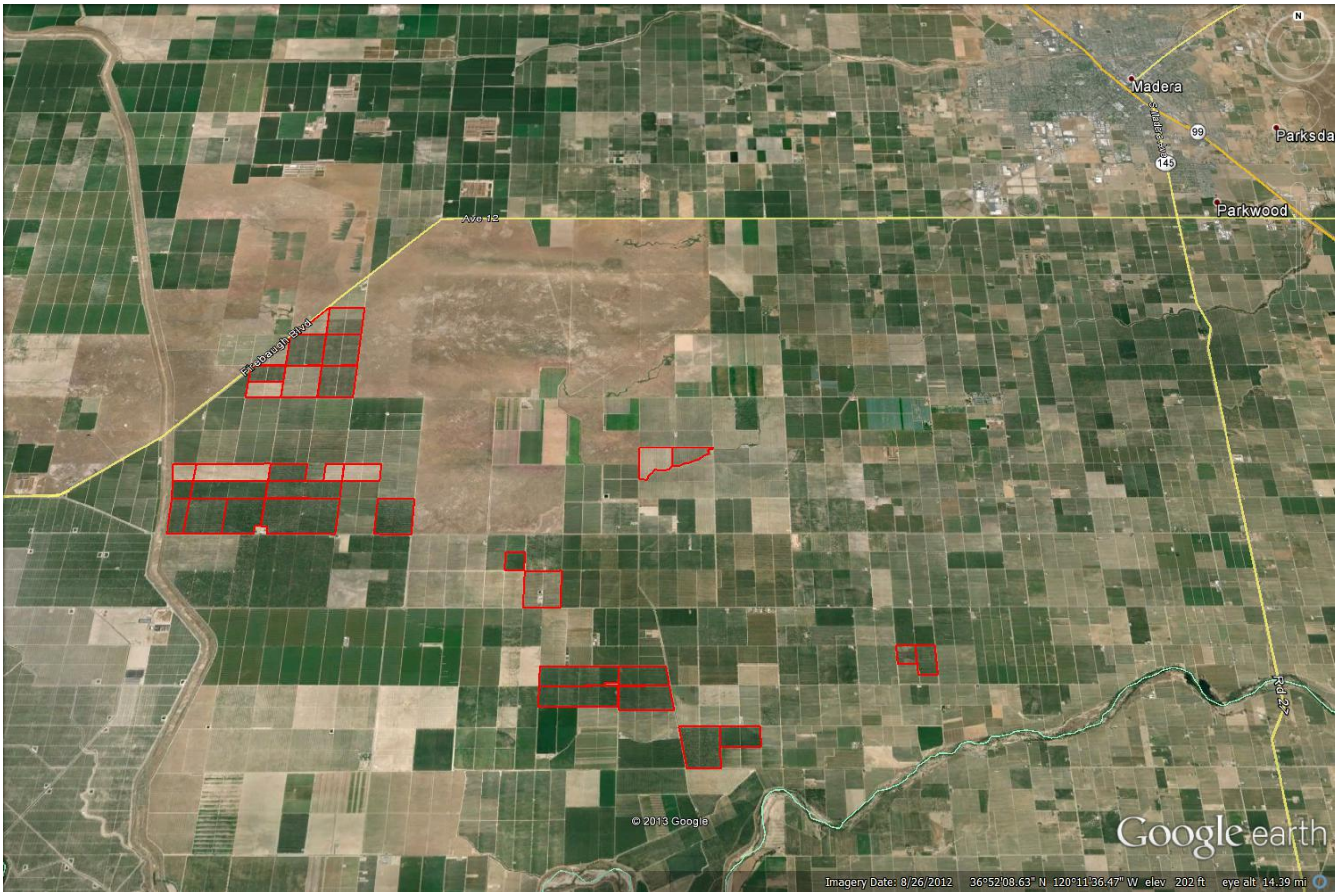

Figure 1: Available ATB Growers orchards reviewed for use in the project.

Department of Water Resources data on ground water levels are relative to sea level and thus, we made an extensive survey of Madera Irrigation District and well drilling companies to acquire a better estimate of depth to groundwater from orchard surface (**Figure 2**).

The two images of **Figure 2** show groundwater depth from surface. Some wells were omitted from the second image because it was determined that their depth was artificially influenced by lateral infiltration from the San Joaquin River. We later determined that this influence was significant and an important element to capture and define. As a result the plan for the Groundwater Monitoring Wells is being modified in an attempt to do this.

Focus was given to the orchards bordered in red in the lower panel of the images shown in **Figure 2**. Soil particle size distribution analysis (texture) was carried out for each site that appeared appropriate following intensive scrutiny. 170 soil samples were taken and analyzed, and nitrogen analysis was done on all available orchard well water to determine suitability for a P&F treatment. From this data the two sites shown in **Figure 4** were selected.

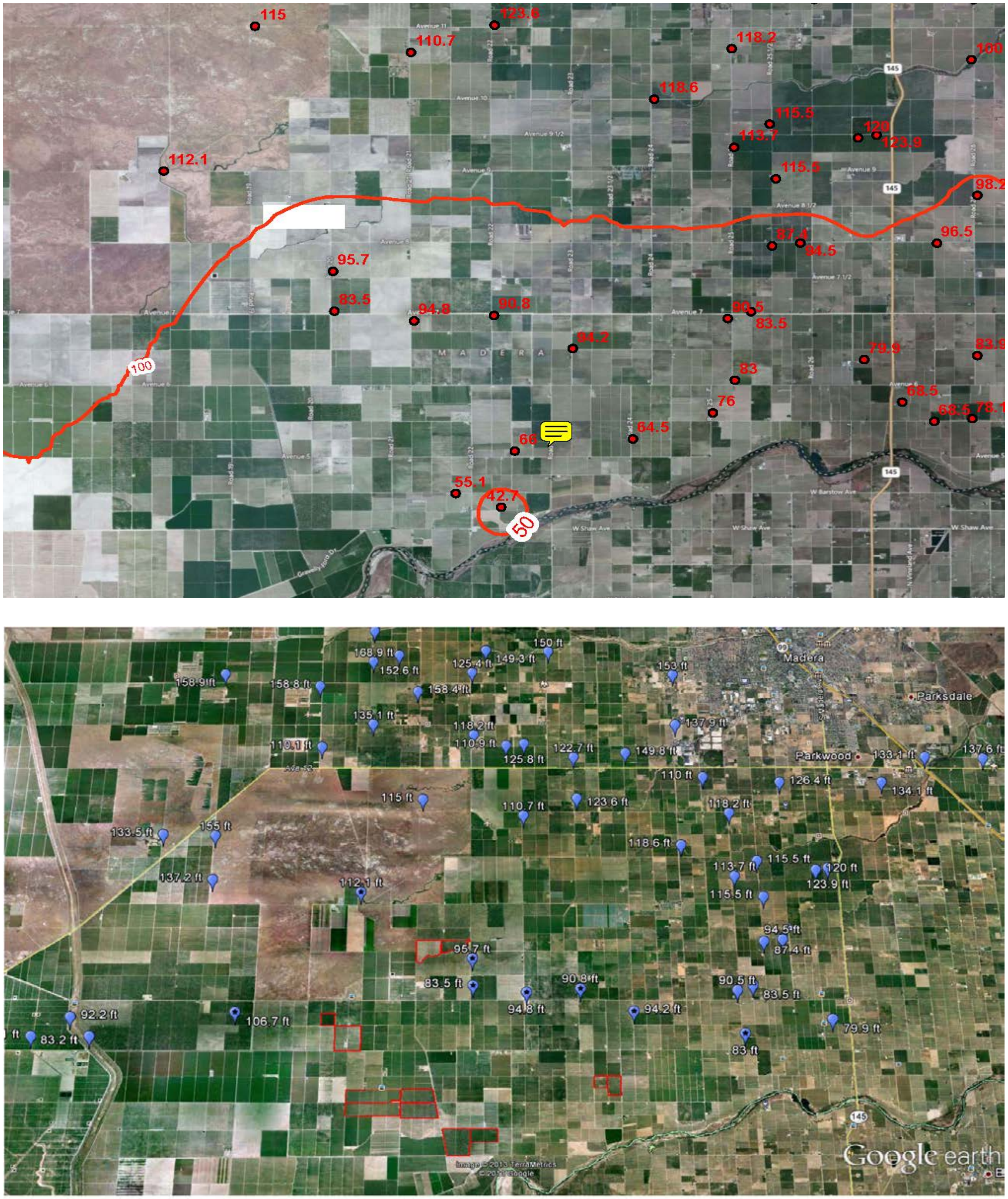

Figure 2: Surveyed groundwater depths for Madera Irrigation District (upper panel) and California Department of Water Resources (lower panel).

Shown in **Figure 3** (left panel) is an example of a soil pit excavated during July 2013 in order to determine horizonation, location of potential water or solution impeding horizons, Ksat, bulk density and other soil chemical and physical analyses relevant to future understanding of water (and NO_3^-) movement through the vadose zone.

Figure 3: Shown in the left panel is Ms. Nicole Niehues, MSc. student in the UC Davis Soils Biogeochemistry Graduate Group who is collecting horizon specific soil bulk density samples. In the right panel is an example of the lack of horizonation in a sandy loam soil in a pistachio orchard and roots on the wall profile that allow us to designate an appropriate root zone for future instrumentation of the site for intensive monitoring of water and NO_3^- solution movement through the vadose zone.

Figure 4: Selected sites highlighted in green for pistachio and yellow for almond for the experiments that will test the hypothesis of pump and fertilize versus advanced grower practice and high frequency low nitrogen fertigation. The sites are in an area S and SW of Madera that has highly sandy soils, high infiltration rates, and is in or adjacent to a designated hydrogeologically vulnerable area.

Sixty four of the texture samples from boreholes were acquired after review of the data by the principle PIs. Based on all of these samples and the soils pit observations, the combination of the two will determine rooting depth. More soil samples were taken from the wall of the pits using a cylinder collection procedure that will allow for analysis of saturated hydraulic conductivity and bulk soil density. Now that we have field location and rooting depth, we can begin to build the instrumentation for data collection. Installation of said instrument should begin around October 2013.

References Cited:

DWR (2000) Hydrogeologically Vulnerable Areas Map. Department of Water Resources (DWR) and US Geological Survey (USGS), California State Water Resources Control Boards, http://www.waterboards.ca.gov/gama/docs/hva_map_table.pdf.

Harter, T.H. and J. Lund et al. (2012) Addressing Nitrate in California's Drinking Water. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis, http://groundwaternitrate.ucdavis.edu.