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

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Introduction

The overarching objective of this project is to test the efficacy of the pump and fertilize approach to nitrogen (N) management in nut crops. The problem of N loss to water (and air) is currently one of the most important challenges to environmental sustainability for California agriculture. Nitrate (NO_3^-) is the primary contaminant of well waters and NO_3^- contamination of water is believed to be "overwhelmingly the result of crop and animal agricultural activities" (Harter et al. 2012), particularly the application of synthetic fertilizers to irrigated crops. In addition, nitrogen fertilizer applications result in emissions from soils of nitrous oxide (N_2O), a greenhouse gas 300 times more potent than CO_2 and that can offset greenhouse gas mitigation by photosynthetic CO_2 assimilation by perennial crops.

In order to assist growers and agencies in understanding this problem and its mitigation will require multi-disciplinary approaches. Information is needed to inform and satisfy impending regulatory demands and to provide growers with improved management tools. Nitrate present in groundwater (GWN) is a potential source of N for crop use, and can potentially reduce fertilizer costs to growers, reduce N concentrations in irrigation water and hence reduce N loading to the environment.

The overall goal of this project is to examine, and provide demonstration sites to optimize understanding of the utility of the 'pump and fertilize' (P&F) approach for integrated N management in Almonds and Pistachio. It basically tests the hypothesis, in a vertically integrated, multidisciplinary project if a unit of N in ground water is functionally equivalent to a unit of synthetic N fertilizer applied to these systems.

Table 1. Examples of Potential N at Various Contamination Levels

NO_3-N in Groundwater	NO_3-N /acre @ 3 ac/ft/yr
1.0 mg/L	8.1 lbs.
5.0 mg/L	40.7 lbs.
10 mg/L	81 lbs.

Methodology

Each experimental block contains three treatments; AGP, P&F, and HFLC (described below and shown in Fig. 2). Each replication of each treatment will have one tree that will have instrumentation (also shown in Fig. 2) to intensively monitor the root zone.

AGP (Advanced Grower Practice) - AGP uses the most current protocol (ABC Nutrient Management Module 2010) for applying fertilizer, except that it does not correct for groundwater nitrate. In order to calculate the N budget for the year, preliminary estimates for the predicted yield will be determined based on historical trends and experience. The first application (20% of total budget) will be applied in March. In April, a leaf and visual analysis will be conducted to adjust the preliminary estimate and this new information will be used to adjust remainder of the year's fertilization. 68 lbs of N will be applied for each 1000 lb kernel of estimated yield. The fertilizer budget is split across 4-5 applications; 20% in late March, 30% April/May, 30% June/July, 20% Aug/Sept.

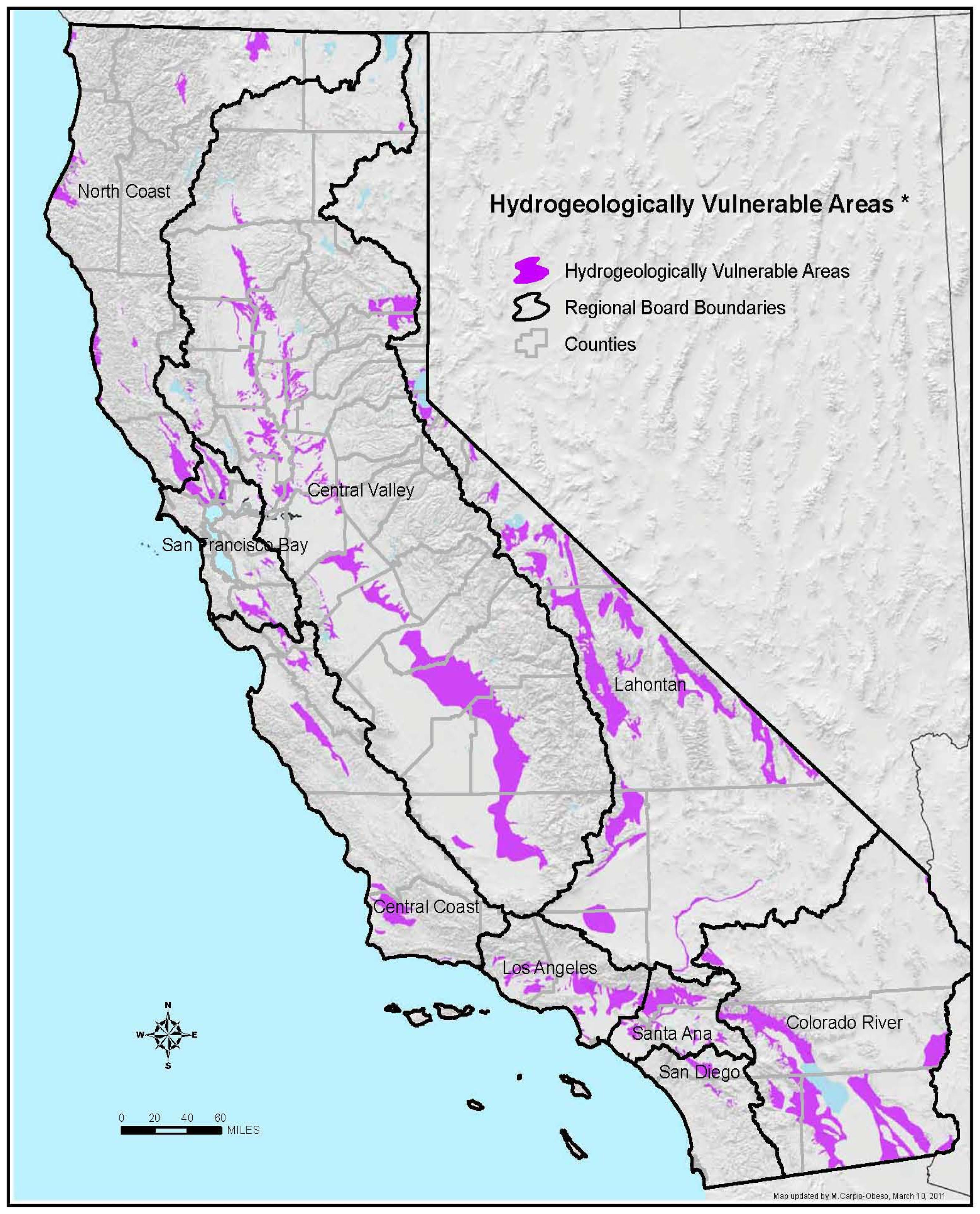
P&F - This treatment is called Pump and Fertilize because it acknowledges that each irrigation from a well with a nitrate load is actually delivering a small amount of fertilizer. P&F will be similar to AGP except the N budget will subtract 70% of the groundwater nitrate load from the total. For example, if a well has 8 ppm N nitrate and you irrigate about 3 ac/ft per season, then the well's contribution is about 65 lbs N nitrate. If the normal N budget is about 200 lbs then the P&F treatment will get 155 lbs of additional N from UAN32 since the balance is (theoretically) provided by the well.

HFLC - High Frequency Low Concentration is sometimes called 'Spoon-feed'. The total AGP N budget will be spread out over approximately 20 fertigations. This will be accomplished by installing a micro-injector to each drip line per treatment and filling them before each irrigation.

At the end of each season crop weights will be collected and compared.

Isotopic information will be gathered from different sources and different stages, looking for distinguishing fingerprints.

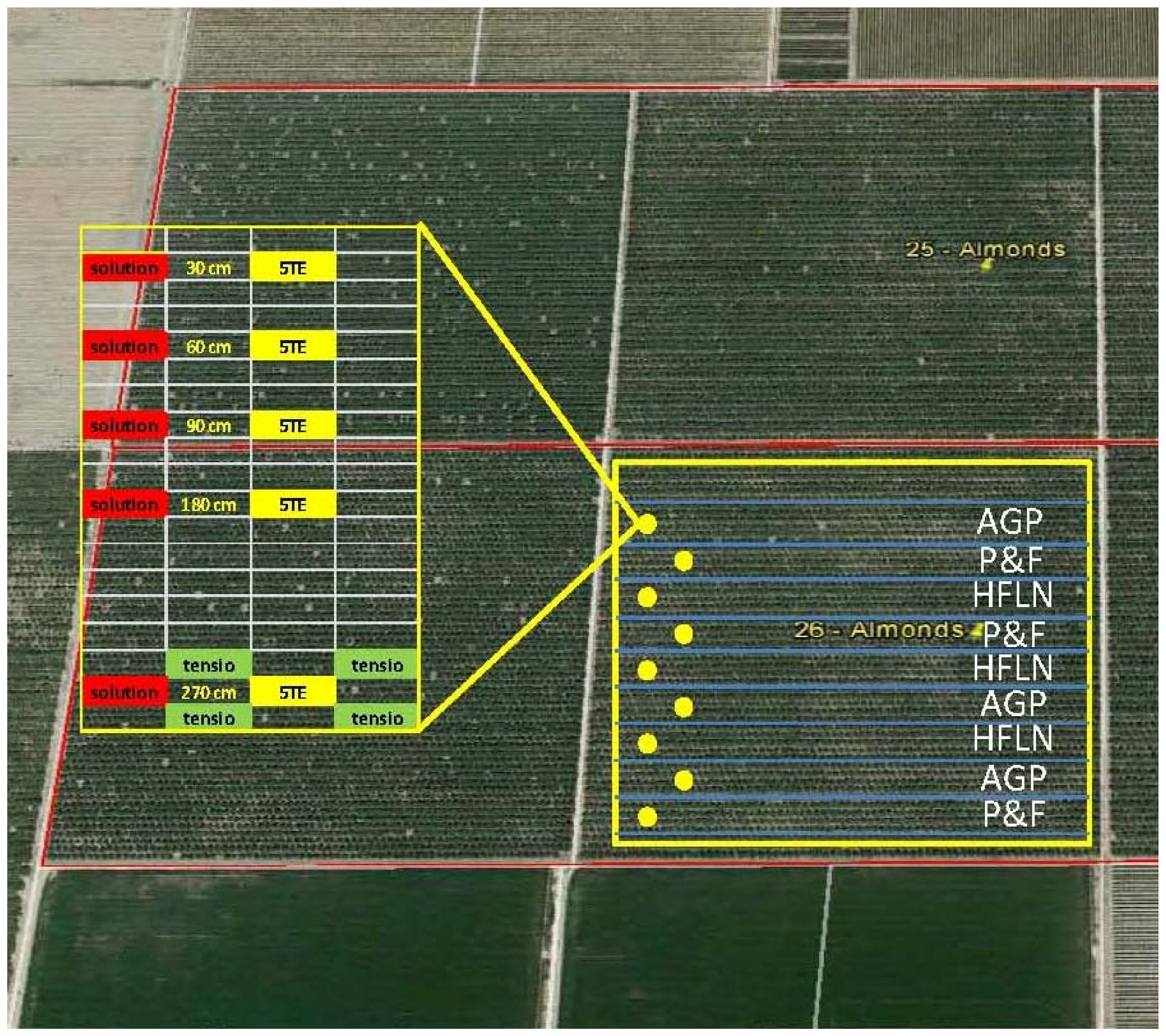
Fig 1. Map of Hydrogeologically Vulverable Areas of California



* Hydrogeologically Vulnerable Areas are where published studies show geologic conditions are more likely to allow surface contaminants to move to groundwater through percolation; for example: areas without an aquitard. Vulnerable areas not mapped, due to their extensiveness, are fractured rock where contaminants can move directly to water.

Water Boards

Fig. 2 The Three Treatments – AGP (Advanced Grower practices), P&F (Pump and Fertilize), and HFLN (High Frequency Low Concentration). Each replication will have an intensivly monitored area that will track water and nitrate as it moves from the surface through the root zone.



Objectives

1) Establish research and demonstration orchards for pump and fertilize (P&F) approach to N management in Almond and Pistachio within 'hydrogeologically vulnerable areas' (HVAs) and contrast with advanced grower practices.

2) Utilize and validate recent developments in yield and nutrient budget N management, early season sampling and yield estimation to describe best management practices and develop metrics for those practices with P&F N management treatments.

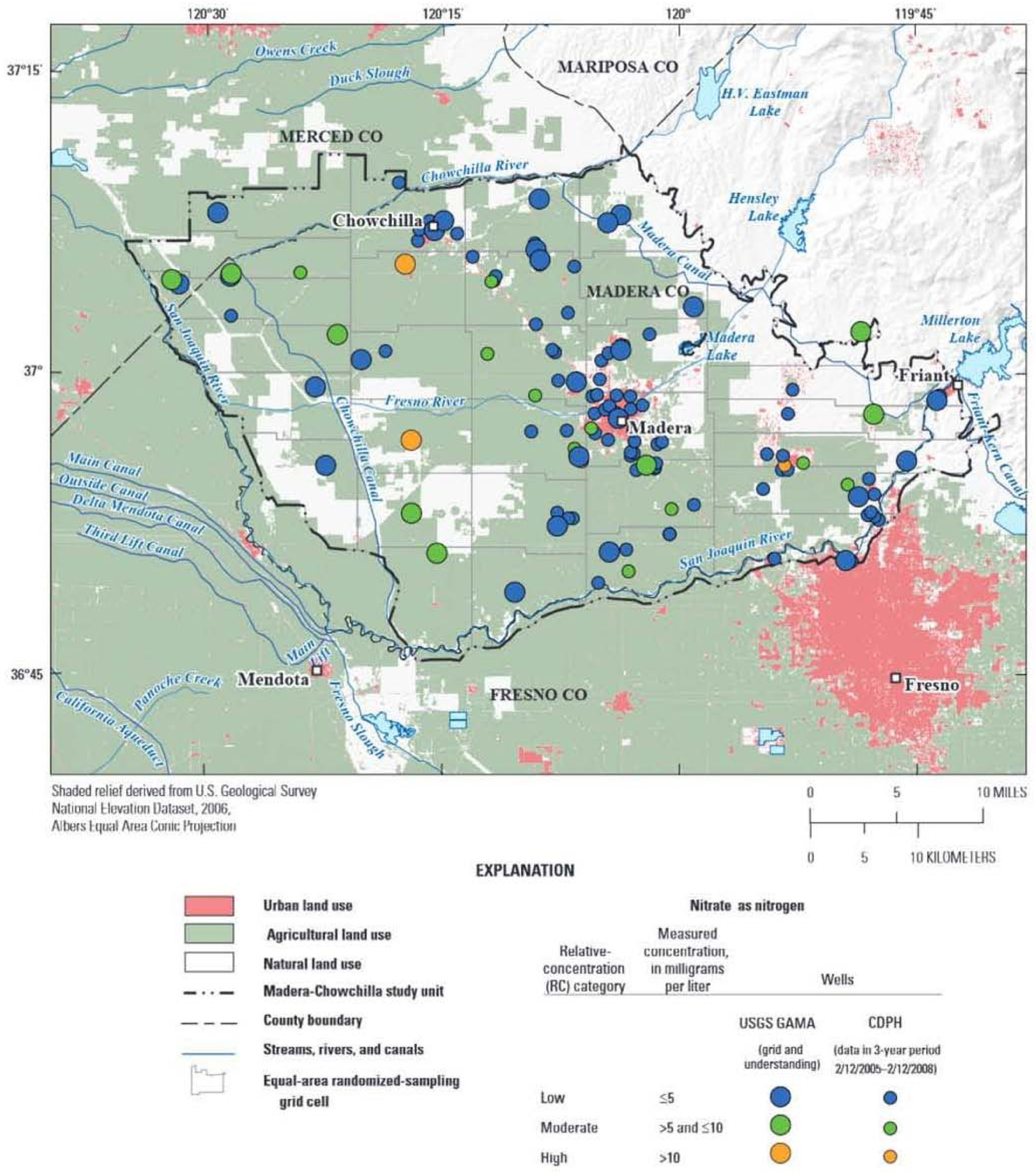
3) Characterize key biological and physical parameters relevant to the P&F concept (seasonal plant-soil N balance, soil NO_3- and water movement).

4) Establish proof of concept for use of stable isotopes of $^{15}NO_3$- in N tracing under P&F practices.

5) Develop and ground verify decision support models (including HYDRUS) to assist growers with optimal management of groundwater nitrogen.

6) Demonstrate and proactively extend developed results, technologies and BMP's to growers.

Figure 3. Concentrations of nitrate, as nitrogen, in USGS-GAMA wells and CDPH wells February 12, 2005–February 12, 2008.



Significance and Implications of Research

- Substituting conventional fertilizer N with existing nitrogen (nitrate) in groundwater will reduce the yearly cost of fertilizer by up to one third.
- Growers in heavily nitrate contaminated areas will be repositioned as nitrate reducers instead of nitrate contributors.
- The comparison of different management options provides growers with choices to farm in a quantitatively sustainable way leading to opportunities for incentives and cross-comparison.

References

1. Harter T, Lund J. 2012. Addressing Nitrate in California's Drinking Water: Executive Summary and Technical Report 1. California State Water Resources Control Board Report.
2. Status and Understanding of Groundwater Quality in the Madera-Chowchilla Study Unit, 2008: California GAMA Priority Basin Project
3. State Water Board response to Executive Order D-5-99. 2000. Map and metadata derived from DWR and USGS.
4. Isotope Tracers in Catchment Hydrology (1998), C. Kendall and J. J. McDonnell (Eds.) Elsevier Science B.V., Amsterdam. pp. 611-646.
5. Smart DR, MM Alsina, MW Wolff, MG Matiasek, DL Schellenberg, JP Edstrom, PH Brown, KM Scow, 2011. N_2O Emissions and Water Management in California Perennial Crops. Understanding Greenhouse Gas Emissions from Agricultural Management. American Chemical Society, pp. 227-255.