california almonds
Almond Board of California

Request for Proposals (RFP)
Supplemental File I Irrigation

ALMOND BOARD IRRIGATION STRATEGY

INTRODUCTION

The Almond Board of California (ABC) began funding research in irrigation in the early 1970s, leading to the adoption of microirrigation instead of flood irrigation. Research in this area accelerated since 2010 recognizing that CA water is a limited, and vital resource for almond production, along with newer technologies to manage irrigation. The Irrigation Improvement Continuum Program launched in 2017 is based on learnings from the research as well as experience of farm advisors and specialists. Nowadays, this program provides online resources as well as a comprehensive manual that helps growers improve the efficiency of water resource management. In the last 5 years the ABC has invested almost four million dollars in irrigation research, encompassing 21 projects, of which 8 are ongoing.

Together with the work of extension specialists, researchers and institutions, the ABC Irrigation Continuum has moved our industry forward toward sustainable water management. The Irrigation Continuum manual has been widely distributed throughout our industry and its impact is continuously tracked through our California Almond Sustainability Program (CASP).

Building on this foundation and facing implications of the Sustainable Ground Management Act (SGMA), the Board of Directors defined a new industry goal for water use efficiency by 2025 to "**Reduce the amount of water used to grow a pound of almonds by 20%**". The baseline to achieve this goal will be the average of water applied over yield in crop years 2015, 2016 and 2017. Aligned with this goal, the ABC strategic research advisory committee brought forward the vision of "**Targeting irrigation and nutrient application through automated monitoring and delivery, ideally at the individual tree level**".

Looking at the roadmap to achieving this vison and goal, it is instructive to examine current industry irrigation practice as measured by CASP (Table 1). This data provides valuable insights and areas for improvement.

Table 1. How irrigation decisions are made by our growers (2019 CASP data).

How irrigation decisions are made by our growers	Percentage of adoption (%)
ETc Based Scheduling	75%
Water District Influenced Schedule	23%
Deficit Irrigation Used at Hull Split	76%
Remotely Read Soil Moisture Sensors	61%
Manually Read Soil Moisture Sensors	59%
Pressure Chamber Used	31%
Pressure Chamber to Determine First Irrigation	20%
Use Flow Meters	43%
Growers Estimate Water Use	57%
Hand Feel Method Used to Determine Moisture	89%
Use Soil Auger to Check Moisture:	49%

Based on this data and in discussions with our Irrigation, Nutrients, and Soil Health Workgroup members, among the principal irrigation gaps and needs of our growers as follows:

- Future work in irrigation should address the fact that **irrigation decisions are significantly influenced by the water district scheduling** and not only by what is best from a horticultural point of view. Specifically, water district influence on the irrigation scheduling is two-fold. First, the water district may place chronological limitations and intervals on growers using surface flood irrigation. Second, the water district may limit the duration or interval periods of irrigation in surface supplied districts that have converted to low volume drip or micro systems because of shared pipelines or ditches with neighboring fields. This limits the flexibility of scheduling crop use-based timings or can affect variable fertility application feasibility.
- **Utility companies compel growers to schedule irrigations around off-peak times for economic reasons**. This can strain the ability to meet water demands during the hottest periods of the year (summer months) which have higher water requirements than other times in the growing season.
- Growers would benefit from having better **recommendations on when to start irrigating early in spring and when to end irrigating by the end of the growing season**.
- The low adoption of the pressure chamber illustrates the **need for more user-friendly devices that could provide plant water status data.**
- Continued outreach efforts in all the areas are important to expand adoption, particularly **enhancing the level of outreach in the use and benefits of flow meters**.

The rapid advancement of commercial precision farming technology, when paired with an understanding of almond tree growth and the drivers of yield developed from years of ABC-funded research, offer new solutions to address these grower needs. Smart irrigation management will consist of a combination of hardware and software that will allow almond growers to make precision irrigation decisions ideally down to the individual tree level. To achieve this vision, the ABC can play a catalytic role, connecting the expertise we have supported through public sector research and extension with the growing arena of commercial technology innovation. Here we outline the priority areas for ABC-funded research to deliver new solutions that will keep California a global leader in sustainable almond production.

ACTUAL ET

A key component of improving the precision of irrigation management is better measuring almond tree water demand. Potential crop evapotranspiration (ETc) is the most commonly used standard for measuring the water needs of the tree. CASP data shows good adoption of this method, pointing out that 75% of our growers use ETc to calculate how much to irrigate. Use of ETc to make irrigation decisions is backed by the California Irrigation Management Information System (CIMIS), which provides a complete network throughout CA to measure the reference ET, used in calculating ETc. In addition, higher adoption of meteorological stations in orchards in the 2000s allowed for even more precise reference values. Further, the ABC has funded years of research to provide more precise crop coefficient values also used to calculate ETc.

While ETc is the widely adopted standard, this technique can lead to potential errors given the use of reference values instead of on-site values. The development of technology that directly measures the evapotranspiration of almond orchards (Actual ET) will improve precision. Until recently, calculating actual ET in almond orchards was only possible by using advanced and expensive research equipment (Eddy Covariance Flux Towers). Around 2013, new commercial technology became available and has seen growing adoption in our industry. The technology, based on the surface renewal approach, was validated for grapes by UC Davis and USDA researchers. By the end of the 2020 crop season, ABC-funded research will validate and optimize this technology in almonds, providing growers a reliable method to measure the actual ET of their orchards.

Tree Physiology & Pomology

To date almond water production function studies have focused on how yield is affected by the percent of potential crop evapotranspiration (ETc). The conclusions of these studies are quite clear: less water than ETc= less yield. However, we believe that this question should be analyzed from a different perspective, where irrigation decisions are driven by yield forecasting at the beginning of the season.

In the last decade our understanding of almond photosynthesis, tree modeling, and how this translates into the amount of energy (i.e. carbohydrates) needed to produce kernels has greatly improved. Building from this body of knowledge, we envision that our ability to forecast yields at the orchard level early in the season will continue to improve. With all this in mind, we would like to further explore the following tree physiology question:

> Should the amount of water applied during the season be the same for an orchard that will produce 4,000 lbs/acre versus an orchard that will produce 2,000 lb/acre if both orchards have a similar canopy size? In other words, why would two otherwise identical orchards need the same amount of water if one orchard is expected to produce 2,000 lb/acre and the other orchard is expected to produce 4,000 lb/acre? We could further suppose that the expected yield difference is due to factors that are not necessarily connected irrigation management. Among those factors classic horticultural examples are:
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> - Strong spatial variability of soils across management units.
> - Varietal variability where the genetic and phenotyping differences between the variety and the pollinizer could create significant yield variability by rows.
> - Poor fruit set due to frost events, low bee hours, reduced number of beehives per acre, boron deficiency, inadequate pest and disease management, etc.

We believe that there is room for water saving in this area from an economic perspective as well as from a tree physiology point of view. We are interested in finding the breaking point between tree water demand and the tree energy needed to support predicted yield early in the season. We envision that the results in this area will provide the means to make decisions on how much to irrigate given a certain crop load and thus translate into water saving capabilities. We would like to further explore this question from a physiological point of view in terms of how water use is driven by yield, without reducing the yield potential defined at fruit set, nor affecting the quality of almond buds for the subsequent season.

REMOTE SENSING TECHNOLOGY

Commercial remote sensing technology in evolving quickly. The accuracy and resolution is reaching down to the individual tree level. Moreover, the speed and complexity of the analytics are improving as companies better integrate engineering with crop expertise. ABC will prioritize catalytic research that enables or demonstrates the use of commercial technology for almonds in the following areas:

- **Satellite or Aerial Measurement of Actual ET:** Even though this concept might sound futuristic, it is not as far from reality as it sounds. Models to calculate actual ET from satellite data already exist for ecological systems and are in the process of validation in grapes. We are interested in research to validate this for almonds, with the more complex canopy and with two or three varieties per irrigation unit.
- **Early tree yield estimation or proxies at the tree level resolution:** The ability to estimate individual tree yield early in the season would produce an important milestone for ABC on multiple fronts, such as irrigation and nutrient use efficiency, and industry forecasting, among others. We believe that remote technology and machine learning approaches that include ground data could improve our ability to forecast almond yield.

ORCHARD SPATIAL VARIABILITY

Over the last two decades irrigation system performance has improved through providing water and nutrients uniformly across the orchard. The next level of advancement in precision will come from being able to account for the variable soils and situations across the orchard that impact the trees' water and nutrient needs. While irrigation technology companies have commercialized variable rate irrigation systems, achieving more precise spatial variability requires research on:

- To identify, standardize, and validate useful and consistent methods to measure spatial variability.
- To analyze the economic Return on Investment (ROI) of irrigating at different resolutions (i.e. at the tree level versus at the block level), accounting for the increased cost associated with additional equipment needed to achieve variability.

TREE SENSORS

In the 1990s researchers from the University of California demonstrated that stem water potential readings as a measurement of plant water status were a useful indicator to define irrigation decisions. This led to the promotion of the use of the pressure chamber as a basis for irrigation management in almonds for more than two decades. However, CASP data confirms that the adoption of this method remains low despite those outreach efforts. We attribute the low adoption of this tool to constraints with the labor, technical training required to run this equipment, and the limited timing within a day to assess midday stem water potential particularly as in larger orchards.

In recent years, new startups and irrigation companies have developed sensors that might measure stem water potential in a more user-friendly way than the pressure pressure chamber. However, it remains to be evaluated if such sensors show sensitive responses to different irrigation treatments.

In the era of tree sensors, ABC has invested significant resources to develop new sensors with UC researchers. Specifically, ABC funded initiatives resulting in the development of a leaf tree sensor and recently on the development of thermal imaging from smartphones. Yet, the leaf sensor still presents challenges and low adoption in our industry, while the latest results from the thermal imaging project have shown this concept is not viable for our current growing conditions. Given our experience in sensor development in our research program and the multiple steps needed to achieve marketability and sustainability, we would like to focus our efforts in the evaluation of current sensor products instead of the development of new tree sensors. Studies that provide third party evaluation & validation in this area are highly needed. There is an opportunity to automatize this technology and develop useful data to define when to irrigate that we find worth exploring.

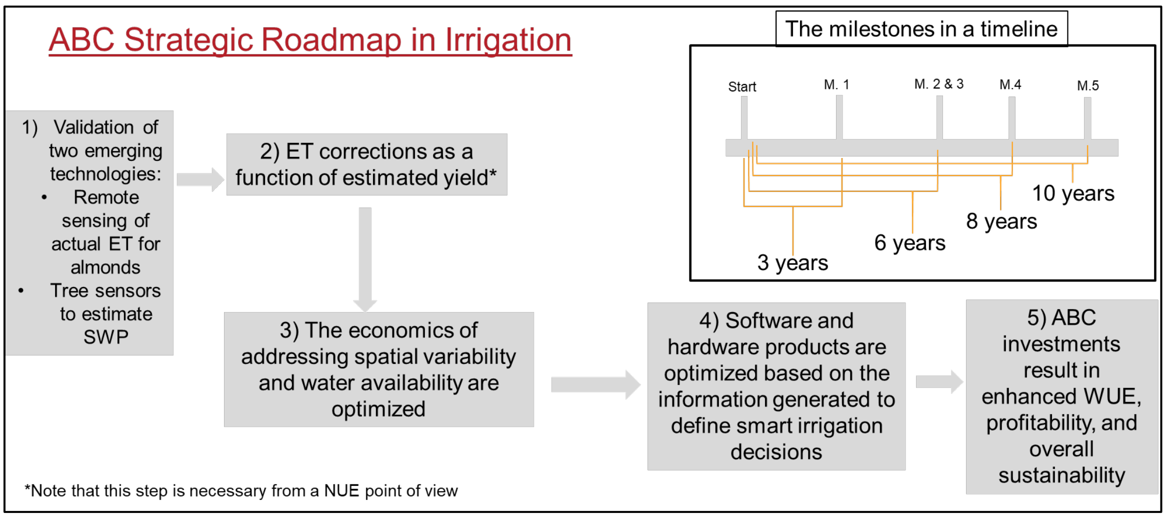
We did not observe research needs in soil sensors. We think that there is a broad range of sensors in this area that our growers can choose from. We find these instruments valuable and we believe that they help to answer the question “when and how much to irrigate?”. We have observed that most of the soil sensors available in the market provide reliable data and there is no apparent need for third party evaluation and validation at this point. However, we recommend that the companies working in this area focus on providing better data integration and data visualization to our growers. There is a need for better data standardization and implementation. For example, sometimes our growers may have multiple fields serviced by different manufacturers and the greatest confusion we observe from growers is deciphering the numbers depending on whether they were generated from a Neutron probe, tensiometer, Watermark, capacitance probe, die-electric sensor, etc. It is difficult to relate one unit to another with charts or tables using y-axis values such as volumetric water content, soil tension, % moisture, bars or kilopascals. Some type of standardization or standardized correlation to crop water use would be helpful.

Integrated Irrigation Decision Support

As we have outlined here, advancements in commercial technology will be at the core of improvements in irrigation efficiency. The role of the ABC is to catalyze the application and adoption of the technologies for almonds. In addition to the research outlined above, additional approaches we will use to bridge the deep understanding of almond production in public research and extension experts and that of commercial technology developers include:

- Promote the development of application program interfaces (API) to allow multiple hardware and software technologies to integrate.
- Develop a standard glossary for almonds for key variables, units and technical terminology from identified by public research with data generated by or inputted into commercial hardware and software technology.
- Support third party testing, validation and demonstration of commercial precision irrigation technology to increase grower confidence in the adoption.

Figure 1 below summarizes our long-term portfolio view and illustrates the framework to develop our smart irrigation model. To establish this framework, we will first validate remote sensing technology to calculate actual ET and stem water potential sensors. Second, we will establish the algorithms to support actual ET as a function of estimated yields. Third, we will optimize the benefit of applying variable rate irrigation given orchard-spatial-variability, return on investment, and water availability. Fourth, we will collaborate with initiatives that assemble a decision support system and translate it to the orchard irrigation system. We will implement this strategy as the core of our future irrigation portfolio by funding the priorities listed in this document and working in collaboration with the other perennial cropping systems.



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