# Optimization of Water Use and Nitrate Use for Almonds under Micro-Irrigation

Department of Land, Air and Water Resources, University of California, Davis

Jan W Hopmans[1], Maziar M Kandelous[1], Andres Olivos[2], Blaine R. Hanson[1] and Patrick Brown[2]
[1]Department of Land, Air, Water Resources, University of California, Davis, CA, 95616, USA
[2]Department of Plant Science, University of California, Davis, CA, 95616, USA

california almonds — Almond Board of California

## Background

This study was funded to monitor soil water and nitrate movement for 2 micro irrigation systems (Drip and Fanjet). We will determine soil physical properties and almond tree root distribution, and simulate soil water movement and nitrate transport and root water/nitrate uptake. System design parameters will be optimized to minimize nitrate leaching

## Objectives

- Collect a full range of data, from both ongoing field tests and other sources, as inputs for evaluating the computer-based HYDRUS-2D simulation model as an optimization tool applicable to almond research and management.
- Evaluate and test the HYDRUS-2D model, using field data from existing fertigation trials.
- Use the HYDRUS-2D model as a system-design and event-scheduling tool to establish irrigation/fertigation guidelines for use by the growers.

## Irrigation system

Two irrigation systems, Drip and Fanjet, will be evaluated, to assess water application system on water and nitrate application efficiency and root water/nitrate uptake. For each irrigation system one tree was selected for detailed instrumentation for the purpose of real-time monitoring of soil – water status.

| Fan Jet | Clay (%) | Silt (%) | Sand (%) | Depth (cm) | Sand (%) | Silt (%) | Clay (%) | Drip |
|---|---|---|---|---|---|---|---|---|
| Sandy clay loam | 21 | 18 | 61 | 10 | 73 | 12 | 15 | Sandy loam |
| | | | | 20 | | | | |
| | | | | 30 | | | | |
| | 27 | 26 | 47 | 40 | 75 | 13 | 12 | |
| | | | | 50 | | | | |
| | | | | 60 | | | | |
| | 21 | 26 | 53 | 70 | 72 | 15 | 13 | |
| | | | | 80 | | | | |
| | | | | 90 | | | | |
| Loam | 28 | 27 | 45 | 100 | | | | |
| | | | | 110 | 37 | 32 | 31 | Clay loam |
| | | | | 120 | | | | |
| Clay | 54 | 27 | 19 | 130 | 43 | 38 | 19 | loam |
| | | | | 140 | | | | |
| Sandy loam | 19 | 25 | 56 | 150 | | | | |
| | | | | 160 | 48 | 27 | 25 | Sandy clay loam |
| loam | 23 | 32 | 45 | 170 | | | | |
| Sandy loam | 14 | 12 | 74 | 180 | | | | |
| | | | | 190 | 21 | 37 | 42 | Clay |
| Silt clay | 44 | 47 | 6 | 200 | | | | |
| | | | | 210 | | | | |
| Clay loam | 29 | 37 | 34 | 220 | 37 | 29 | 34 | Clay loam |
| | | | | 230 | | | | |
| | | | | 240 | | | | |
| | | | | 250 | 62 | 19 | 19 | Sandy loam |
| | | | | 260 | | | | |
| | | | | 270 | | | | |

Fig. 1. A schematic of soil layers for both Drip and Fanjet plot and soil particles percentage for each layer.

## Soil Profile

The soil profile under both Drip and Fanjet system was analyzed for soil texture, bulk density and soil layering. Figure 1 shows represnetative soil layers and differences of soil profile between Drip and Fanjet.

## Soil water content and matric potential

A total of 34 5TE Echo sensors were installed for each tree in a 3 by 3 grid pattern at different depth to monitor temporal and spatial variations in soil water content, EC, and temperature within the rooting zone. In addition, we installed four MPS1 sensors around each tree , at the 30 and 70 cm depths, to monitor temporal changes in soil water matric potential in the root zone.


## Tree instrumentation

(X,Y) notation represents Cartesian coordinate system, with both X and Y, representing distances (cm) for the tree trunk. For example (0 150) denotes the location of a sensor which is 150 cm away from the tree along the Y direction. Figure 2 shows the sensor installation for both Drip and Fanjet irrigation system.

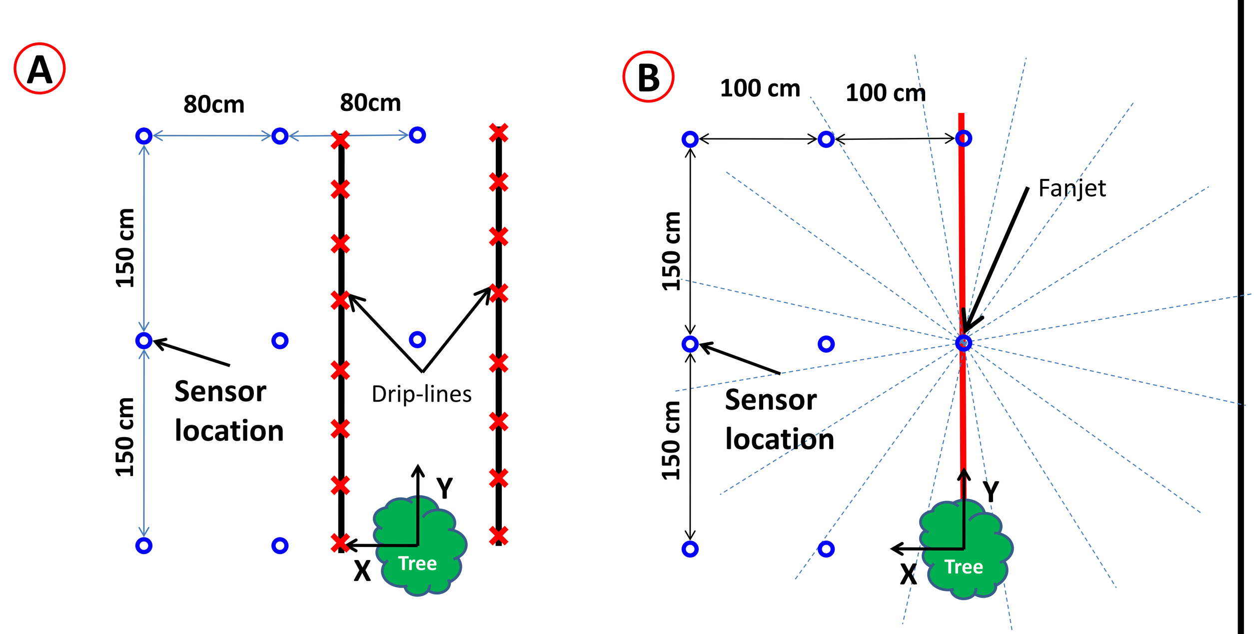



Fig. 2. A schematic top view of the installation of soil moisture sensors.

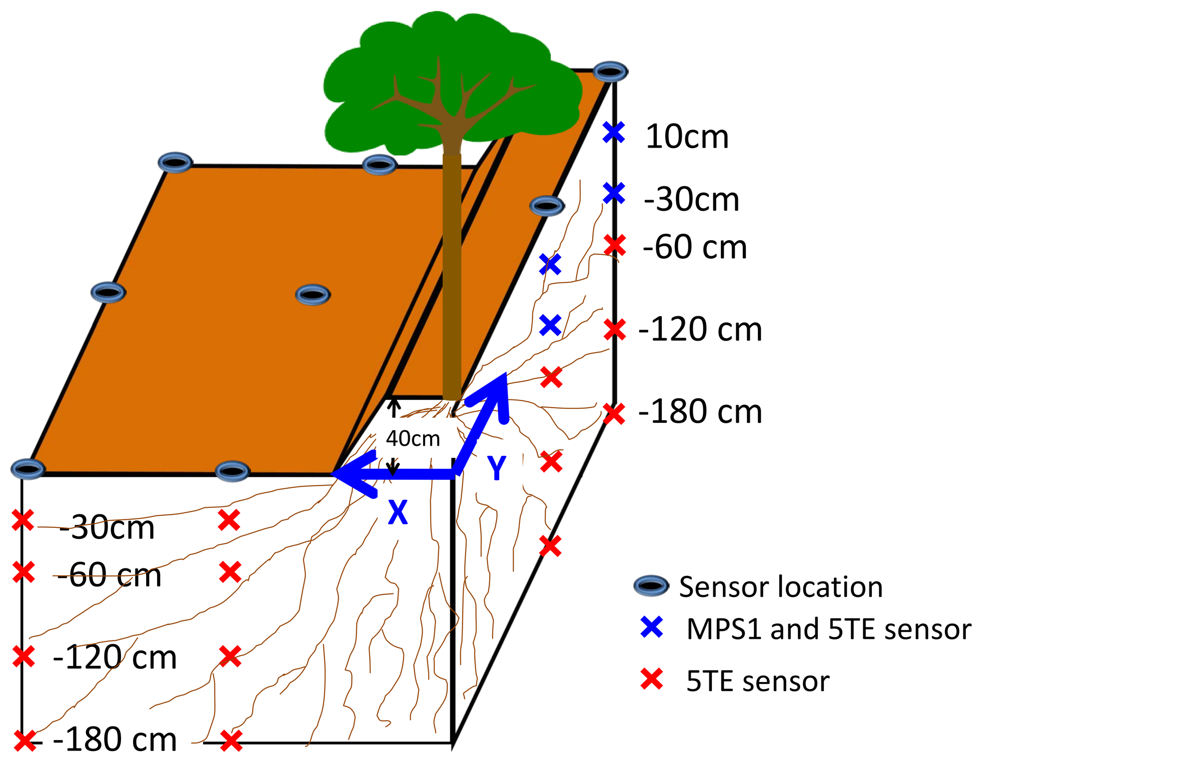


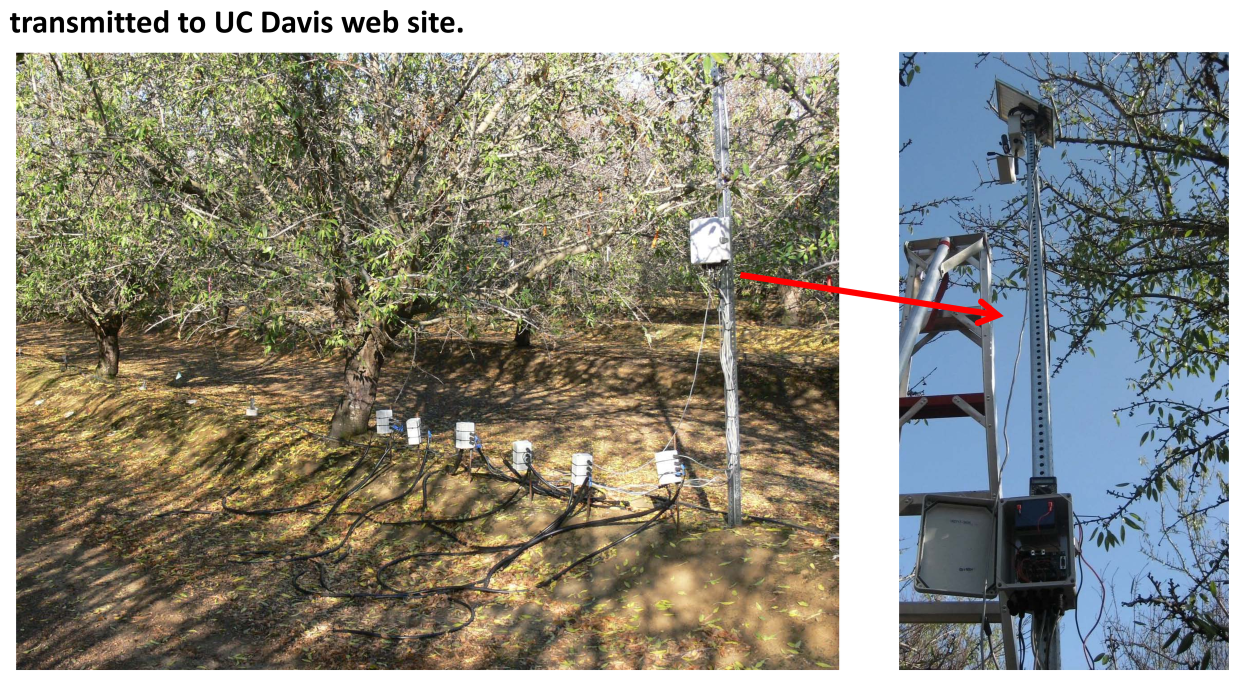

Fig. 3. A schematic of the sensors installation at different depth within the root zone.

## Sensor installation

Whereas the 32 sensor at the 30 and 60 cm depths were installed manually, the other 32 sensors at the 120 and 180 cm depths were installed by a newly designed installation device, using a hand-operated horizontal crank, in conjunction with a miniature camera to monitor installation progress.

## Data transfer

All sensors were connected to a data logger and radio, by which data were wirelessly transmitted to UC Davis web site.



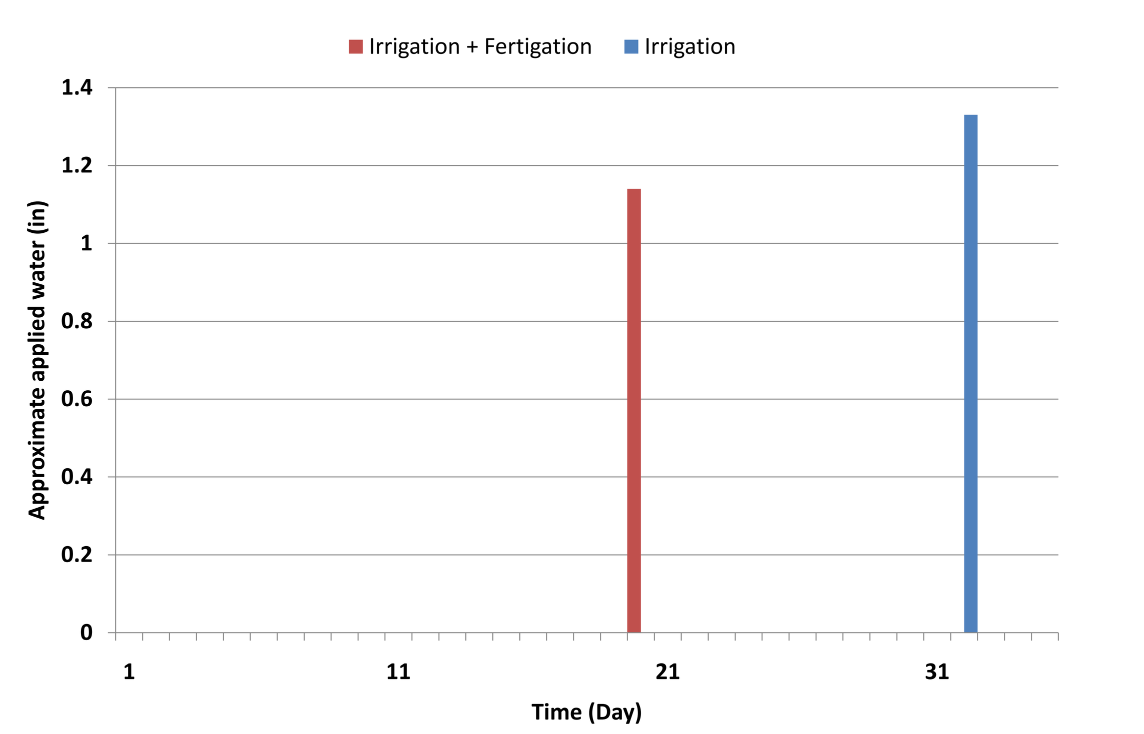



Fig. 4. The approximate amount of applied water during the period of monitoring the soil water content. The fertigation event happened on the first irrigation.

## Spatial and temporal soil moisture distribution

Figure 5 shows the temporal and spatial variation of soil water content in the root zone. (X,Y) denotes the spatial coordinate of sensors with tree placed at the origin.

- Soil water content at depth of 180 cm is very low.
- There is high water content at depth 120 cm which is right above of the clayey layer.
- Different spatial water content due to non-uniform water application of fanjet.
- Wetting front of both irrigation did not reach to the depth of 120 cm.
- Low amount of infiltration into the berm. For example location (0 300) and (0 150).
- Dryer condition at depth of 120 cm at the middle distance between two trees (Y=300).

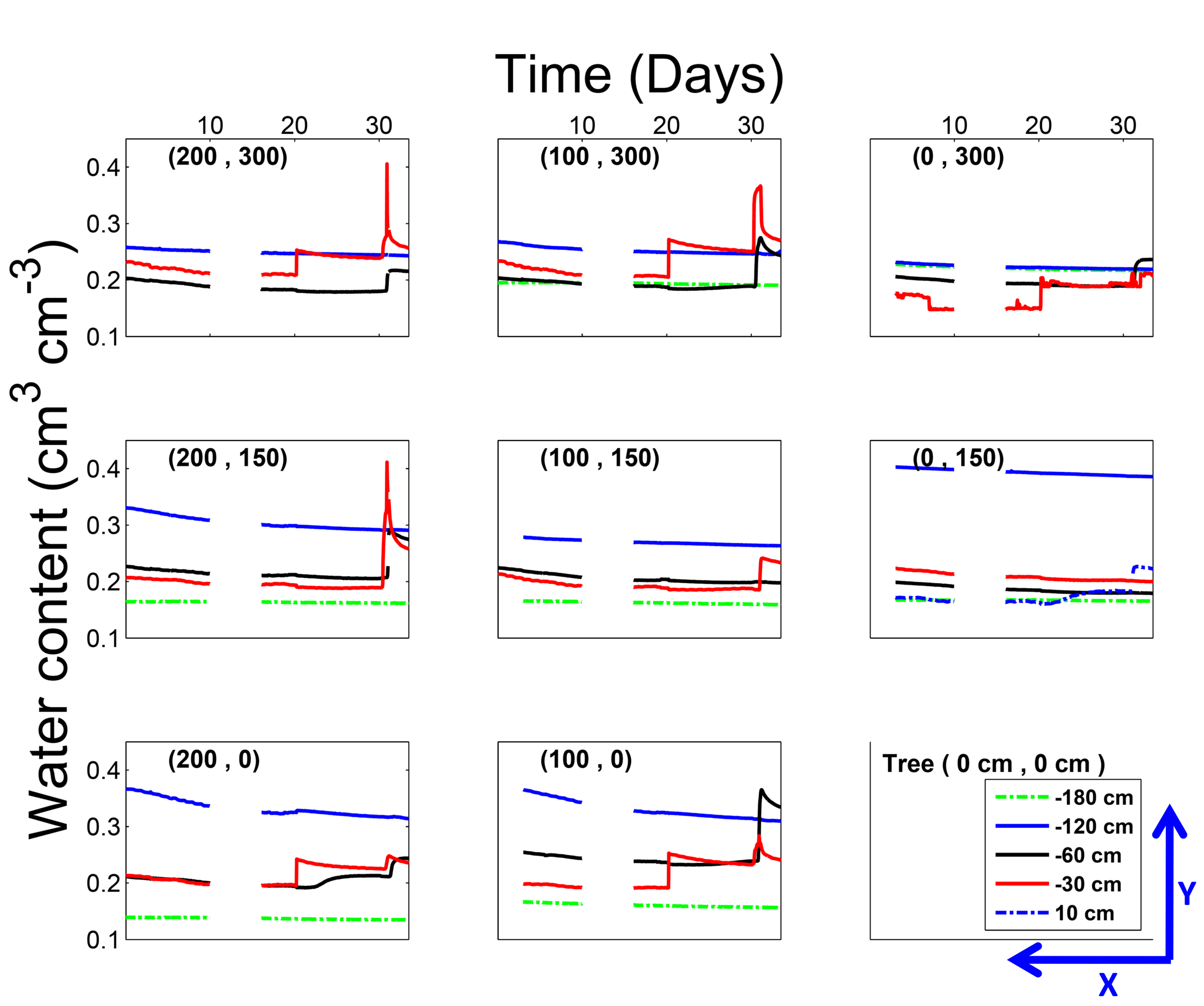



Fig. 5. Spatial and temporal variation of soil moisture in the root zone under Fanjet irrigation system

## Next Steps

### 1-Tensiometer installation

Installation of tensiometers to evaluate leaching of water and dissolved nitrates.

$$q_{A-B} = -K(\theta)\frac{H_B - H_A}{\Delta z_{A-B}}$$

$q =$ leaching $(cm/day)$
$K(\theta) =$ average unsaturated hydraulic conductivity between A and B
$\theta =$ Volumetric soil water content
$H_B =$ total head at B
$H_A =$ total head at A
$\Delta z_{A-B} =$ distance between A and B

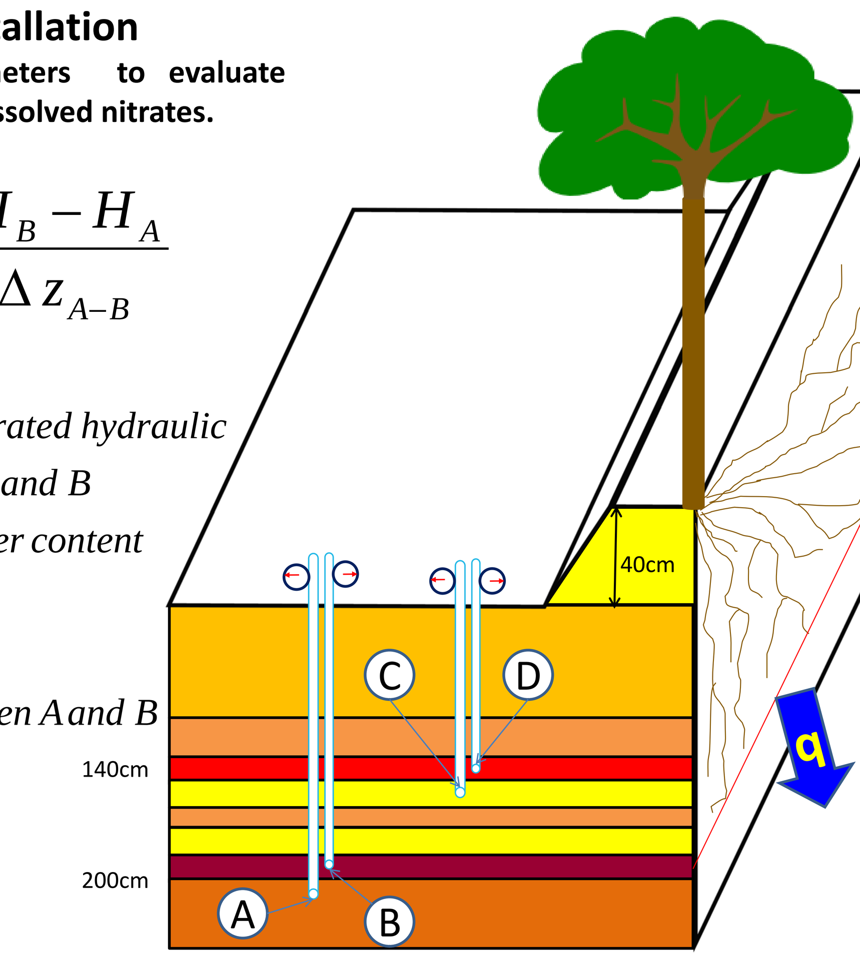



Fig. 6. A schematic of the tensiometer installation at different layer in the soil profile.

### 2-Soil hydraulic properties

Using the outflow method (Buchner funnel ) the soil hydraulic properties for each layer will be measured in the laboratory (Nasta and Hopmans, 2010). Saturated hydraulic conductivity and bulk density will be measured in the laboratory.

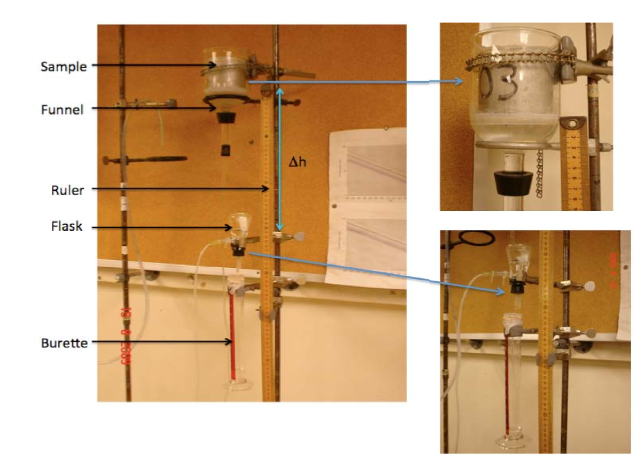


Fig 7. Measurement of soil hydraulic properties in the laboratory (outflow method - Buchner funnel )

### 3-Sap flow

A heat pulse sensor will be installed on both tree in Fanjet and Drip irrigation system to measure actual tree transpiration of tree for each irrigation system.

Fig 8. A picture of sap flow sensor, that are installed in White fir trees of the Southern Sierra Critical Zone Observatory field site.

### 4-Modeling

The soil profile, hydraulic properties and evapotranspiration from weather station along with irrigation/fertigation rate for each irrigation system will be used as input file for the numerical model HYDRUS-2D to simulate soil water movement, solute transport and root water uptake.

Measured soil water content, nitrate leaching and sap flow will be used to calibrate the HYDRUS model for the almond orchard condition. Finally, the calibrated model will be used as guideline for irrigation system selection, irrigation and fertigation management .

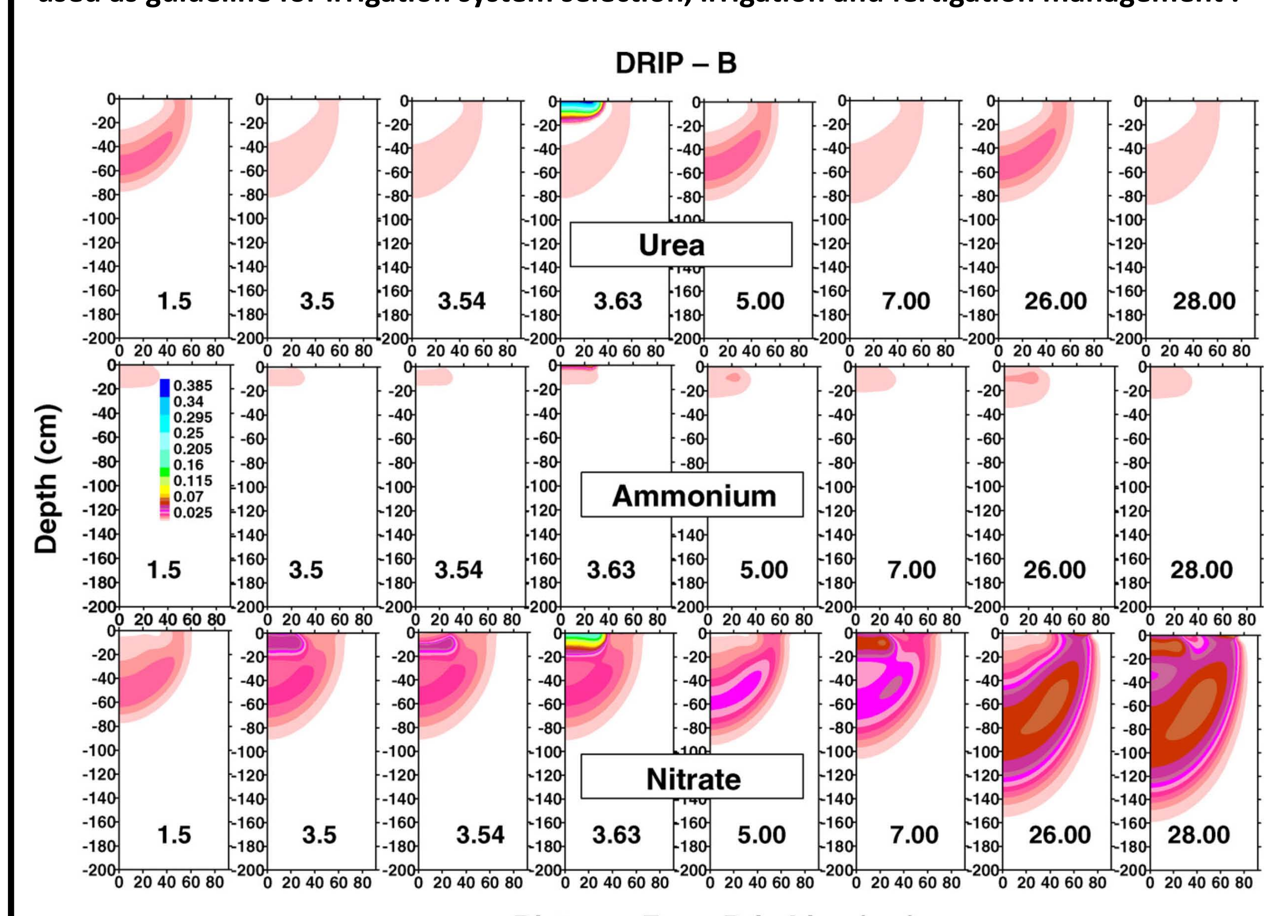



Fig. 9. Spatial distributions of soil solution urea, ammonium, and nitrate (M LS3) for the B strategy of DRIP for various days during the simulation period. The times (days) correspond to end of first irrigation (1.50), beginning of the second irrigation (3.5), beginning of second fertigation (3.54), end of second fertigation (3.63), end of second irrigation (5.00), beginning of third irrigation (7.00), end of last irrigation (26.00), and end of simulation period (28.00). (Hanson et al. 2006).

## Acknowledgment

Supported jointly by the Almond Board of California, the Pistachio Research Board, and the U.S. Department of Agriculture

## References

Nasta, P., and J.W. Hopmans. 2010. Adapted multistep outflow experiment for hydraulic characterization of coarse-textured soils. Soil Science Society of America Journal. Accepted

Hanson, B. R., Šimůnek, J. Hopmans, J. W. 2006. "Evaluation of urea-ammonium-nitrate fertigation with drip irrigation using numerical modeling." Agricultural Water Management 86(1-2): 102-113.