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

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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, are evaluated, to 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.

Fanjet application pattern

Figure 1 shows the spatial distribution of fanjet wetting pattern. A very non-uniform application pattern results the variation of water distribution and therefore a variation of root distribution within the root zone.

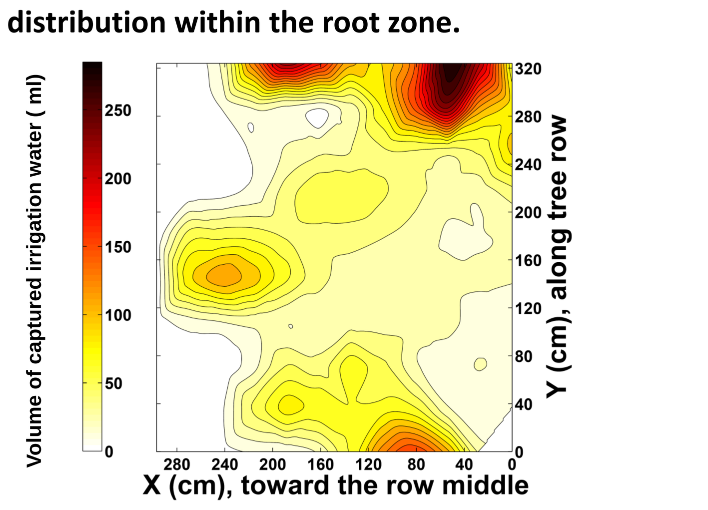


Fig. 1. Spatial distribution of fanjet application pattern . The contoured values represent the total irrigated water captured (ml) over one hour irrigation

Soil Profile

The soil profile under both drip and fanjet system was analyzed for soil texture, bulk density and soil layering. Figure 2 shows representative soil layers and measured soil properties for drip and fanjet.

Fanjet	clay (%)	silt (%)	sand (%)	Bulk density (g/cm^3)	Depth (cm)	Bulk density (g/cm^3)	sand (%)	silt (%)	clay (%)	Drip
					10					
	21	18	61	1.37	20	1.52	73	12	15	
					30					
					40					
Sandy clay loam	27	26	47	1.4	50	1.54	75	13	12	Sandy loam
					60					
					70					
	21	26	53	1.37	80	1.51	72	15	13	
					90					
					100					
Loam	28	27	45	1.37	110	1.55	37	32	31	Clay loam
					120					
Clay	54	27	19	1.35	130					
					140	1.27	43	38	19	Loam
Sandy loam	19	25	56	1.49	150					
					160					
Loam	23	32	45	1.55	170	1.56	48	27	25	Sandy clay loam
Sandy loam	14	12	74	1.49	180					
					190					
Silt clay	44	47	6	1.14	200	1.36	21	37	42	Clay
					210					
					220					
					230		37	29	34	Clay loam
Clay loam	29	37	34		240					
					250					
					260		62	19	19	Sandy loam
					270					

Fig. 2. A schematic of soil layers for both Drip and Fanjet plot and soil particles percentage for each layer.

Soil water content

A total of 32 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.

Tree instrumentation

(X,Y) notation represents Cartesian coordinates, with both X and Y, representing distances (cm) from 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. Figures 3 and 4 show the sensor installation for both Drip and Fanjet irrigation system.

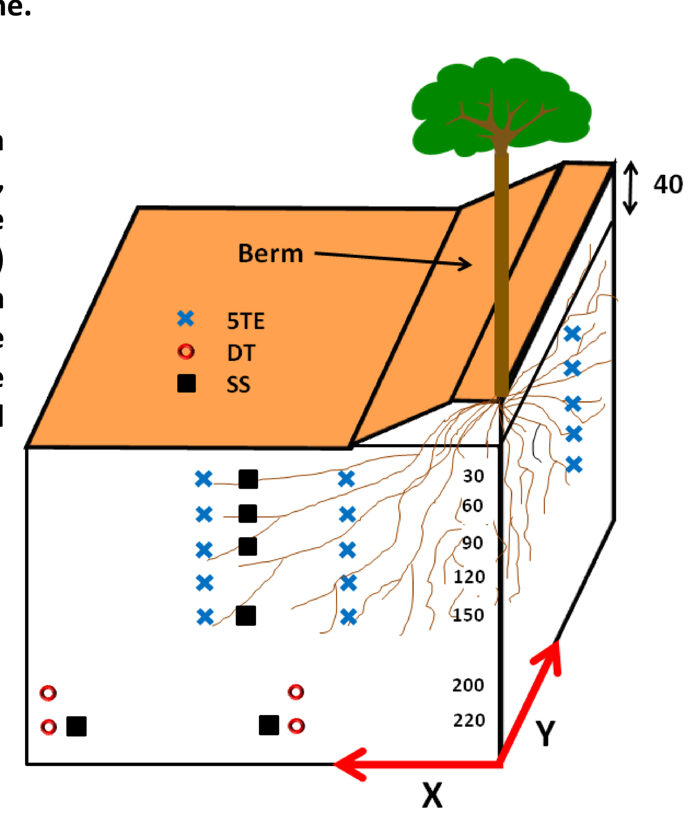
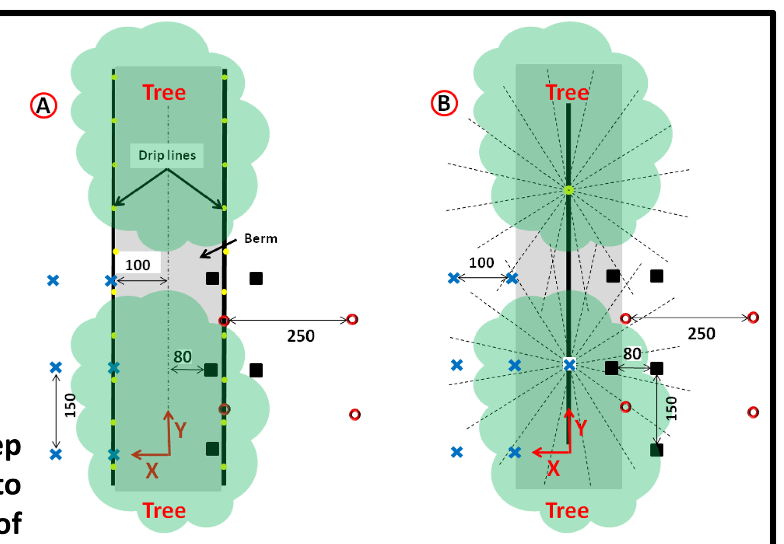


Fig. 3. A schematic showing installation depths of various sensor types , with 5TE representing the ECHO-5TE soil moisture, DT the deep tensiometers, and SS referring to soil solution samplers.

Fig. 4. A schematic top view of the installed soil moisture sensors, deep tensiometers, and solution samplers in (A) Drip and (B) Fanjet site.



Deep tensiometer

For each tree four pairs of deep tensiometers have been installed to evaluate the possible leaching of water and dissolved nitrates using the equation below.

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

$q = leaching\ (cm/day)$

$K(\theta) = average\ unsaturated\ hydraulic\ conductivity\ between\ A\ and\ B$

$\theta = Volumetric\ soil\ water\ content$

$H_B = total\ head\ at\ B$

$H_A = total\ head\ at\ A$

$\Delta z_{A-B} = distance\ between\ A\ and\ B$

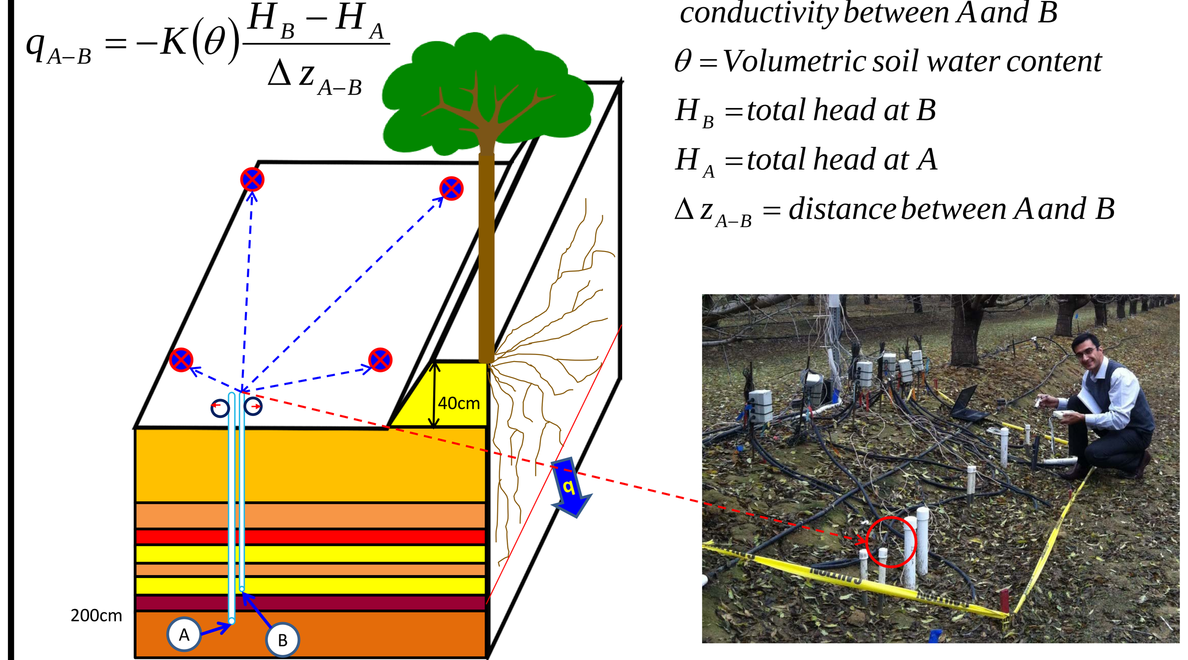


Fig. 5. A schematic of the tensiometer installation below the tree root zone.

Soil hydraulic properties

Using the multi-step outflow method the soil hydraulic properties of collected undisturbed soil cores are being measured in the laboratory (Nasta and Hopmans, 2010; Tuli et. al. 2001).

Fig. 6. Collecting undisturbed soil sample in the field and measurement of soil hydraulic properties of undisturbed soil core in the laboratory (outflow method –Tempe cell)

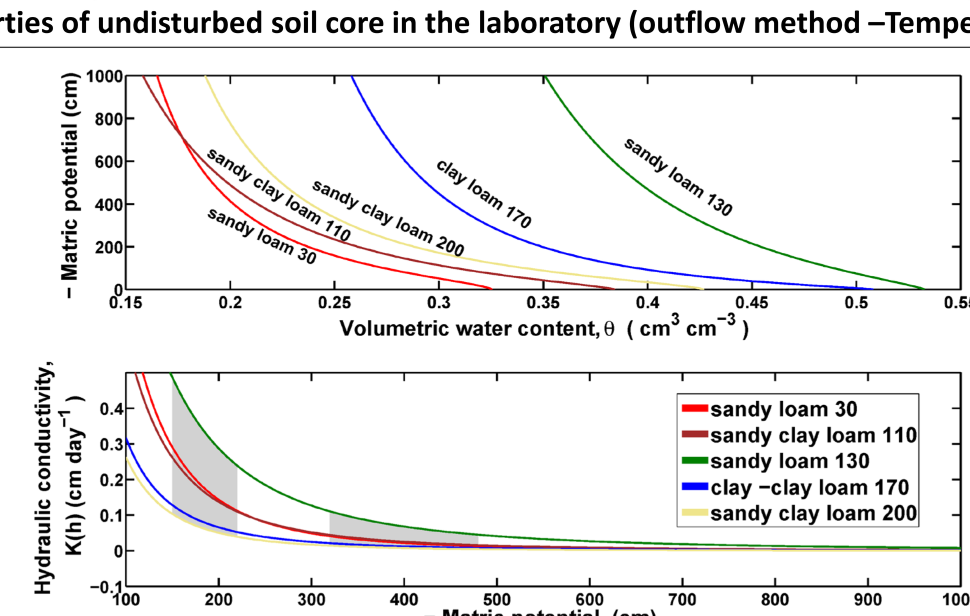
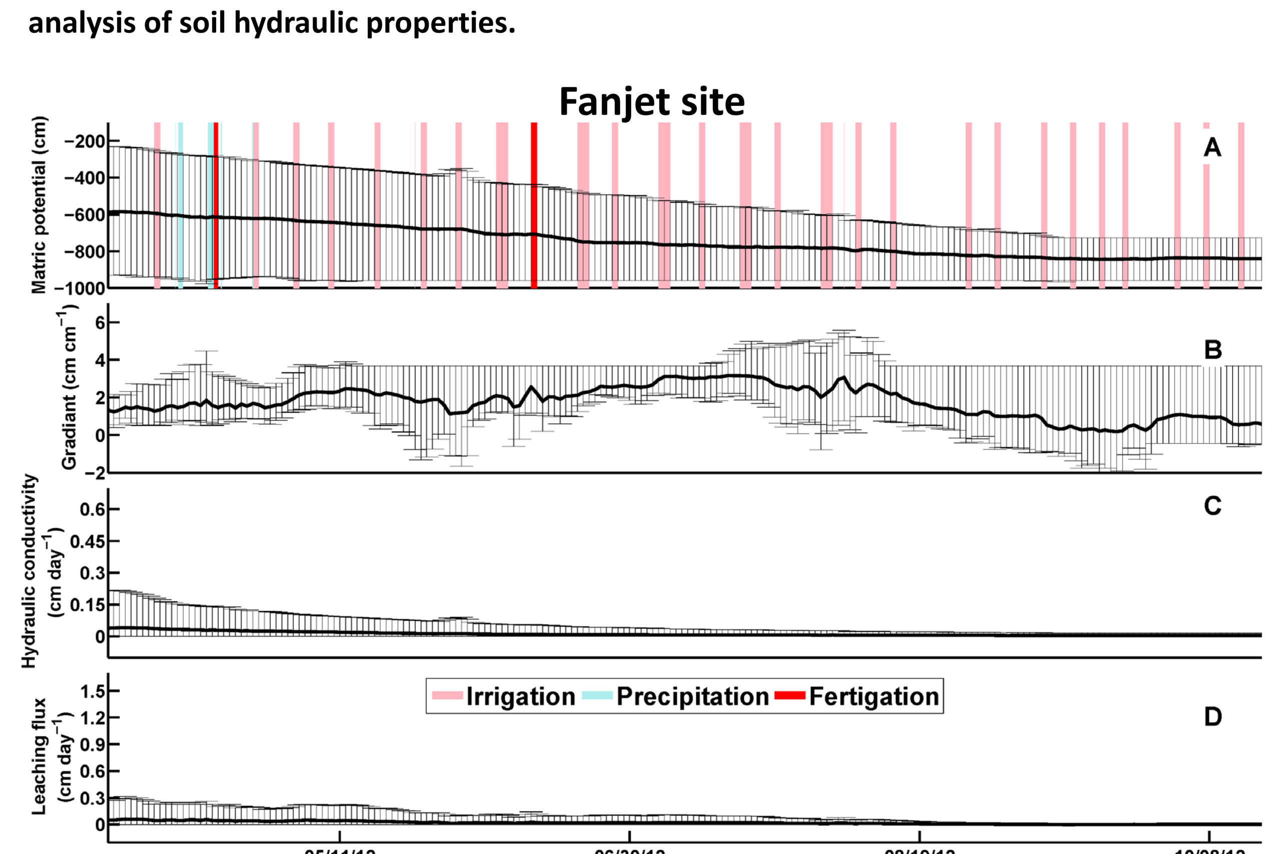


Fig. 7. Soil water retention and unsaturated hydraulic conductivity curves for the different soil types. Shaded portions represent the variation in unsaturated hydraulic values as a result of variations in measured soil water pressure head values across the field plot sites.

Leaching flux

For each tree four pairs of deep tensiometers were used to calculate the leaching of water out of the root zone.

- Larger variation of soil matric potential in fanjet site compare to the drip site.
- Similar decreasing trend of soil matric potential from spring through summer.
- Lower water leaching in fanjet site due to finer soil material and a shallow clay layer in addition to a deep clay layer compare to the drip site where only one deep clay layer exist.
- Significant uncertainty on soil unsaturated hydraulic conductivity requiring additional analysis of soil hydraulic properties.



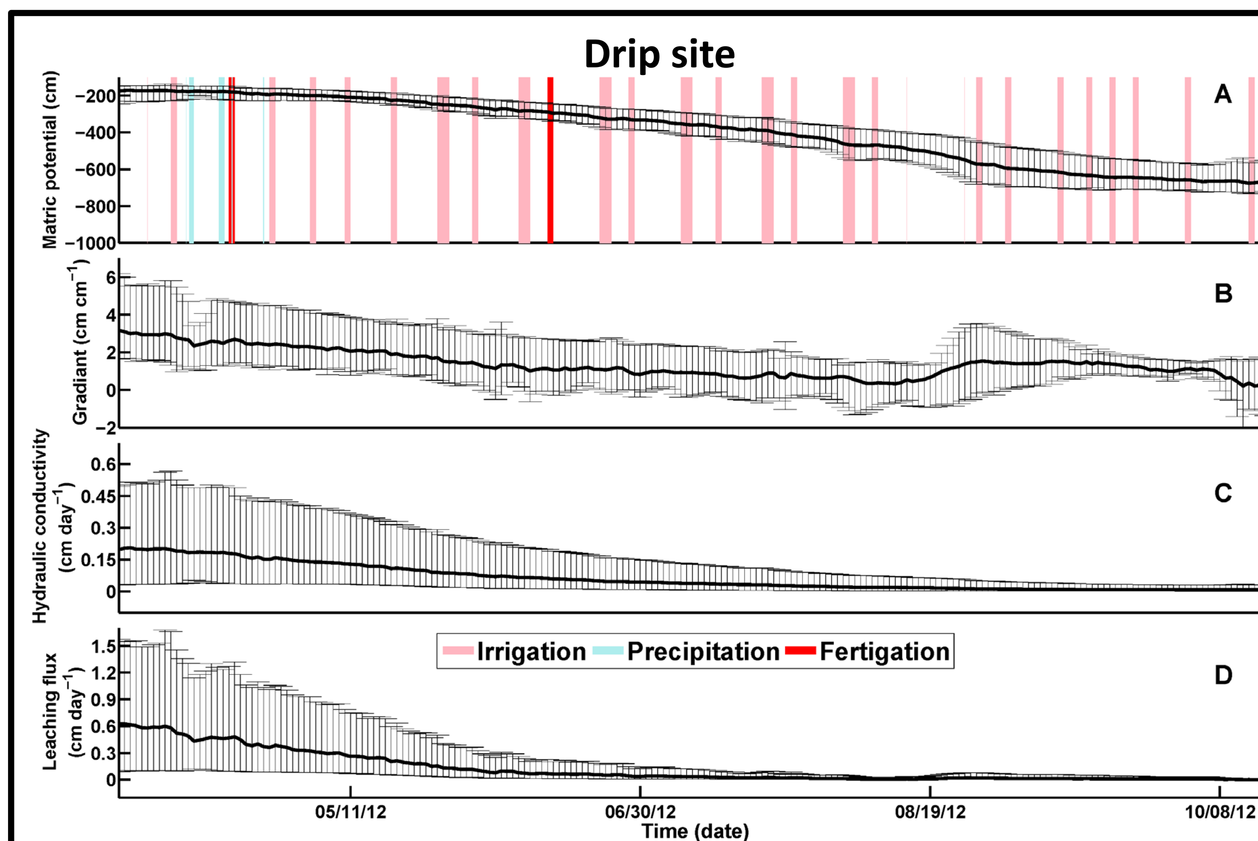


Fig. 8. Spatial variations of (a) matric potential at the 200 and 200 cm soil depth, (b) total head gradient, (c) unsaturated hydraulic conductivity, and (d) leaching rate for the fanjet and drip system, as measured at 4 locations (Fig. 5), starting April 1 through October 17. Average values are presented by the thick black lines, whereas the spatial variations are presented by the error bars. The pink, blue, and red bars represent irrigation, precipitation, and fertigation events, respectively.

Preliminary result of one dimensional HYDRUS modeling

Figure 5 shows the measured and simulated temporal and spatial variation of soil water content in the root zone under fanjet irrigation system. The hydraulic properties of different soil layers in the soil profile and the evapotranspiration from weather station along with irrigation rate for fanjet irrigation system was used as input parameters for the numerical model HYDRUS-2D to simulate soil water movement and root water uptake.

- Soil water content at depth of 180 cm is very low in fanjet site, while it is relatively high in the drip site indicating possible leaching.
- There is high water content at depth 120 cm which is right above the clay layer.
- Different spatial water content due to non-uniform water application of fanjet.
- Immediate response of sensors at depths 30 and 60 cm to the irrigation/precipitation event, while gradually decreasing/increasing the water content over the dry/wet season.
- Simulated water content at depths of 30 and 60 cm shows similar trend as what was measured in the field.
- Not significant change in measured water content at deeper depth , while the simulation results shows responses of deeper depth to irrigation and precipitation.

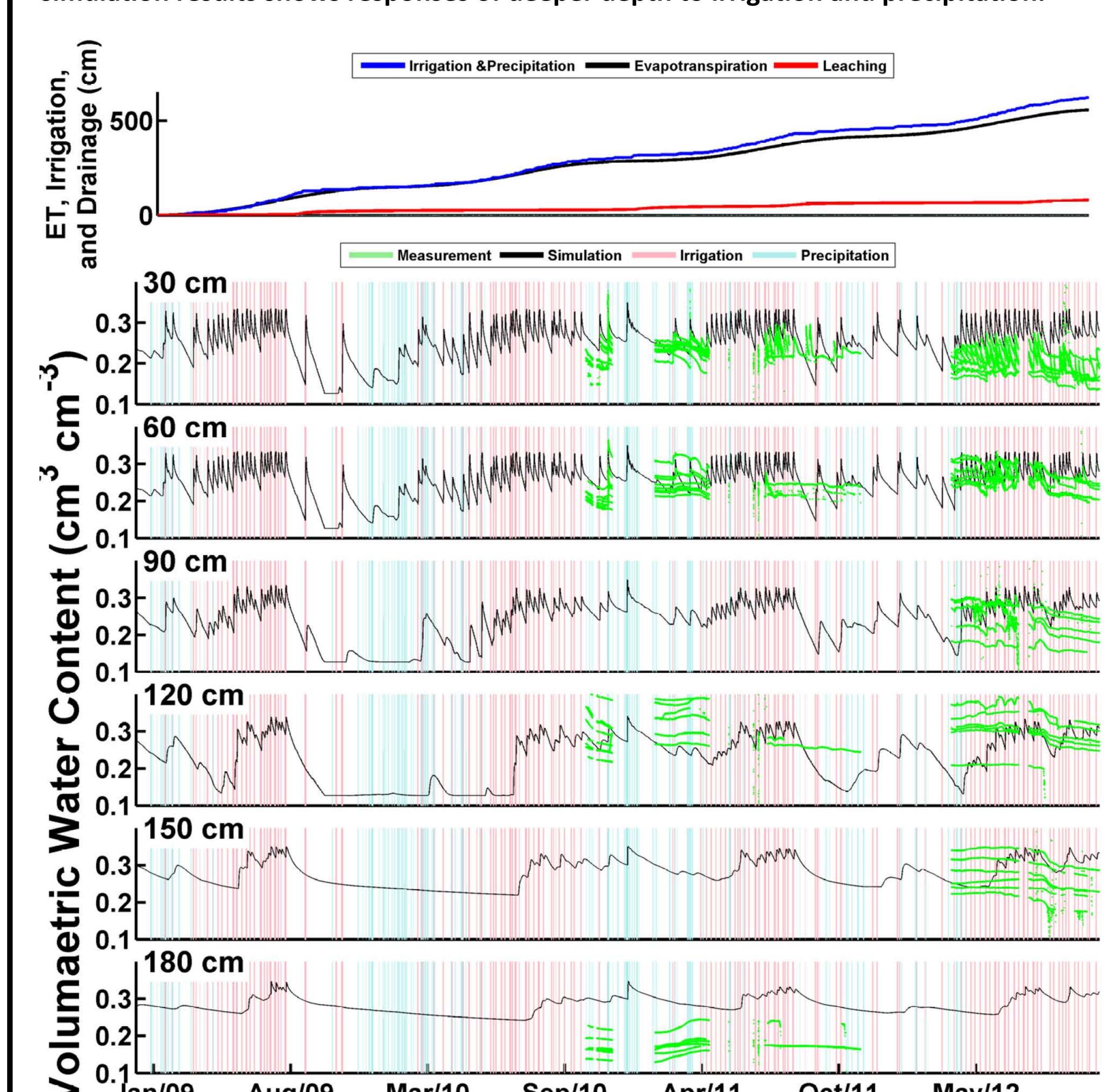


Fig. 9. Temporal and spatial variations of measured (green line), and simulated (black line) water content in the root zone under fanjet irrigation system.

Next step

Calibration

Measured soil water content, water and nitrate leaching will be used to calibrate the HYDRUS model for the almond orchard condition. Finally, the calibrated model will be used to run various scenarios and provide the growers with a guideline for irrigation system selection, irrigation and fertigation management .

Acknowledgement

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