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

Maziar M Kandelous[1], Andres Olivos[2], Patrick Brown[2], Jan W Hopmans[1]
[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

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

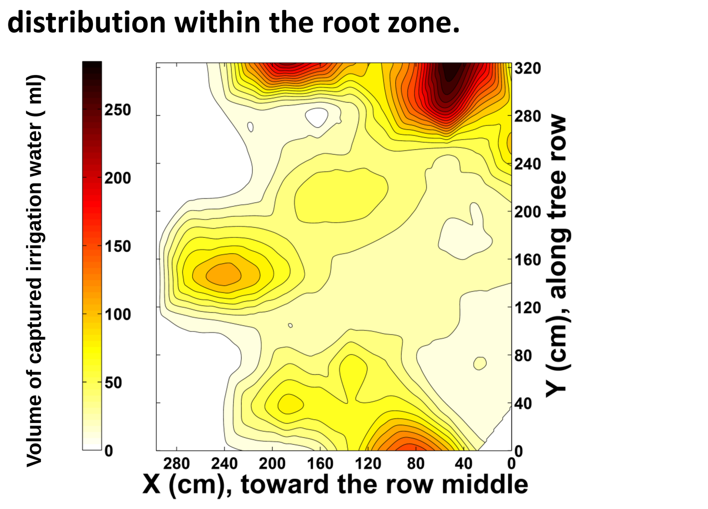
- Collect a full range of data, from both ongoing field tests and other sources, as inputs for evaluating the computer-based HYDRUS-2D simulation model as an optimization tool applicable to almond research and management.
- Evaluate and test the HYDRUS-2D model, using field data from existing fertigation 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.

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.



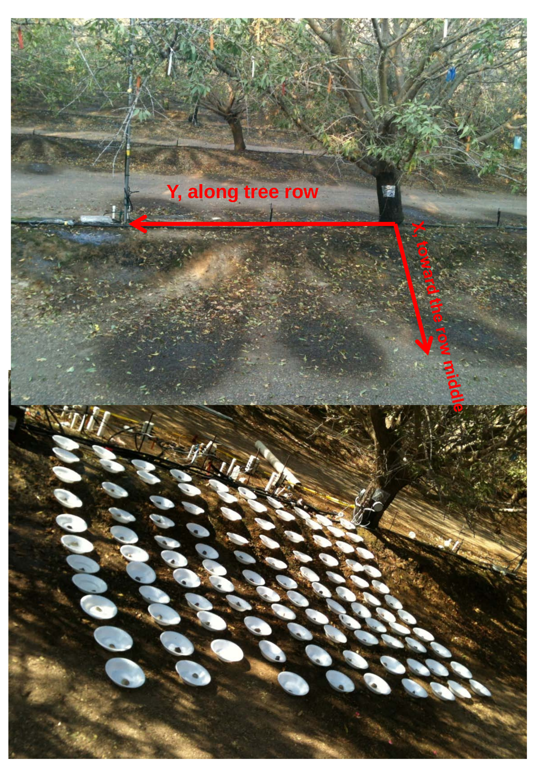


Fig. 1. Spatial distribution of fanjet application pattern . The contoured values represent the total irrigated water captured (ml) over one hour irrigation

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 differences of soil profile between drip and fanjet.

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

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

Soil water content and matric potential

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. In addition, we will install MPS2 sensors around each tree , at the 30 and 60, and 90 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. Figures 3 and 4 show the sensor installation for both Drip and Fanjet irrigation system.

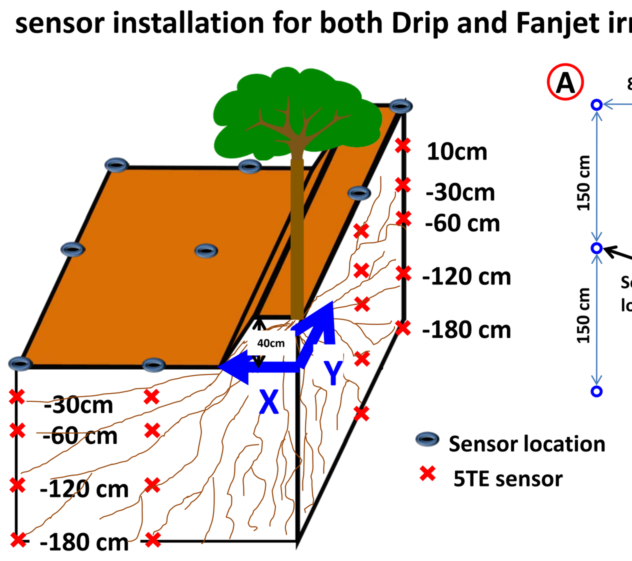


Fig. 3. A schematic of the sensors installation at different depth within the root zone.

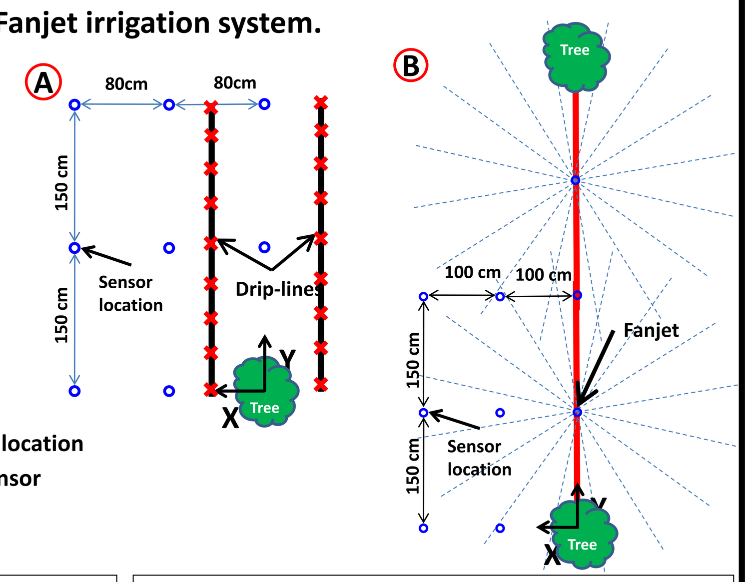
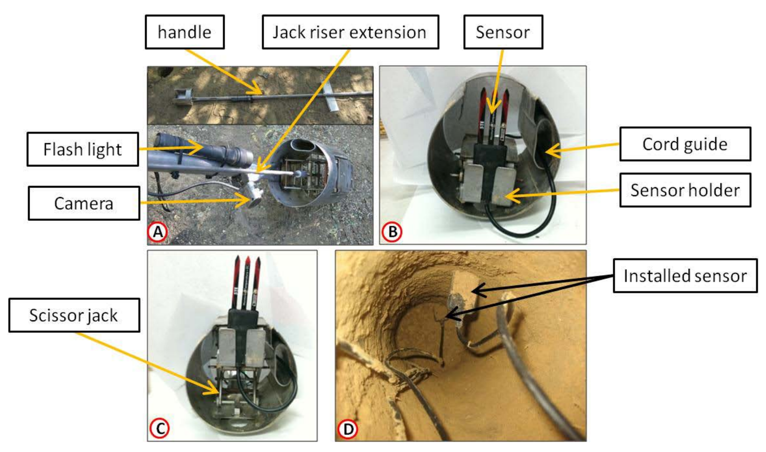


Fig. 4. A schematic top view of the installation of soil moisture sensors.

Sensor installation

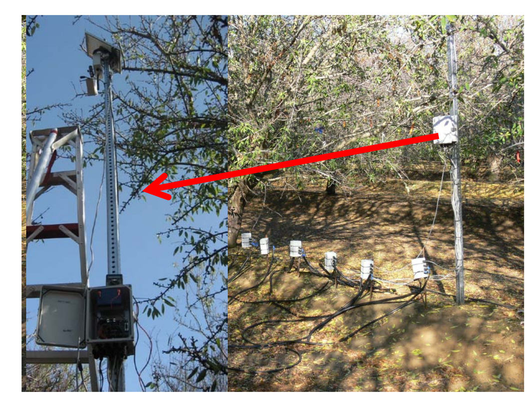
Whereas the 32 sensor at the 30 and 60 cm depths were installed manually, the other 32 sensors at the 120 and 180 cm depths were installed by a newly designed installation device, using a hand-operated horizontal crank, in conjunction with a miniature camera to monitor installation progress.

Fig. 5. (A) Sensor installation device, (B) sensor placement in the device with the hand-driven jack closed and ready for the sensor to be installed, (C) sensor positioned in the device with jack fully opened and the sensor is completely inserted into the soil, and (D) installed sensor at different depths with the new installation device.



Data transfer

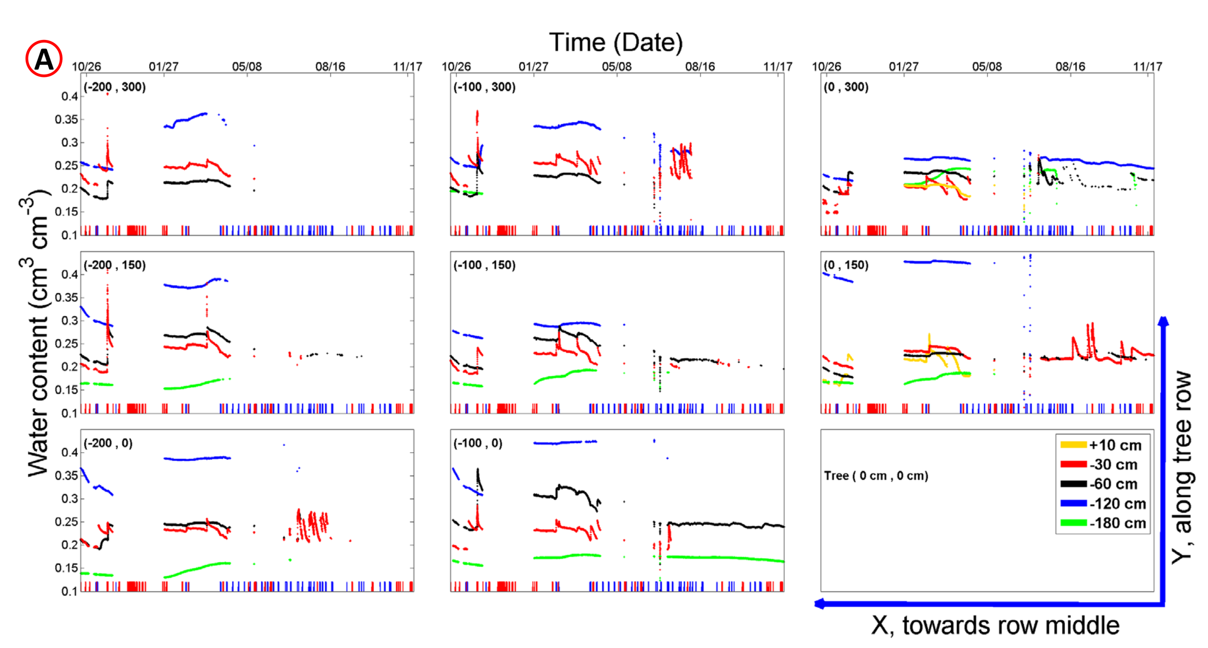
All sensors were connected to a data logger and radio, by which data were wirelessly transmitted to UC Davis web site.



Spatial and temporal soil moisture distribution

Figure 5 shows the temporal and spatial variation of soil water content in the root zone under fanjet and drip irrigation system. (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 in fanjet site, while it is relatively high in the drip site addressing possible leaching.
- 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.
- 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.
- Low amount of infiltration into the berm in drip site. (e.g. location (0 300) and (0 150)).



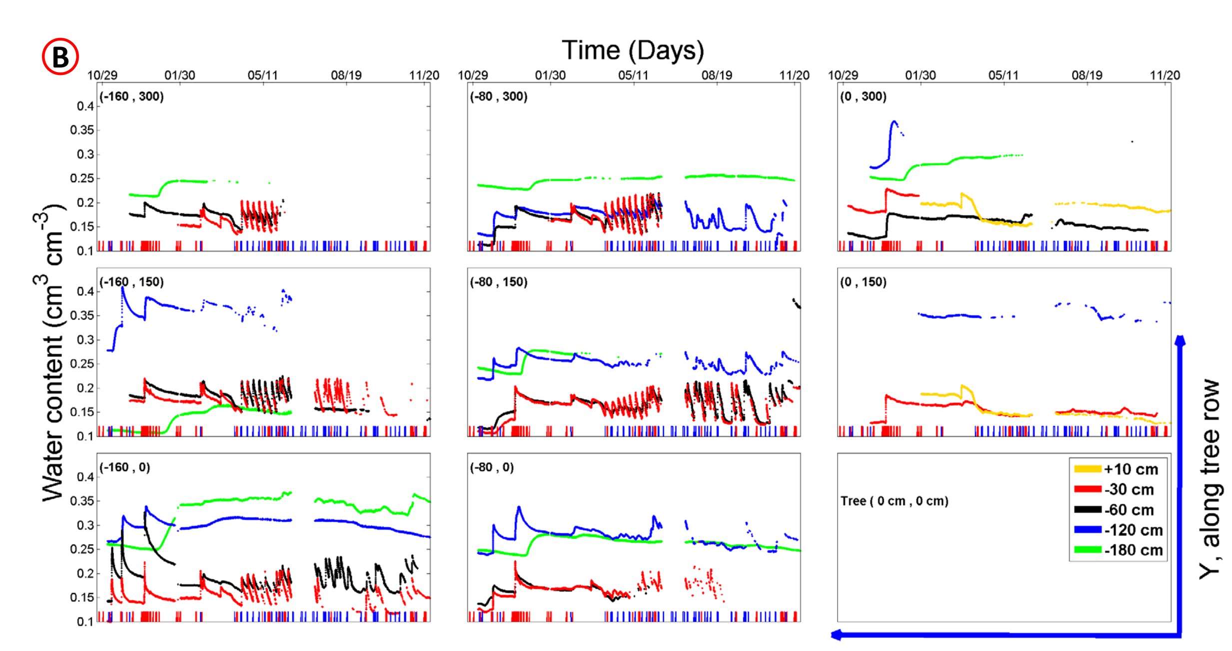


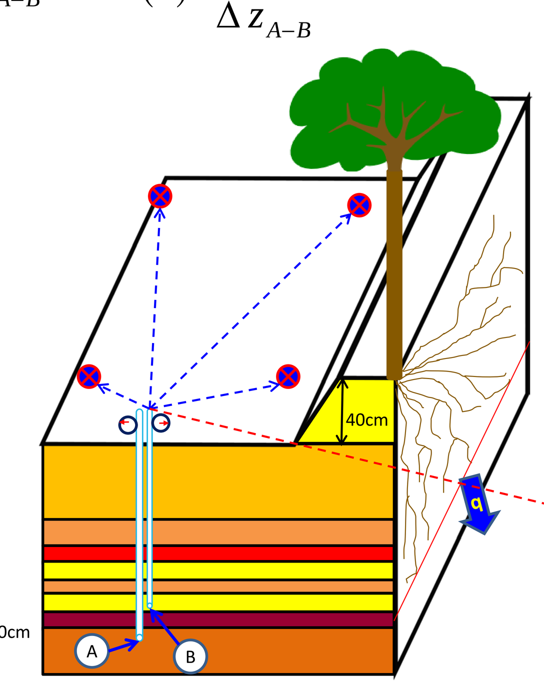
Fig. 6. Spatial and temporal variation of soil moisture in the root zone under A- Fanjet and B- Drip irrigation system. The small red bars denotes the precipitation events, while the blue bars represent the irrigation events.

Deep tensiometer installation

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
θ = Volumetric soil water content
H_B = total head at B
H_A = total head at A
Δz_{A-B} = distance between A and B



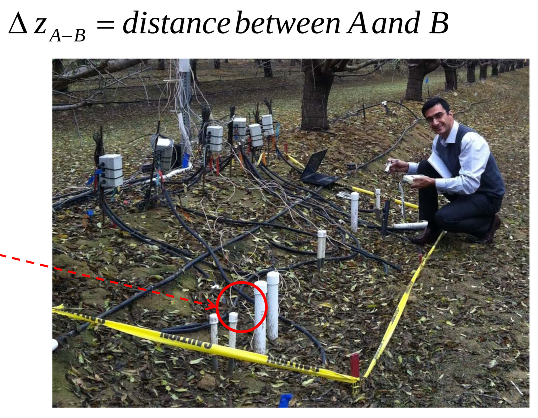
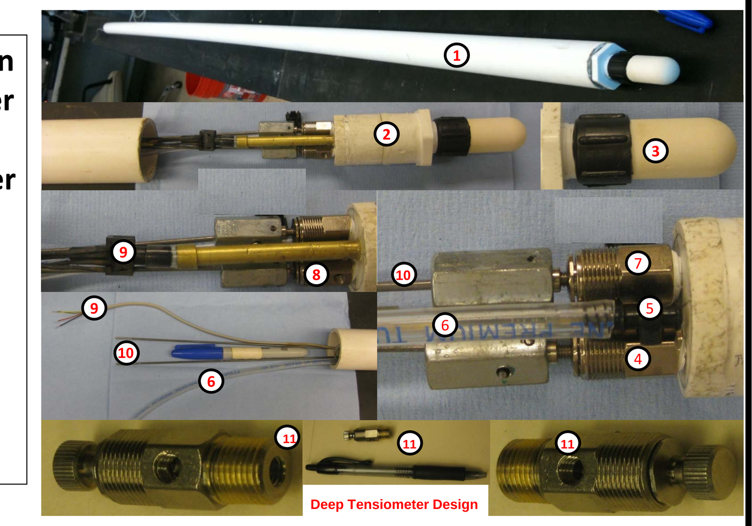


Fig. 7. A schematic of the tensiometer installation below the tree root zone.

A special tensiometer has been designed for monitoring the leaching below the root zone with no limitation within the tensiometer application range.

Fig 8. Special deep tensiometer design in which 1-Custom length tensiometer (no limit), 2- Tensiometer heart and water storage, 3- Porous cup, 4- Water supply valve for servicing, 5-Water inlet, 6- Plastic tube to inject the water, 7- Air release valve, 8- Air outlet, 9- Pressure transducer and its wire, 10- Turning rod to open and close the valve, 11- Water supply/air release valve.



Soil hydraulic properties

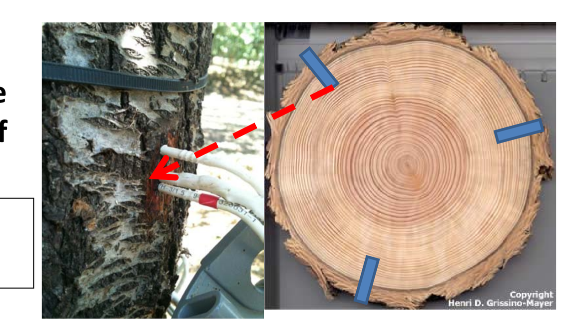
Using the multi-step outflow method the soil hydraulic properties of collected undisturbed soil cores are being measured in the laboratory (Nasta and Hopmans, 2010).

Fig. 9. Collecting undisturbed soil sample in the field and measurement of soil hydraulic properties of undisturbed soil core in the laboratory (outflow method –Tempe cell)

Sap flow

Three heat pulse sensors in each tree were installed to measure actual tree transpiration of tree for each irrigation system.

Fig. 10. A picture of sap flow sensor installed in almond tree of Paramount farm in Belridge.



Soil solution sampler

Six pairs of solution samplers (at depths of 30 and 60 cm) were installed to collect the soil solution to evaluate the soil nitrate distribution within the root zone and its variation due to root nutrient uptakes or leaching.

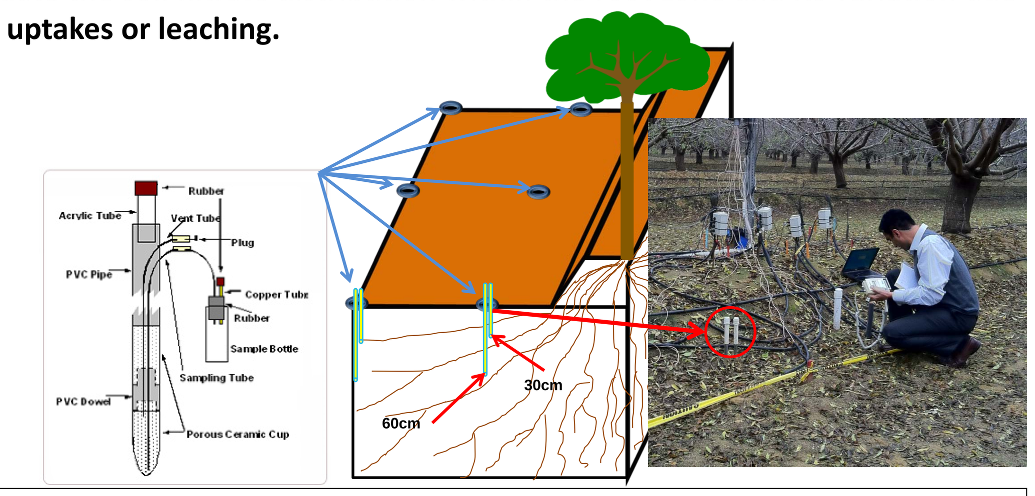


Fig. 11. A schematic of the solution sampler installation at different layer in the soil profile.

Next step

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 .

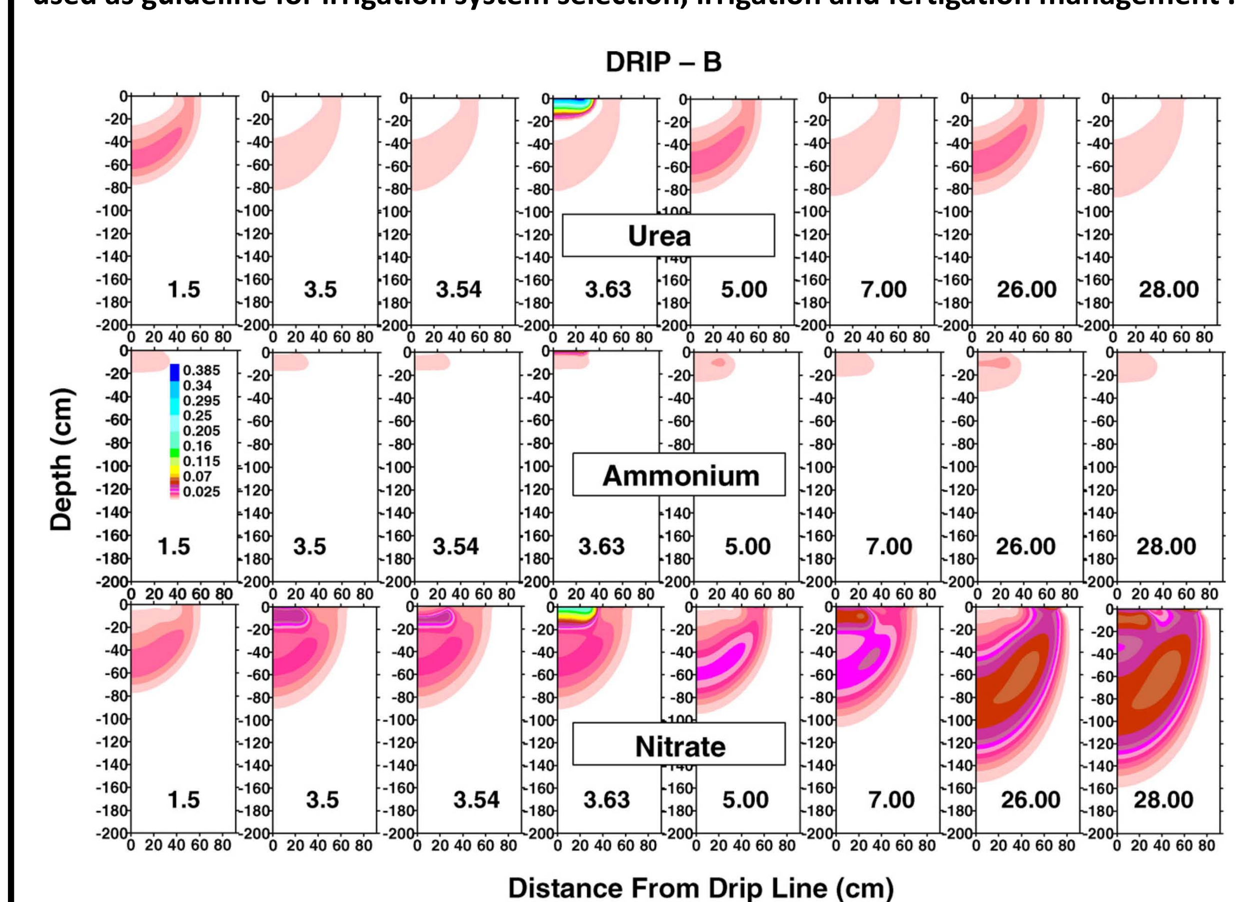


Fig. 12. Spatial distributions of soil solution urea, ammonium, and nitrate (M LS3) for the B strategy of DRIP for various days during the simulation period. The times (days) correspond to end of first irrigation (1.50), beginning of the second irrigation (3.5), beginning of second fertigation (3.54), 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

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