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

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Background

This study was funded by Almond Board of California to monitor soil water and nitrate movement for 2 micro irrigation systems (drip and fanjet). We determine soil physical properties, the extend of almond tree root zone, while monitoring water and nitrate movement within and below the root zone with the ultimate goal of simulating water movement and nitrate transport and root water/nitrate uptake. Irrigation and ferigation scheduling 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 to be compiled into 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.

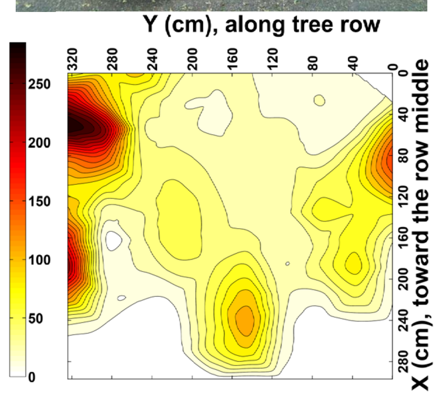


Fig. 1. Spatial distribution of fanjet application pattern . The contoured values represent the total irrigated water captured (ml) over one hour irrigation

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
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 physical properties for each layer.

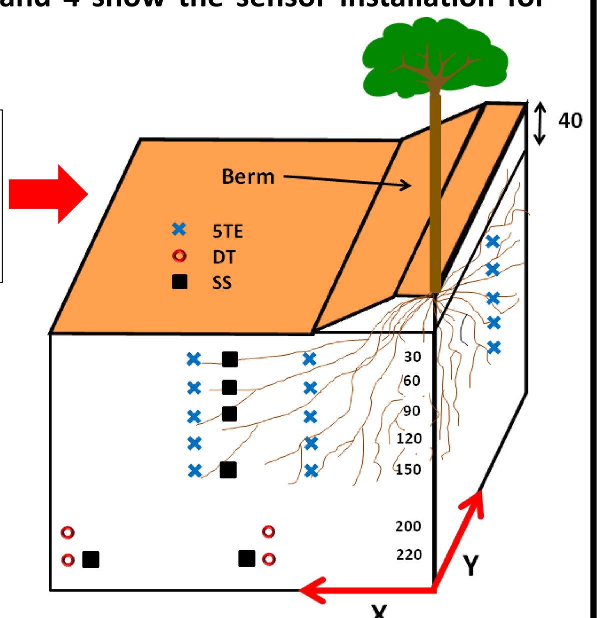
Soil water content, matric potential, and nitrate concentration

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 to the 5TE sensors, 5 neutron probe access tubes were installed for each tree for weekly monitoring of soil water content at every 30 cm down to the depth of 270 cm. Four pairs of deep tensiometers were installed at each tree to estimate the head gradient below the root zone with the ultimate goal of estimating the leaching. A total of 24 solution samplers were installed for each tree for monitoring the soil solution nitrate concentration within and below the root 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.



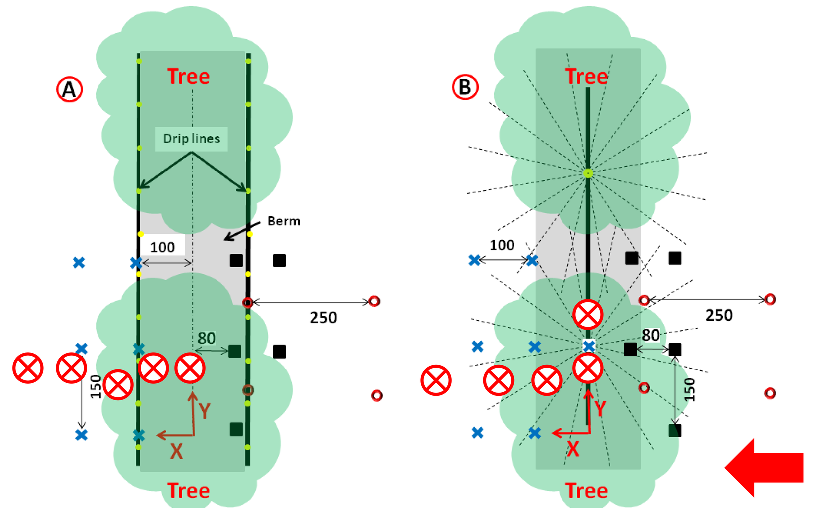


Fig. 4. A schematic top view of the installed soil moisture sensors, deep tensiometers, and solution samplers in (A) Drip and (B) Fanjet site.

Leaching rate

The amount of water leaching (LR, inches) for both irrigation sites was analyzed using water balance and Darcy equation approaches.

Water balance

Leaching (L) = Applied Irrigation Water (IW) + Precipitation (P) – Evapotranspiration (ET) – Soil Water Storage (ΔS)

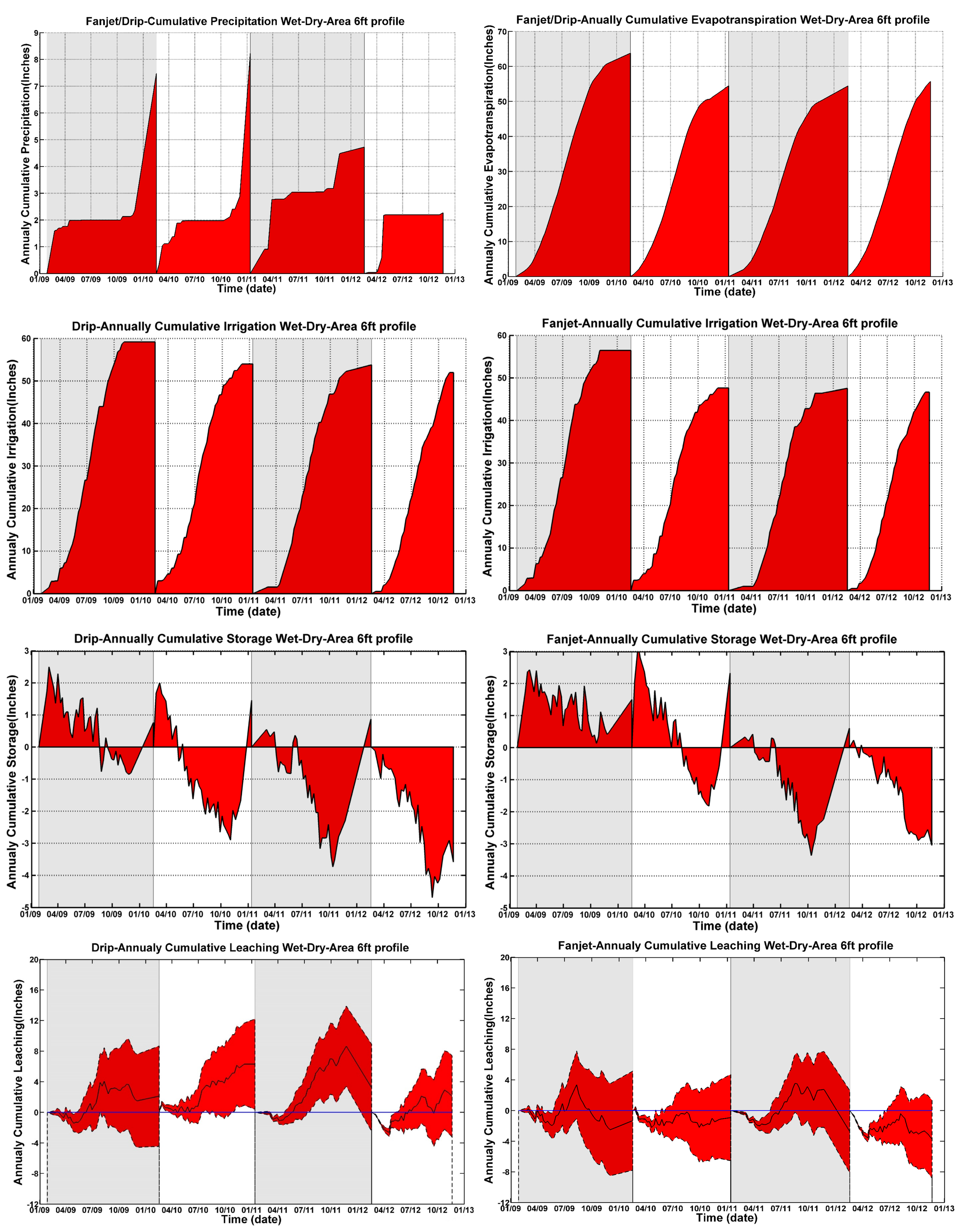


Fig. 5. Annually cumulative amount of precipitation, evapotranspiration, applied irrigation water, soil water storage, and leaching for both drip (left) and fanjet (right) site.

Darcy equation

In the second approach, we applied Darcy equation, to compute leaching rates (Figs. 9) from tensiometric soil water potential measurements (Figs. 6), combined with predicted unsaturated hydraulic conductivity values using the multi-step outflow (Fig. 7) and Neuro Multistep methods (Fig. 8).

$$q_{A-B} = -K(\theta)\frac{H_B - H_A}{\Delta Z_{A-B}};\ q = leaching\ (L/T)$$

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

$\theta = volumetric\ water\ content;\ H_B = total\ head\ at\ B$

$H_A = total\ head\ at\ A;\ \Delta Z_{A-B} = distance\ between\ A\ and\ B$

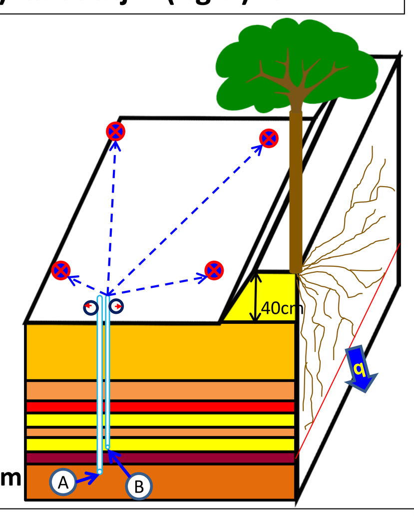


Fig. 6. A schematic of the tensiometer installation below the tree root zone.

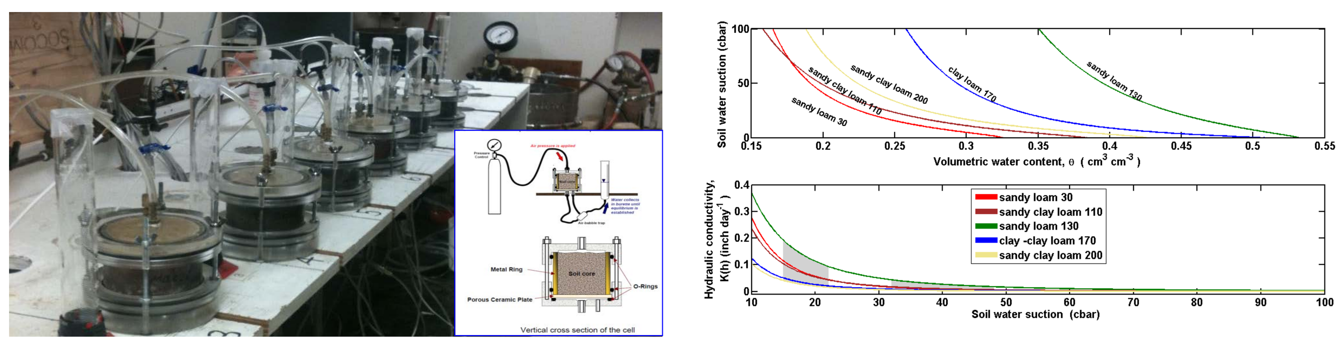


Fig. 7. Measured of soil hydraulic properties of undisturbed soil core in the laboratory (outflow method –Tempe cell, Tuli et al. 2001)

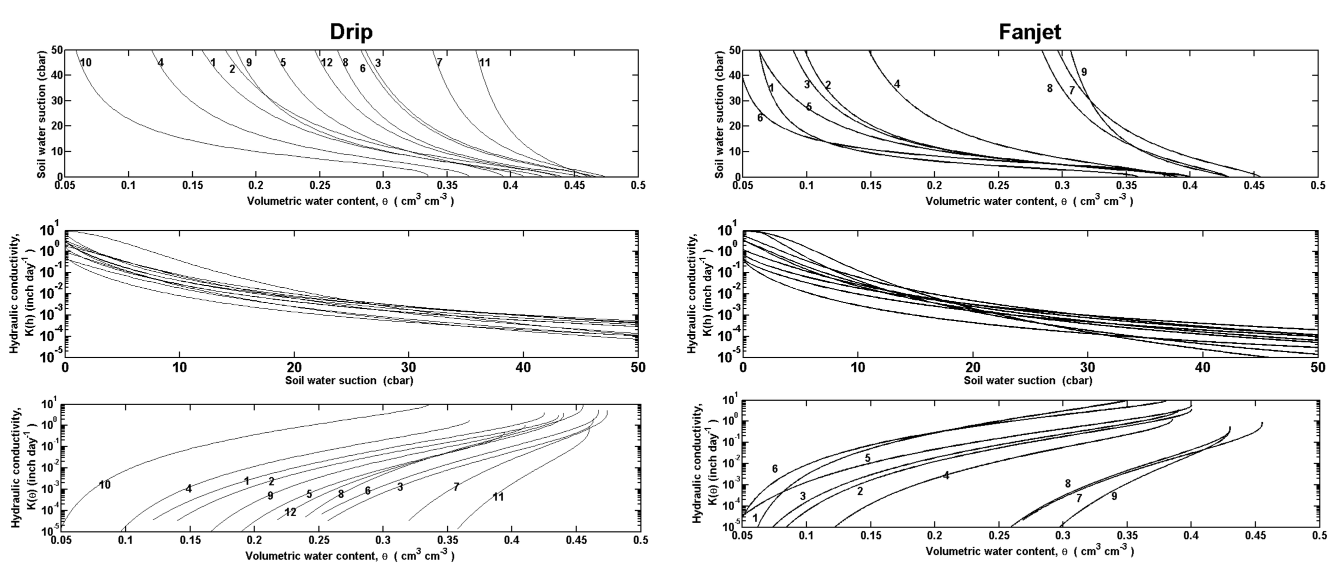


Fig. 8. Predicted of soil hydraulic properties using Neuro Multistep methods (Minasny, et al. 2004)

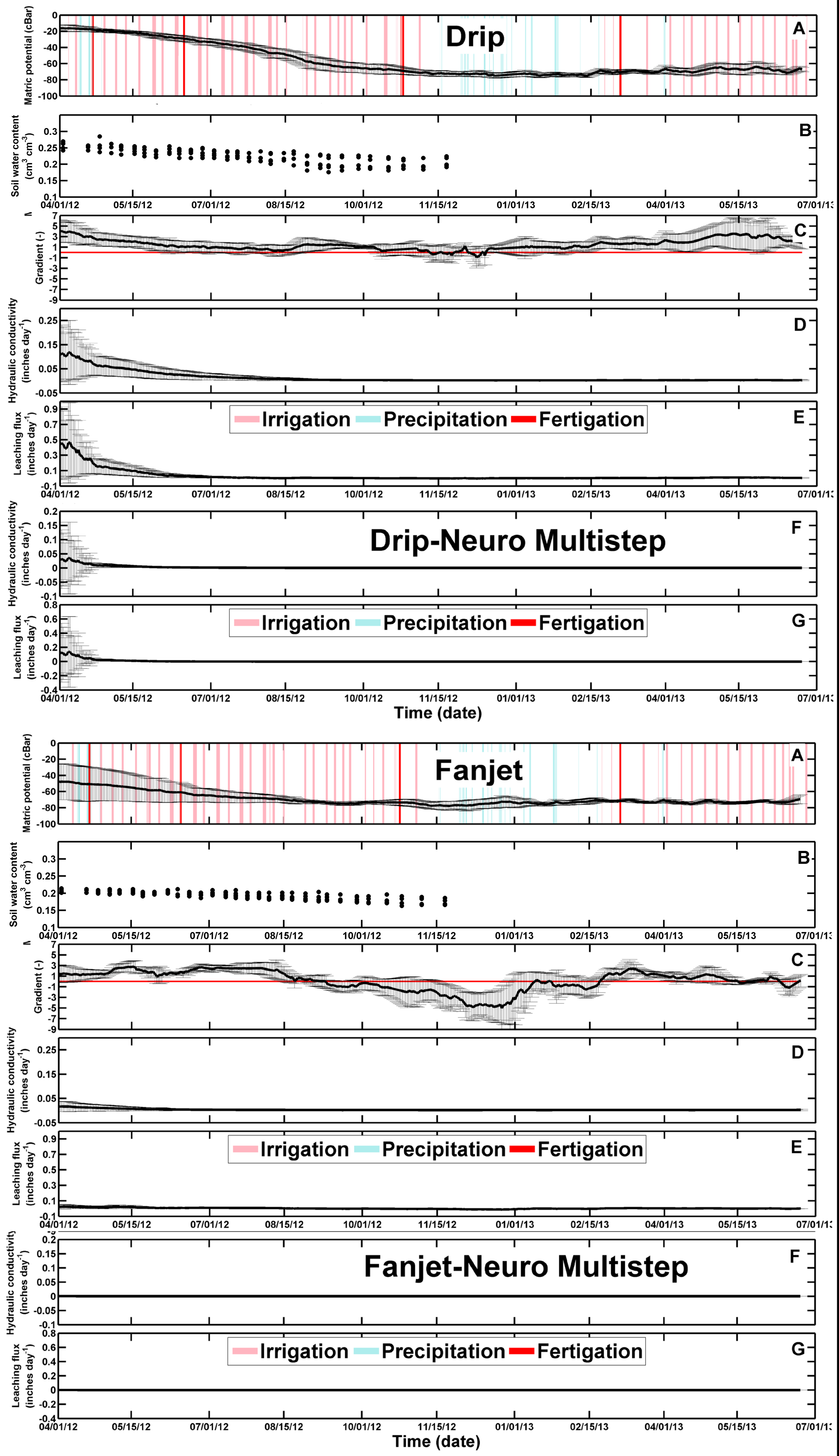


Fig 9. Spatial and temporal variations of (a) matric potential at the 200 and 220 cm soil depth, (b) deep soil water content at 210 cm, (c) total head gradient, (d and f) unsaturated hydraulic conductivity for multistep and Neuro Multistep methods, respectively, and (e and g) leaching rate for multistep and Neuro Multistep methods, respectively, as measured for 4 locations (Fig. 1), starting April 1, 2012 through July 1, 2013. Average values are presented by the thick black lines, whereas the spatial variations are presented by the error bars, defined by standard deviations (error bars). The pink, blue, and red bars represent irrigation, precipitation, and fertigation events, respectively.

Comparison of LR between water balance and Darcy equation approaches

Table 1 shows a comparison between leaching rates estimated using the water balance approach with the Darcy equation approach. We note that the estimated uncertainty is significantly larger for the Darcy calculations, but than in general annual total L values are reasonably close between the two methods.

This huge uncertainty, especially for the drip site, comes from the uncertainty of the unsaturated conductivity, especially in the wet end, because LR values tend to be near zero in the dry water content range. We believe that inverse modeling, using HYDRUS and in-situ soil moisture and water potential data could be realistic better approach to determine the soil hydraulic properties in the future

Table 1. A comparison between leaching rates estimated using the water balance approach with the Darcy equation approach.

			Water balance	Darcy-Multistep K(h)	Darcy-Neuro Multistep K(h)
Leaching (inches)	Drip	Average	4.07	12.91	2.32
	Fanjet	Average	-1.2	1.43	0.03

References

Minasny, B., J.W. Hopmans, T.H. Harter. A.M. Tuli. S.O. Eching and D.A. Denton. 2004. Neural network prediction of soil hydraulic functions for alluvial soils using multi-step outflow data. Soil Science Soc. Amer. J. 68:417-429.

Tuli, A., M. A. Denton, J. W. Hopmans, T. Harter, and J. L. Mac Intyre. 2001. Multi-step outflow experiment: From soil preparation to parameter estimation. LAWR Rep. 100037(http://researchers.lawr.ucdavis.edu/tuli/REPRINTS/MULTISTEPOUTFLOW.pdf)