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 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, 20 trees were monitored to evaluate the field scale variation in applied water and change in soil water storage. In addition, one tree from each site was selected for detailed instrumentation for the purpose of real-time monitoring of soil – water status. In addition

Soil Profile

The soil profile under both drip and fanjet system was analyzed for soil texture, bulk density and soil layering. Figure 1 shows representative soil layers and measured soil properties for drip and fanjet irrigation site.

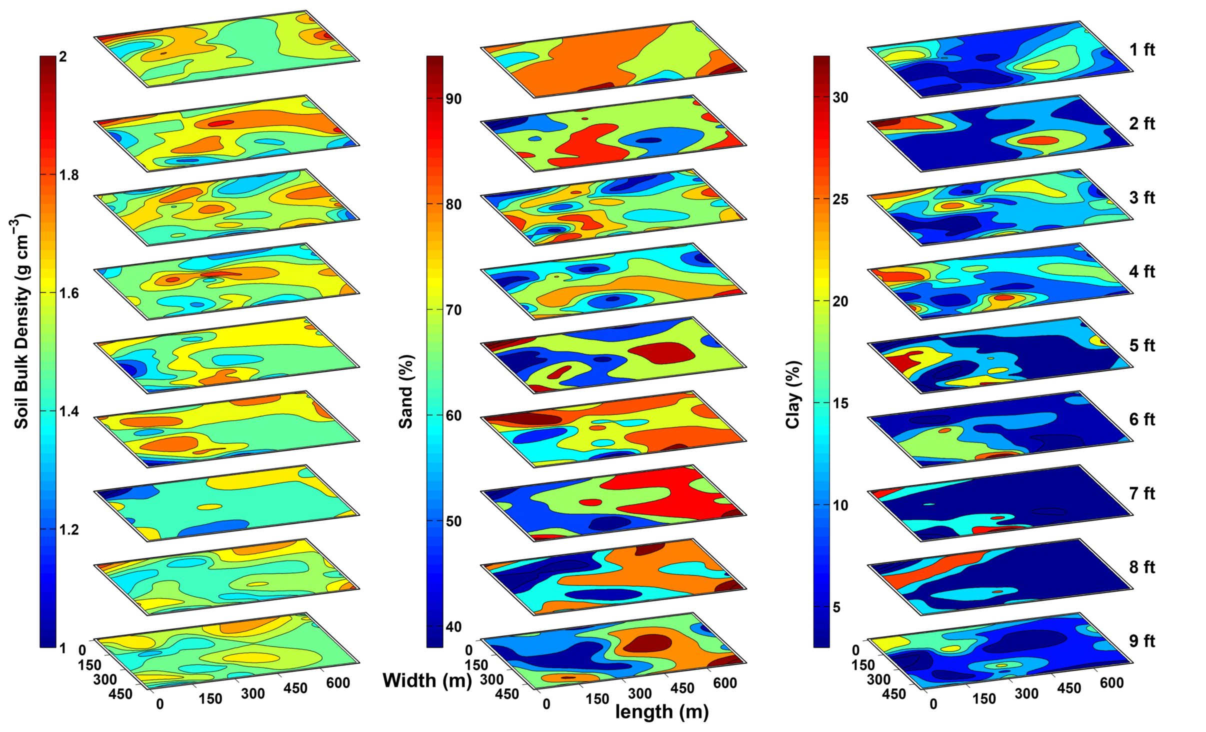


Fig. 1. The variation in soil layers for both Drip and Fanjet plot and soil physical properties for each layer.

Soil water content, matric potential, and nitrate concentration

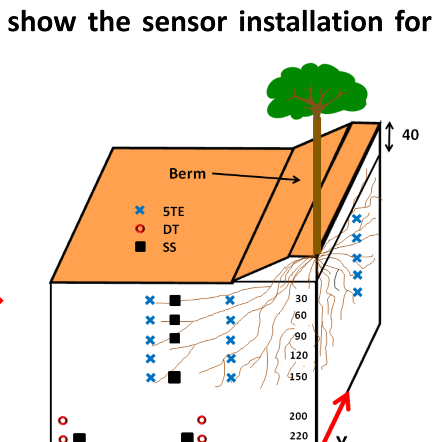
A total of 32 5TE Echo sensors were installed for each tree in a 3 by 3 grid pattern at different depth to monitor temporal and spatial variations in soil water content, EC, and temperature within the rooting zone. In addition to the 5TE sensors, 40 trees in total were equipped with neutron probe access tubes 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 of the heavily instrumented 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 of the heavily instrumented tree for monitoring the soil solution nitrate concentration within and below the root zone

Fig. 2. Top view of the orchard and monitored trees in (A) Fanjet and (B) Drip site.

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.



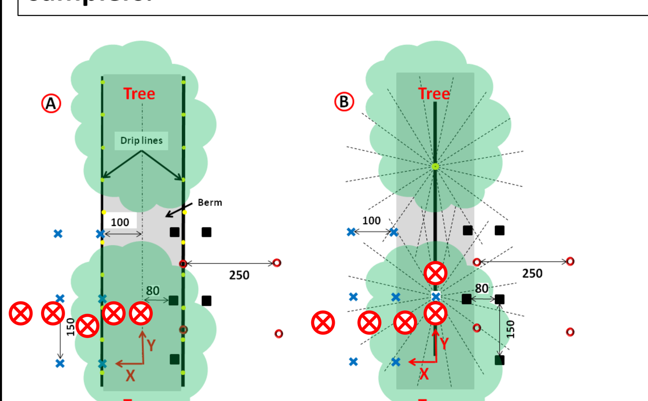
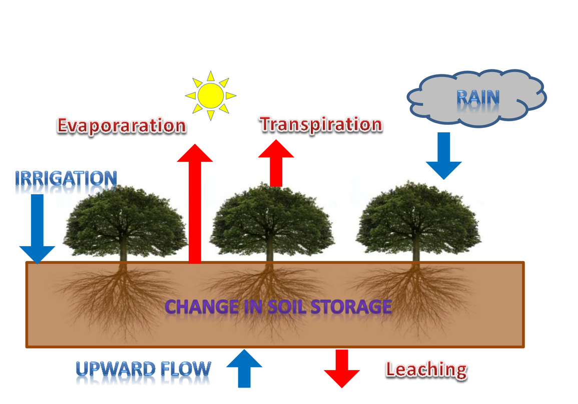


Fig. 4. A schematic top view of the installed soil moisture sensors, deep tensiometers, and solution samplers in (A) Drip and (B) Fanjet site.

Leaching rate

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



Water Balance

As first approach, we applied water balance equation, to compute leaching using the ET and P obtained from on-site Flux tower and soil water storage monitored by Neutron Probe

Water balance

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

Applied Irrigation Water, Precipitation, and Evapotranspiration

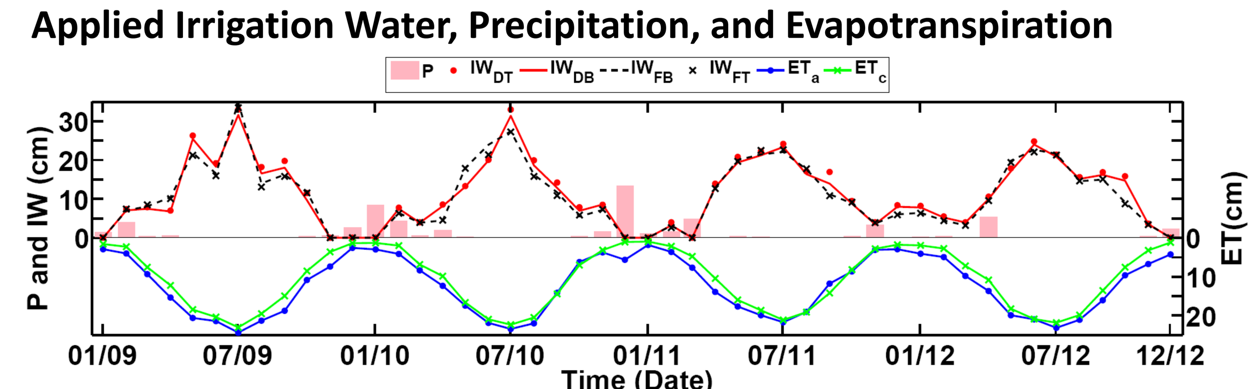


Figure 5. Monthly evapotranspiration, ET, and applied irrigation water, IW, and precipitation, P. The applied water, IW, for DT, DB, FB, and FT, respectively are shown by red circle, red solid line, dashed black line, and black cross. Pink bar plot shows precipitation. In right y-axis, potential evapotranspiration, ETp, is shown by cross-marked green line, while actual evapotranspiration, ETa, is presented by circle-marked blue line.

Change in Soil Water Storage and Leaching

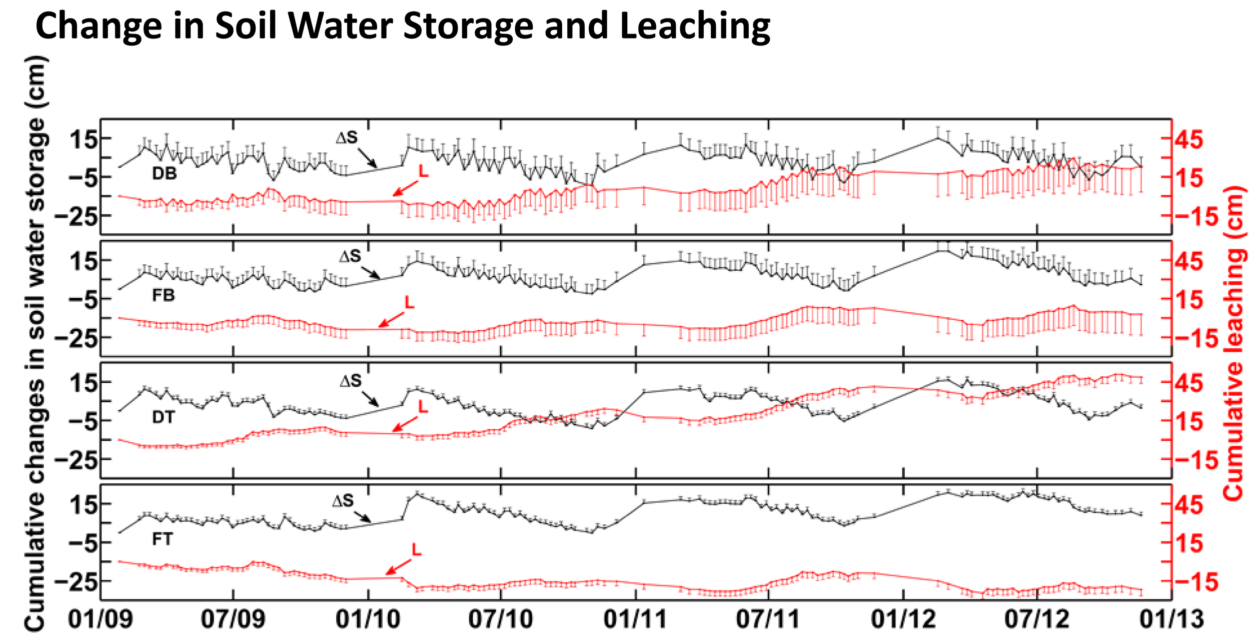


Figure 6. Cumulative amount of in soil water storage (black line), and leaching (red line) in DT, DB, FB, and FT for four consecutive of years of 2009-2013. Average values are presented by the thick lines, whereas the spatial variations are presented by the error bars, defined by standard deviations.

Correlation between Irrigation (size) and Leaching (color)

Figure 7. Locally measured Irrigation Water (IW) (circle size) and leaching (color bar) across the orchard. The minimum and maximum amount of total IW is 492 and 564 cm, respectively.

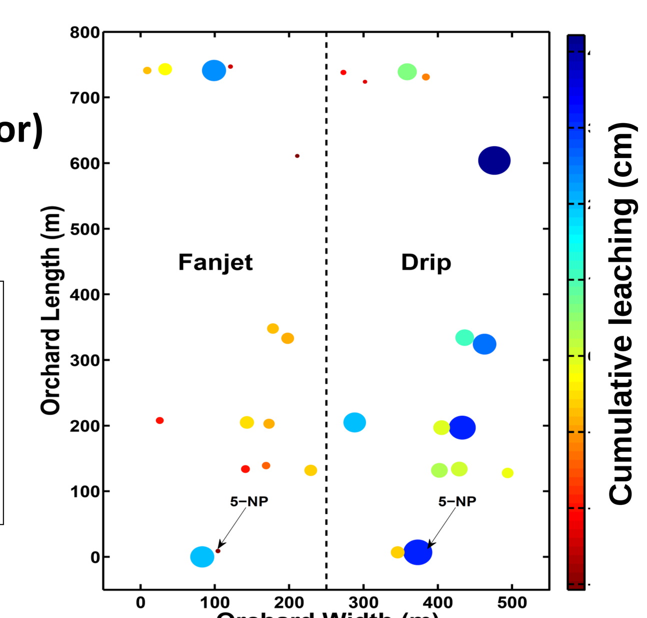


Table 1. Temporal and spatial variation in cumulative amount of precipitation, evapotranspiration, applied irrigation water, soil water storage, and leaching for field, irrigation block, and tree scale

		2009	2010	2011	2012	Total
Rainfall		3.88	9.28	4.71	3.43	21.3
ET_c		63.78	54.33	54.33	55.91	228.35
Irrigation	Field	55.3(±2.7)	50.3(±3.1)	49.3(±2.7)	48.6(±2.3)	205.7(±7.5)
	Drip	55(±3.4)	52(±3.1)	49.8(±2.6)	50(±1.7)	208.7(±7.9)
	Fanjet	55.5(±1.8)	49.5(±2.4)	48.7(±2.7)	47.3(±2.1)	202.8(±5.8)
Change in Soil Storage	Field	1.6(±2.2)	1.9(±1.7)	3(±1.5)	-6.2(±2)	0.5(±2)
	Drip	0.3(±2)	1.8(±1.9)	3.2(±1.3)	-5.8(±1.9)	0(±2)
	Fanjet	2.9(±1.6)	2(±1.5)	2.8(±1.6)	-6.6(±1.9)	1(±1.9)
Leaching	Field	-2.6(±3.3)	2.1(±3.2)	-3.4(±2.9)	1.4(±2.9)	-0.5(±7.8)
	Drip	-1.5(±3.7)	3.5(±3)	-3(±2.8)	2.3(±2.5)	2.9(±7.7)
	Fanjet	-3.6(±2.6)	0.7(±2.7)	-3.8(±2.9)	0.5(±3.1)	-3.8(±6.3)

Darcy equation

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

$$q_{A-B} = -K(h)\frac{H_B - H_A}{\Delta Z_{A-B}};$$

$q = leaching\ (L/T)$
$K(h) = average\ unsaturated\ hydraulic\ cunductivity\ between\ A\ and\ B$
$h = matric\ head;$
$H_B = total\ head\ at\ B$
$H_A = total\ head\ at\ A;$
$\Delta Z_{A-B} = \text{distance between } A \text{ and } B$

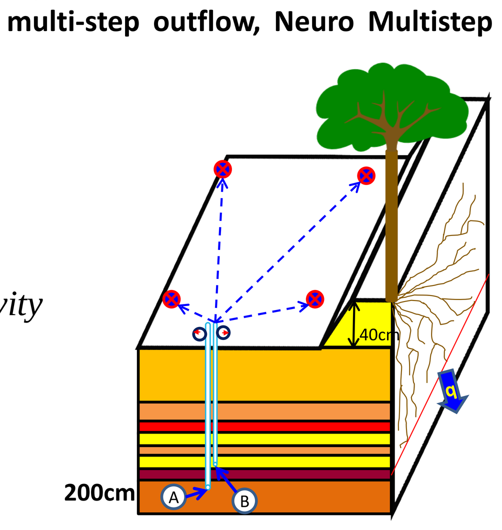


Fig. 8. A schematic of the tensiometer installation below the tree root zone.

Soil water retention and hydraulic conductivity curves

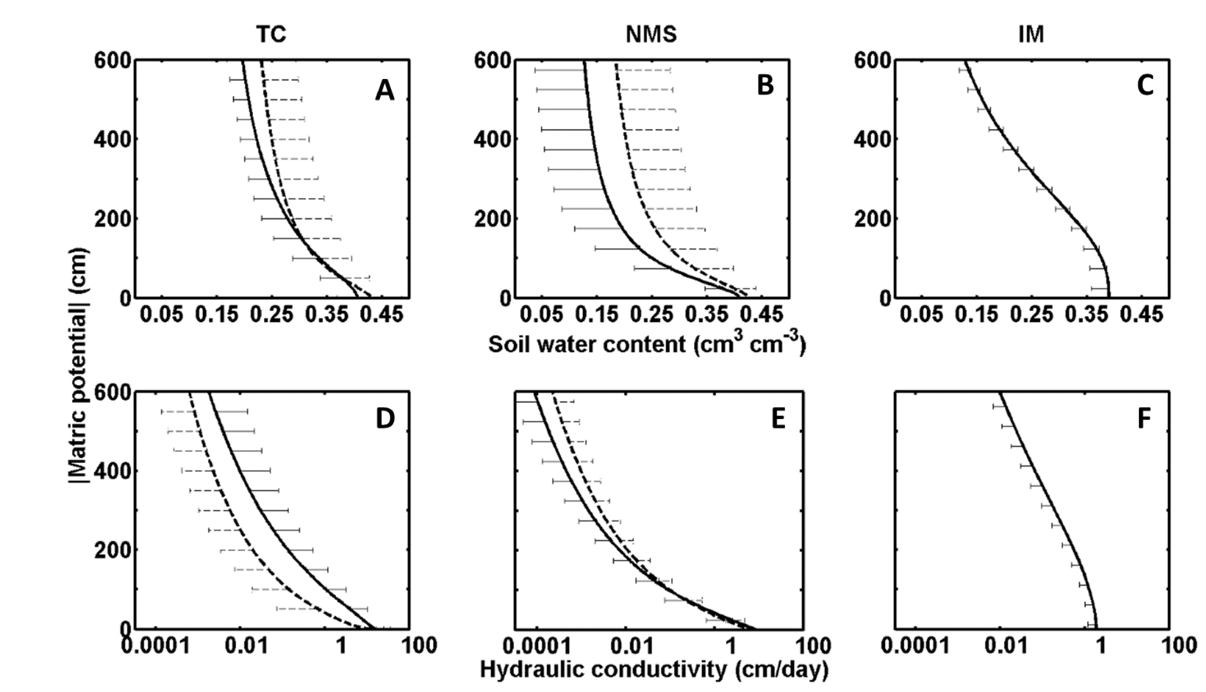


Figure 9. The soil water retention (top panels) and unsaturated hydraulic conductivity (bottom panels) curves of 195-225 cm soil layer of FT (solid lines) and DT (dashed lines) tree plots.

Soil water status: Observation vs. Simulation

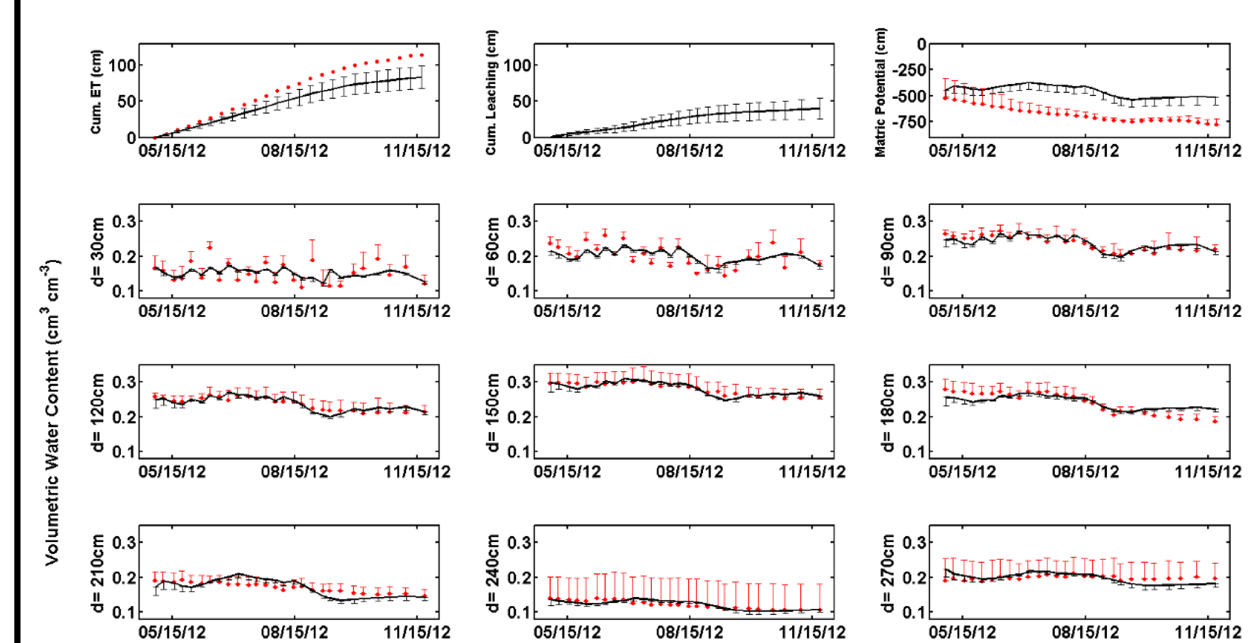


Figure 10: Comparison of simulated (black lines) and observed (red circles) ET and soil water status. The top tree panels show cumulative ET (left), cumulative leaching (middle), and soil matric potential at depths 200 and 220 cm (right). The bottom nine panels show the soil water contents at depth "d". The red error bars represent the uncertainties (standard deviation) of observed soil water content. The black error bars show the standard deviation of simulated values using soil hydraulic properties and ET estimated through the 17 inverse modeling scenarios.

Leaching rate calculated by Darcy equation

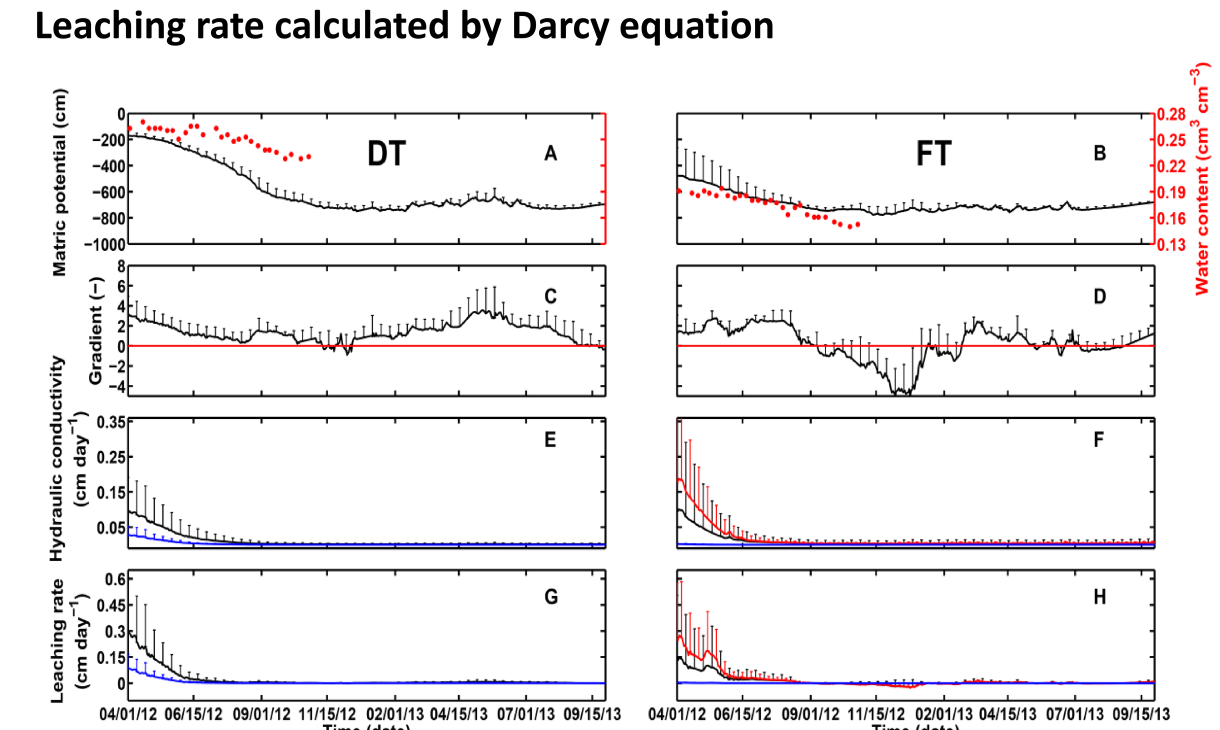


Figure 11: Spatial and temporal variations of matric potential (black line) at the 200 and 220 cm, and soil water content at 210 cm (red circles) soil depth for (A) DT and (B)FT, total head gradient for (C) DT and (D)FT, hydraulic conductivity for (E) DT and (F)FT, and leaching rate for (G) DT and (H)FT as measured for 4 locations (Fig. 3.1), starting April 1, 2012 through Sep 30, 2013. Average values are presented by the thick lines, whereas the spatial variations are presented by vertical error bars, represented by standard deviation.

Table 2: Cumulative leaching (cm) in DT and FT estimated using different approaches of WB, DL, and NM.

		WB	DL			NM	
			TC	NMS	IM	FET	IMET
May2012 - Nov.2012	DT	11(±2.5)	4.2(±5.6)	1(±0.8)	49(±28)		
	FT	-1.3(±2.4)	3.1(±7.9)	0.1(±0.1)	5(±6)	21(±6)	40(±14)
Feb.2009 - Nov.2012	FT	-21.8(±4.7)				21(±5)	171(±64)

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