Quantifying Nitrate Leaching from Central Valley Irrigated Lands using the Soil & Water Assessment Tool (SWAT)

BACKGROUND AND OBJECTIVES

Central Valley growers regulated under the Irrigated Lands Regulatory Program (ILRP) are required to assess the effects of crop management practices on groundwater quality. Such assessments are complex, even when performed on a single, relatively uniform experimental plot. The methods used for such small areas cannot be readily adapted to evaluate the Central Valley's approximately 6.2 million acres of irrigated lands. Fortunately, over the last 30 years, USDA-ARS at Texas A&M have developed a computer-based, user-friendly approach: the Soil and Water Assessment Tools (SWAT). SWAT contains physically and biologically based models of crop growth, hydrologic, and soil processes, operates at field and soil-mapping-unit scales, and combines results for whole watersheds or regions. Processes are simulated within SWAT based on user-defined management parameters. Applications have been documented extensively in over 3,500 peer reviewed papers on diverse topics, including surface water and groundwater assessments, sensitivity analysis, model calibration, validation, and specific applications, all at a variety of scales, and in varied geographies and cropping/management systems (Arnold et al., 2012). **SWAT is being used by 12 ILRP water quality coalitions to evaluate the effects of alternative management practices on water quality. Nitrate leaching to groundwater is a particular focus during this phase of work.**

SWAT MODEL DEVELOPMENT

Domain
The spatial domain is the Central Valley. Modeling domains include the Southern San Joaquin, San Joaquin, and Sacramento valleys. Outputs are reported for Hydrologic Response Units (HRUs). HRUs are unique combinations of climate, crop, and soil mapping unit (Fig 1).

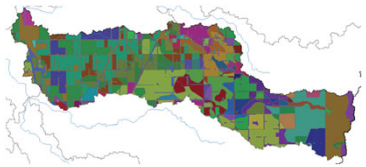

Figure 1. Representation of Hydrologic Response Units in a sub-watershed, as defined in SWAT.

Model Inputs
SWAT inputs include the following:

- Climate data from CIMIS (30-years) [https://cimis.water.ca.gov/WSNReportCriteria.aspx accessed on October 19, 2018]
- Digital Elevation Model from the USGS (SRTM 30-meter)
- Land use data from DWR (2014: https://gis.water.ca.gov/app/CADWRLandUseViewer/) were postprocessed based on information from actual evapotranspiration (ETa) estimates, commodities groups, satellite imagery, and expert judgment (Paul et al. 2018). Consolidated classes were split to distinguish among types of forages and grapes.
- The SWAT soils database was refined in collaboration with NRCS, including hydraulic properties for the majority of map units in the study area. The Saxton and Rawls (2006) pedotransfer functions were used to determine each profile layer's hydraulic conductivity and soil available water capacity.

Soil properties considered:
- Hydrologic group
- Max. soil depth
- Rooting depth
- Bulk density
- Available water capacity
- Hydraulic conductivity
- Soil texture (% clay, silt, sand and rock)

Management Scenario Information
An initial set of model runs represent four scenarios/runs of irrigation practice and nitrogen (N) management. Run 1 (a base case) considers standard "good" irrigation practice and N management, based on the most recent, survey-based information on irrigation amount and timing for each crop, and up-to-date, N rates that are known to be sufficient to produce a good crop. Three other scenarios examine the effects of less efficient irrigation practice and N management, individually and together (Table 1).

Table 1. Initial SWAT Model Run Scenarios

Management		SWAT Run Number			
Quality	Parameter	1	2	3	4
Standard "good"	Irrigation practices	x	x		
	Nitrogen management	x		x	
Less efficient	Irrigation practices			x	x
	Nitrogen management		x		x

SWAT MODEL CALIBRATION

Calibration targets based on the best current understanding of Central Valley cropping systems' hydrology and N management/uptake.

Hydrology based on the CalETa data set: CalETa - 7 years, daily, 30-meter-scale (5-pixel/acre), statewide, actual ET. These data informed irrigation practice definitions, and provided a standard against which modelled evapotranspiration (a key rootzone hydrologic parameter) could be compared (Fig 2).

Nitrogen Management Plan (NMP) data to evaluate the SWAT N budget: Anonymized 2016 NMP data were used to help guide N management definitions (Fig 3).

Crop parameterization to precisely simulate crop growth: SWAT contains more than 130 crop models that can adapted to local conditions. Considerable modification was necessary to ensure that results for the largest among the 37 final irrigated lands classes aligned with targets. Detailed information was developed for each crop and model parameters were adjusted to calibrate growth, N and water uptake, leaf area, biomass production, yield, N fate, and other parameters based on scientific literature and extensive consultation with UC Extension Specialists, Farm Advisors, and industry experts (e.g. Table 2).

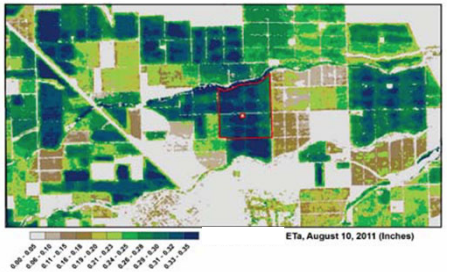

Figure 2. Actual evapotranspiration map from CalETa.

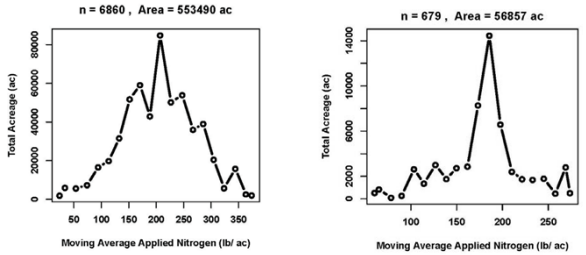

Figure 3. Distributions of reported nitrogen application rates for over 600,000 acres planted with two crops. These served as references when developing parameters to represent realistic management scenarios for these crops.

Table 2. Almond management operations in one SWAT scenario.

Date	N fertilization (kg/ha)	Harvest		
12-Mar	35			
19-Apr	45			
10-May	50			
1-Jun	50			
30-Jun	40			
24-Aug		xxx		
7-Sep	30			
Total	250			
Irrigation schedule	Irrigation Dates	mm per irrigation	# of irrigations	mm applied
Jan	5	40	1	40
Feb	15	25	1	25
Mar	1, 12, 24	25	3	75
Apr	1, 7, 13, 19, 25	25	5	125
May	1, 5, 10, 14, 19, 24, 29	25	7	175
Jun	1, 4, 7, 10, 14, 17, 20, 24, 28	25	9	225
Jul	1, 4, 7, 10, 13, 16, 19, 22, 25, 28	25	10	250
August	1,4, 7, 10, 14, 17, 28	25	7	175
Sep	1, 7, 13, 19, 24, 29	25	6	150
Oct	2, 9, 17	25	3	75
Total			52	1315 (51.8 in.)

RESULTS

- SWAT simulated water and nutrient balance components for each HRU. Average HRU area was 173 acres in the SSJV.
- Figures 4 and 5 show aggregated monthly results for selected crops.

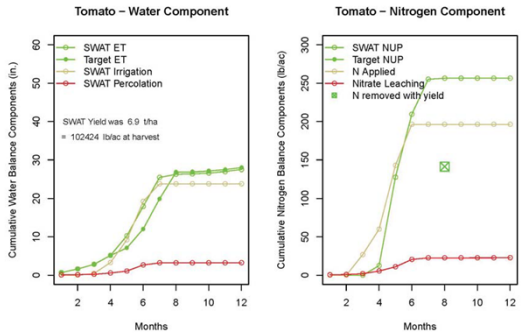

Figure 4. SWAT simulated vs. target monthly crop hydrology and nitrogen cycle components, aggregated for tomato HRUs.

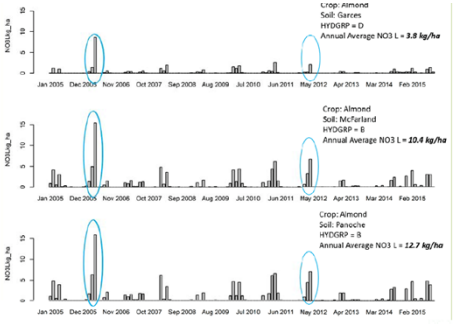

Figure 5. SWAT simulated monthly nitrogen leaching results for 3 almond HRUs (planted on 3 different soils).

NEXT STEPS

- Evaluation of varied suites of management practices, initially for major crops, and eventually other land use land cover classes.
- Serving of grower views of results on web-based tools to facilitate comparisons of performance among alternative management systems.

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SSJV MPEP Committee Coalitions

Buena Vista Coalition
Cawelo Water District Coalition
Kaweah Basin Water Quality Association
Kern River Watershed Coalition Authority
Kings River Watershed Coalition Authority
Tule Basin Water Quality Coalition
Westside Water Quality Coalition

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