Adaptation of the Soil and Water Assessment Tool (SWAT) To California's Central Valley By Long-Term Irrigated Lands Regulatory Program Water Quality Coalitions

Ken Miller – Formation Environmental

CWEMF 2023 Annual Meeting – Session 17

April 18, 2023

FORMATION ENVIRONMENTAL

Topics

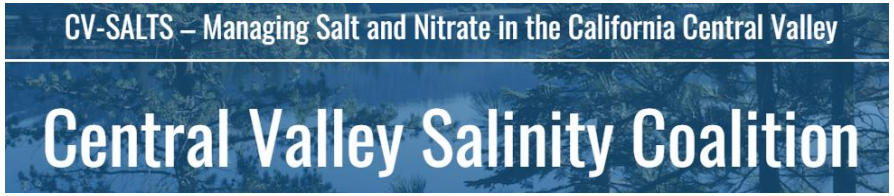
1. Background on water quality concerns and regulations
2. Adaptation of SWAT to reflect Central Valley Agriculture (CV-SWAT)
3. Use of CV-SWAT to estimate nitrate loading below the root zone
4. CV-SWAT Augmentation to model salt fate and transport

FORMATION ENVIRONMENTAL

mpepTEAM

University of California
Agriculture and Natural Resources

Southern San Joaquin Valley Management Practices Evaluation Program Committee

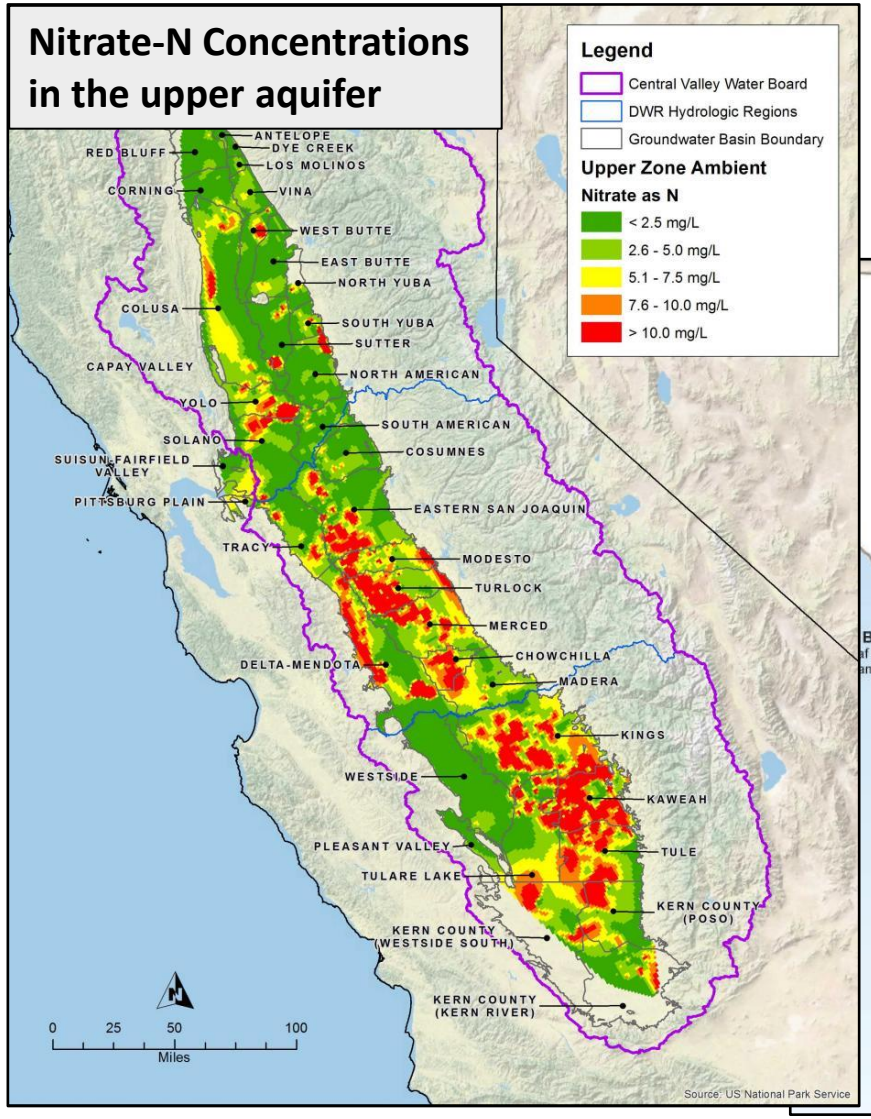


Sacramento Valley Water Quality Coalition

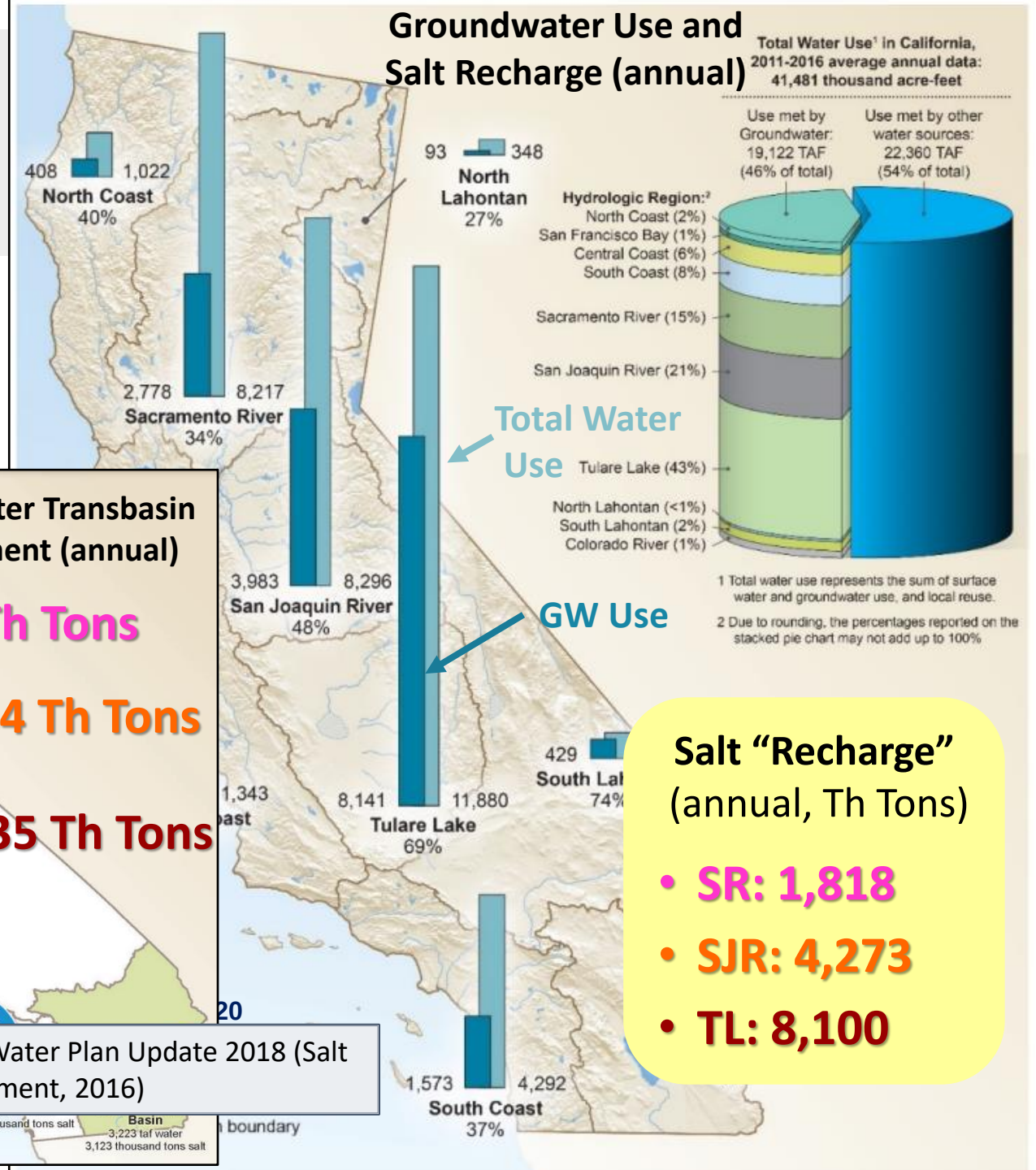
USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Grasslands Drainage Area

Nitrate and salt accumulation in the Central Valley Aquifer



From DWR, Calif. Water Plan Update 2018 (Salt & Salinity Management, 2016)

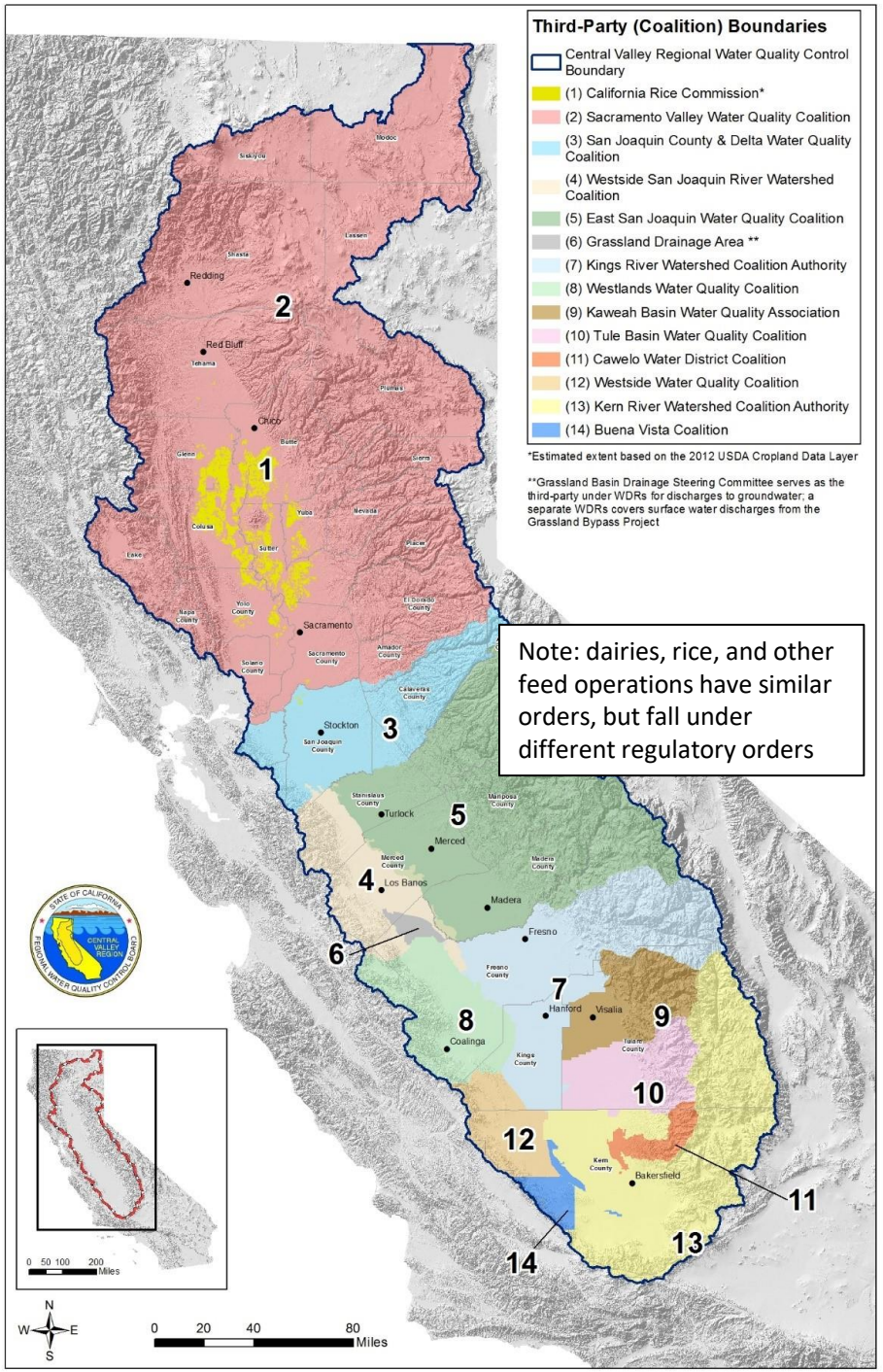


Salt "Recharge"
(annual, Th Tons)

- **SR: 1,818**
- **SJR: 4,273**
- **TL: 8,100**

Irrigated Lands Regulatory Program (ILRP)

- Goal – Restore and/or maintain the highest reasonable water quality while maintaining economic viability of agriculture in the Central Valley
- In response, growers organized into 14 water quality coalitions (see map)
  - 24,000 members farm ~5.5 million acres
- Select program components:
  - Management Practices Evaluation Program (MPEP)
  - Groundwater Protection Program (GWP)
  - Monitoring and reporting: Irrigation and Nitrogen Management Plan Summary Reports



Strengths of the SWAT model

- Feasible to implement landscape-level assessments
- Physically based, comprehensive
- Long time periods, but short modeling intervals (daily routine)
- Sub-field spatial resolution
- Considers crop growth, nutrient and water uptake, local climate, local soil properties
- Management practices can be specified, and management scenarios compared

SOIL & WATER ASSESSMENT TOOL

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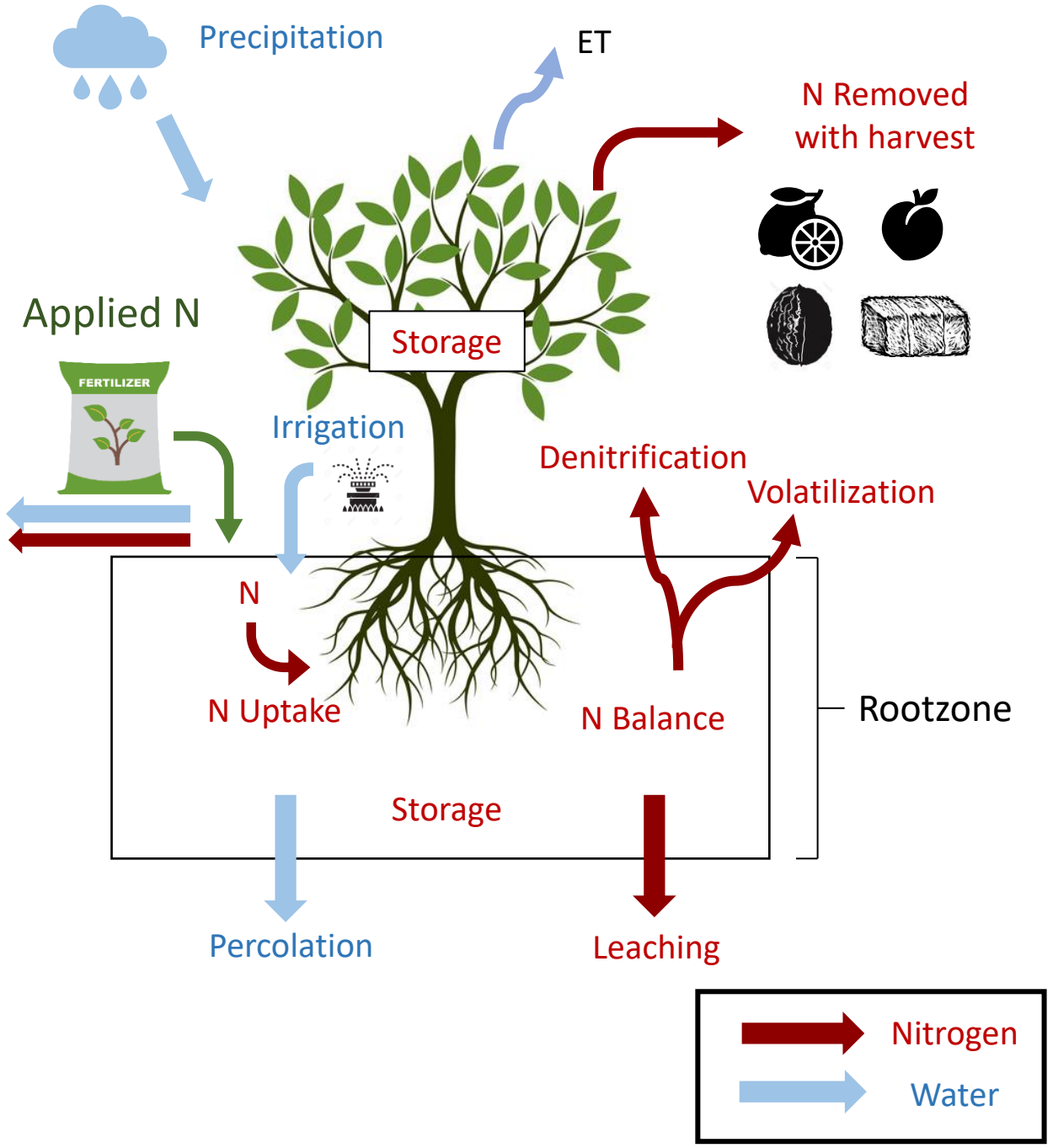

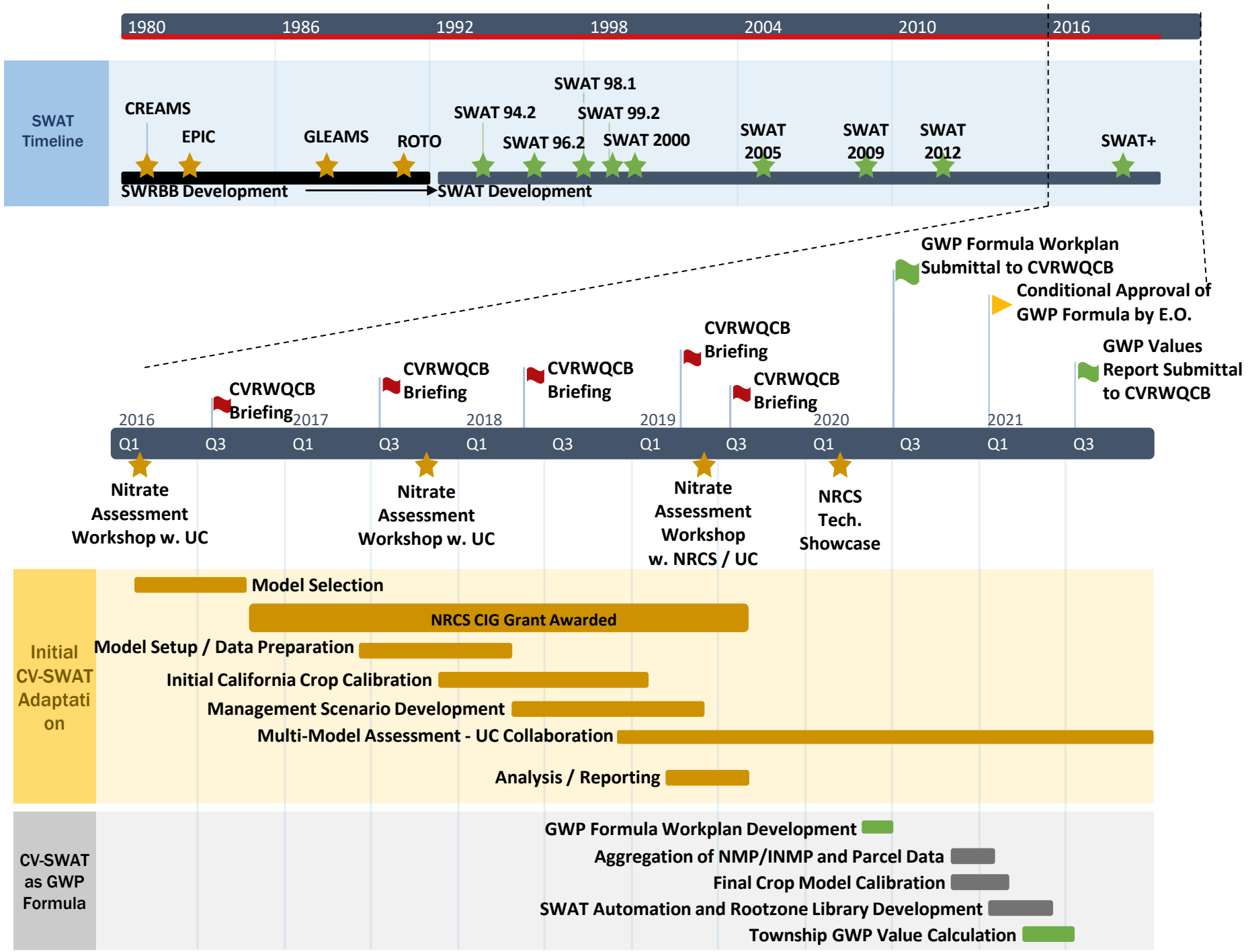
1980
1986
1992
1998
2004
2010
2016
SWAT Timeline
CREAMS
EPIC
GLEAMS
ROTO
SWAT 94.2
SWAT 96.2
SWAT 98.1
SWAT 99.2
SWAT 2000
SWAT 2005
SWAT 2009
SWAT 2012
SWAT+
SWRBB Development
SWAT Development
GWP Formula Workplan Submittal to CVRWQCB
Conditional Approval of GWP Formula by E.O.
GWP Values Report Submittal to CVRWQCB
CVRWQCB Briefing
CVRWQCB Briefing
CVRWQCB Briefing
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2016
2017
2018
2019
2020
2021
Q1
Q3
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Q1
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Q1
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Q3
Q1
Q3
Nitrate Assessment Workshop w. UC
Nitrate Assessment Workshop w. UC
Nitrate Assessment Workshop w. NRCS / UC
NRCS Tech. Showcase
Initial CV-SWAT Adaptation
Model Selection
NRCS CIG Grant Awarded
Model Setup / Data Preparation
Initial California Crop Calibration
Management Scenario Development
Multi-Model Assessment - UC Collaboration
Analysis / Reporting
CV-SWAT as GWP Formula
GWP Formula Workplan Development
Aggregation of NMP/INMP and Parcel Data
Final Crop Model Calibration
SWAT Automation and Rootzone Library Development
Township GWP Value Calculation

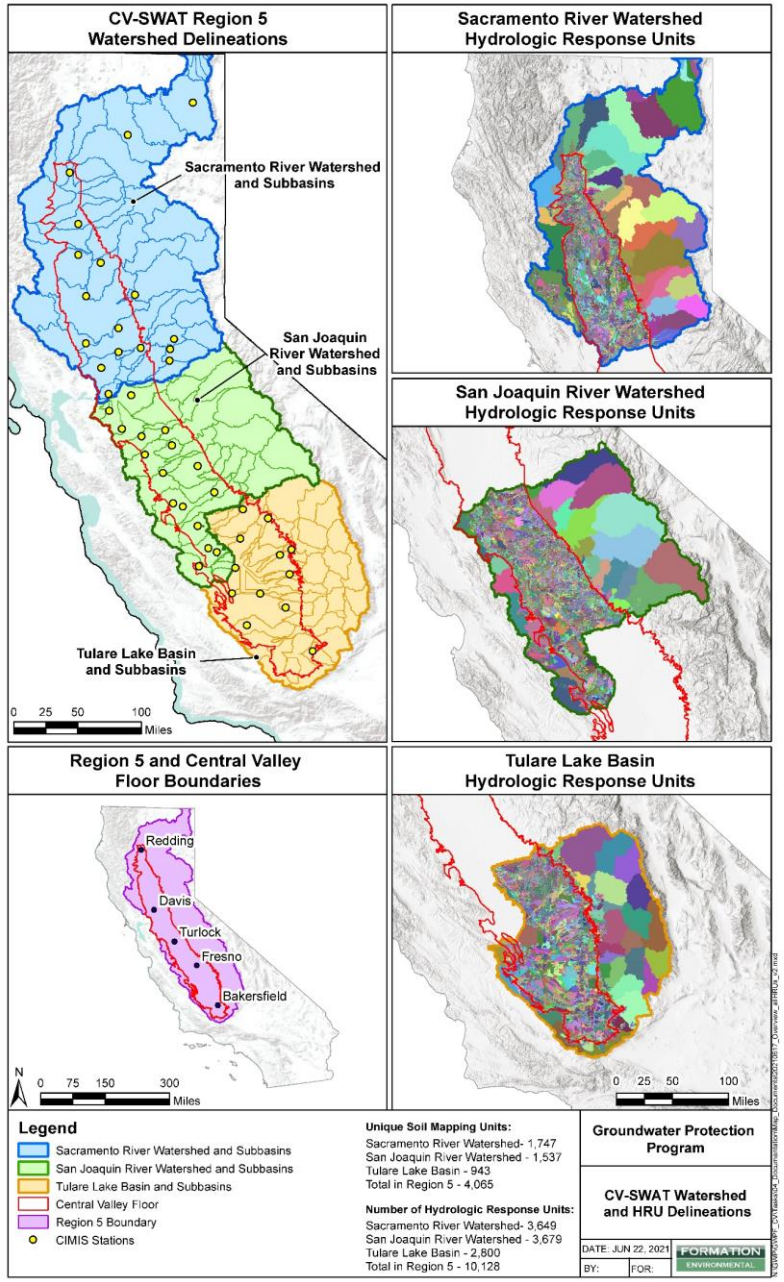
CV-SWAT Inputs

Climate

- CIMIS - daily record from 1983 – Present
- Solar radiation, Relative humidity and wind speed, temperature, precipitation
- Crop growth, ET, hydrology, nutrient cycling

Soil

- Modified version of SSURGO from NRCS Modelers under CEAP program– “PEDON”
- Properties used in SWAT:
  - Texture, bulk density, organic carbon, water holding capacity, ksat, hydrologic group, depth



Management

- Reflective of current practices and recommendations
- Based upon extensive reporting by growers on irrigation and nitrogen management (“INMP Reports”)
- Informed and vetted by UC and industry experts
- Consideration of rate and timing
  - Crop demand, mode of application
  - Grower reported data
  - Region

Example management for 4 SSJV crops.

Irrigation

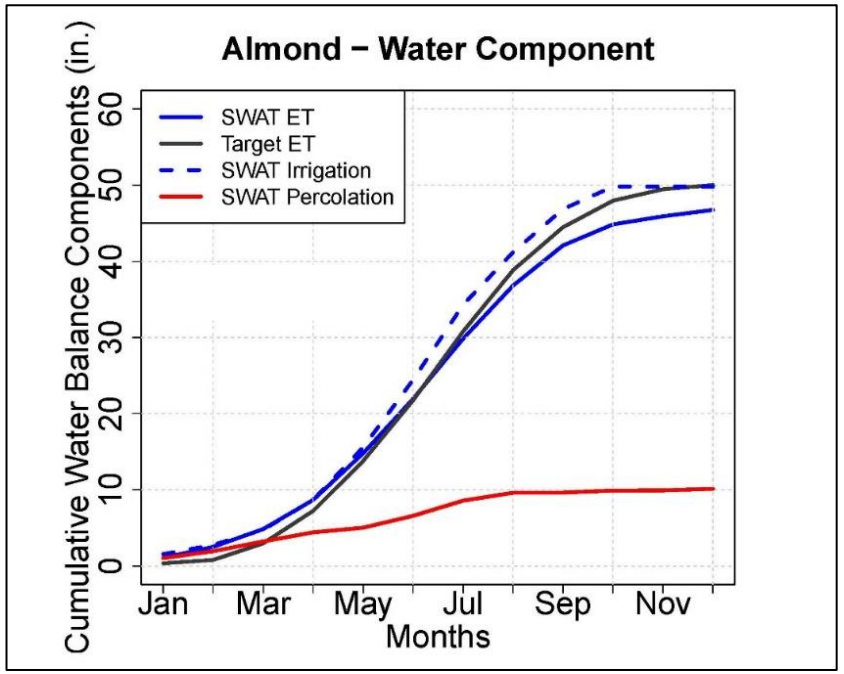
Crop	Irrigation Type	Irrigation Events	Total Applied Water (mm)
Almond	Micro-sprinkler	48	1215
Table Grape	Surface Drip	44	880
Processing Tomato	Subsurface Drip	38	605
Winter Wheat	Sprinkler	4	325

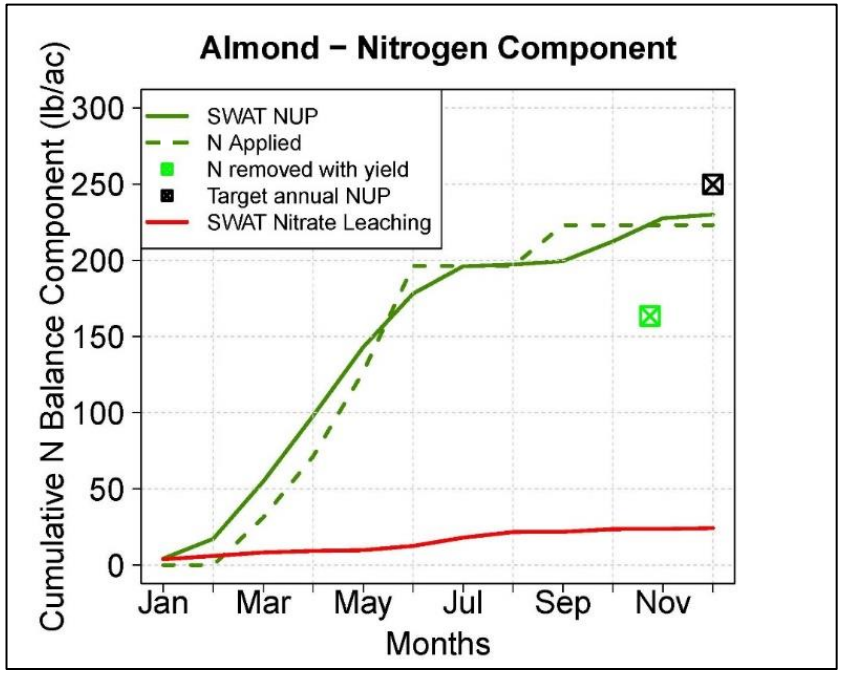
Fertilization

Crop	Fertilizer Type	Fertilization Events	Total Applied N (kg/ha)
Almond	URAN32	6	235
Table Grape	URAN32	2	70
Processing Tomato	$(NH_4)_2SO_4$(preplant) URAN32 (in-season)	7	230
Winter Wheat	$(NH_4)_2SO_4$ (preplant) Urea (in-season)	3	190

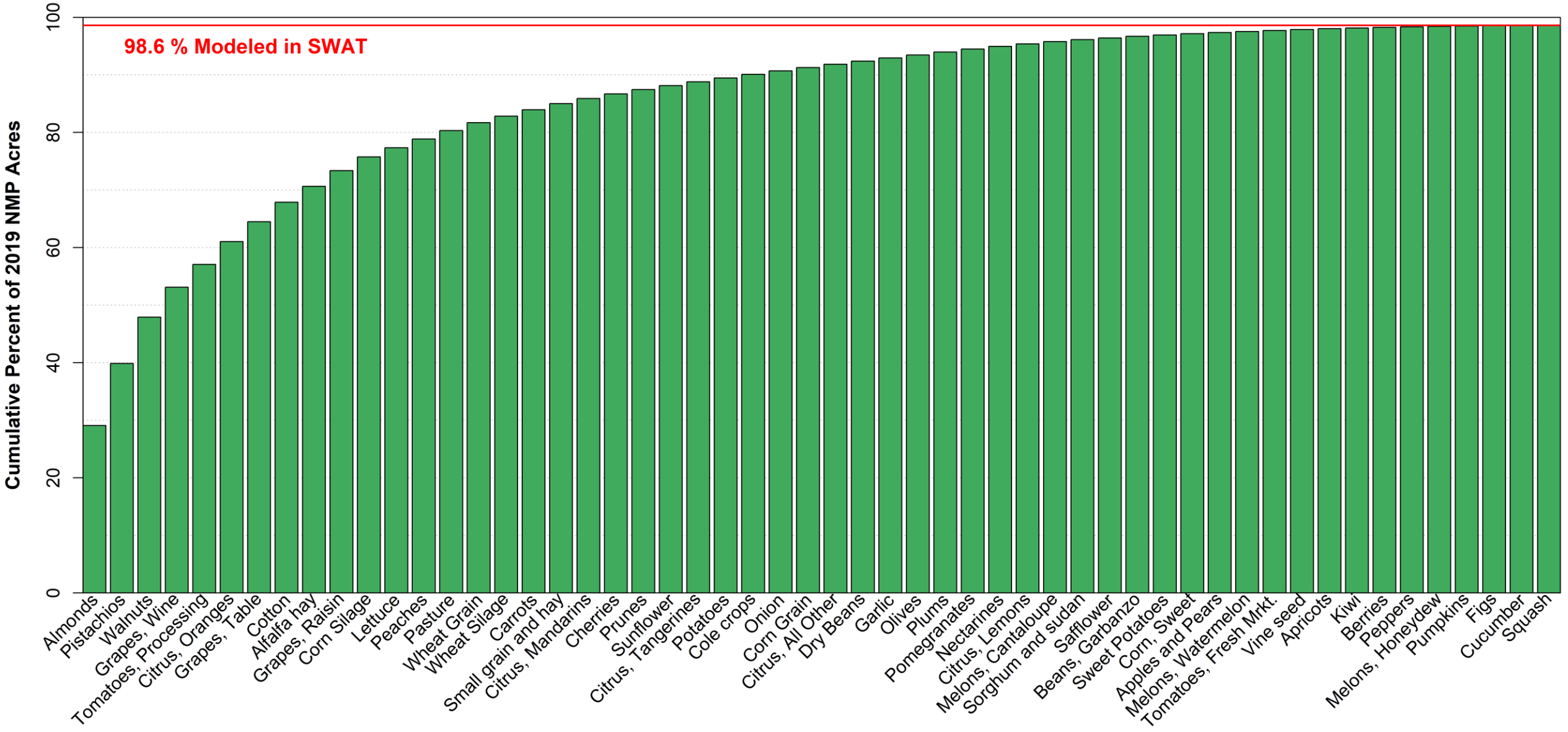
Crop Model Calibration

- Iterative process, evaluated over space and time
- In-season N and water balances, growth and yield
- Informed by literature, grower-reported data, County Ag Comissioners, spatial CIMIS, CalETa



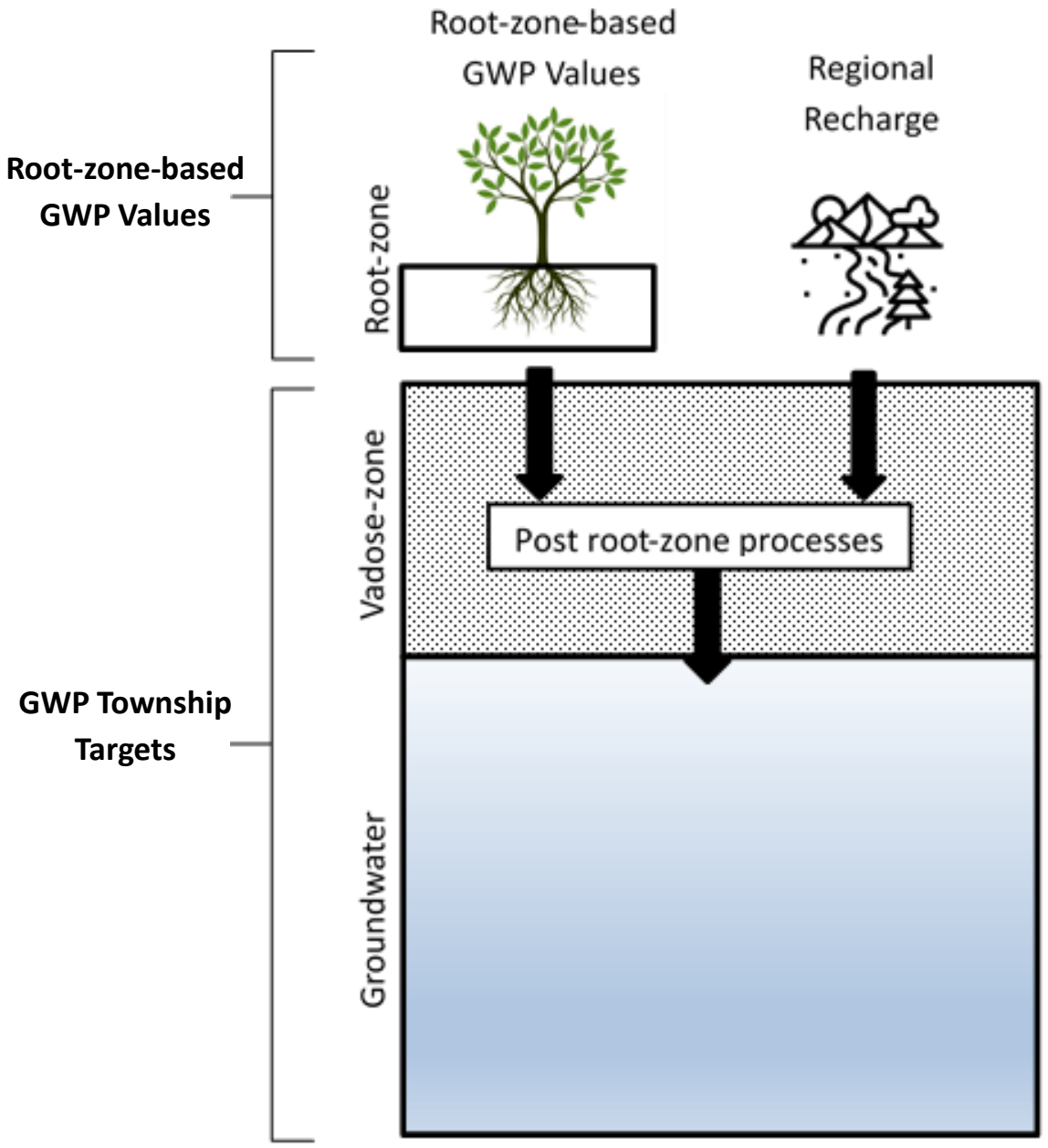


Crops modeled in CV-SWAT



Groundwater Protection Program

- The Order Requires:
  - **GWP Formula:** Data and Methods
    - Grower INMP data + CV-SWAT model
  - **GWP Values:** Township Leaching Estimates
  - **GWP Targets:** Township Targets to Achieve Compliance for irrigated agriculture



Root-zone GWP Formula and Values

Step 1 – Aggregate Data

Aggregate & analyze data

Finalize Formula Components and Crop/ Mgmt. Matrix

+

Step 2 – Develop Root-zone Library

Develop Root-zone Library using the Central Valley SWAT Model

=

Step 3 – Calculate Root-zone GWP Values

Soil Type

Land Use & Climate

Parcels

INMP Data

Data Analysis

Soil

Land Use

Mgmt.

Final Crop Mgmt. & Yield Matrix

Automated CV-SWAT

Soil Type

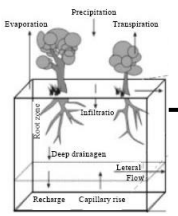
Crop Type

SWAT

Soil & Water Assessment Tool

Mgmt.

Climate



Crop "Books"

Rootzone Library

SQL Database and Query Logic

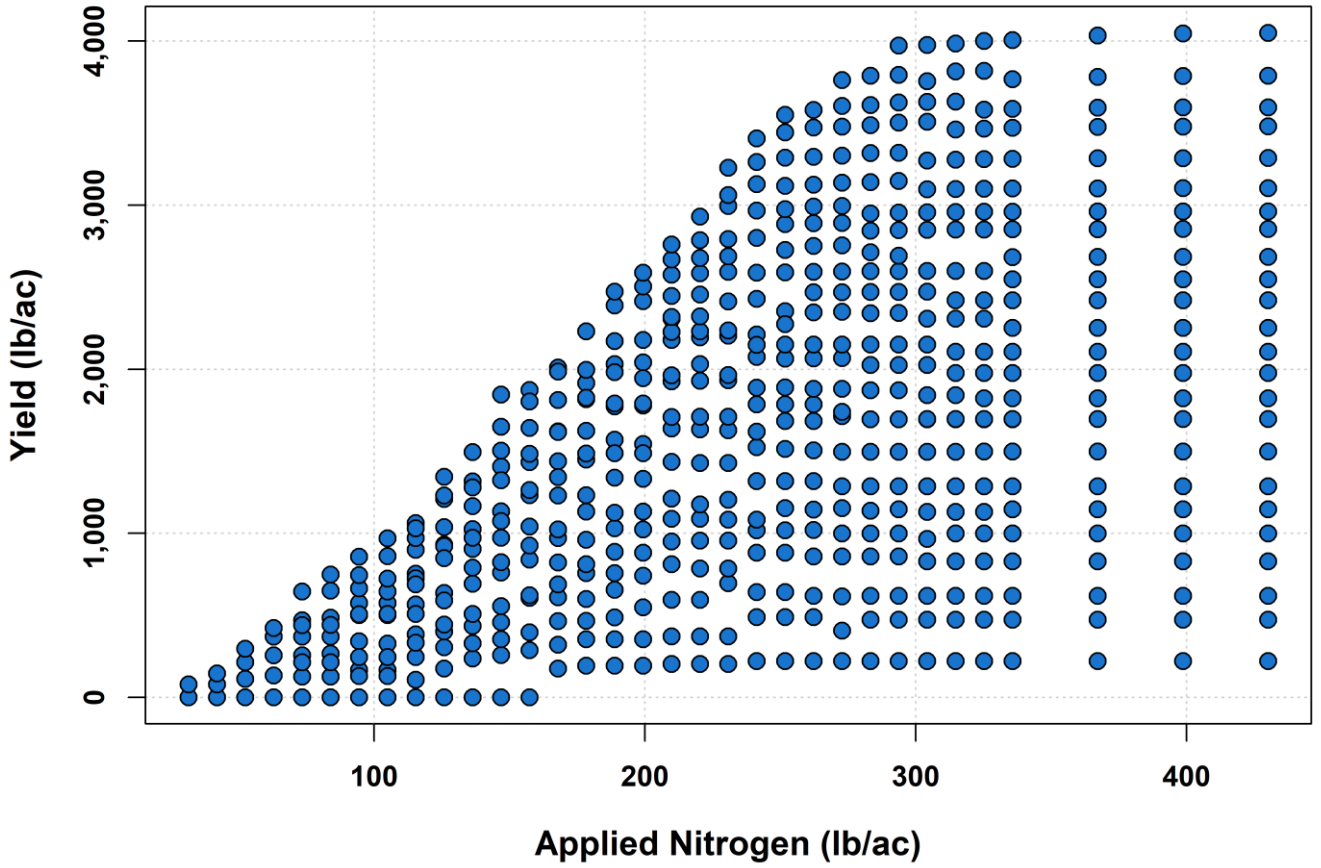
Final Township Value Calculator

Reporting

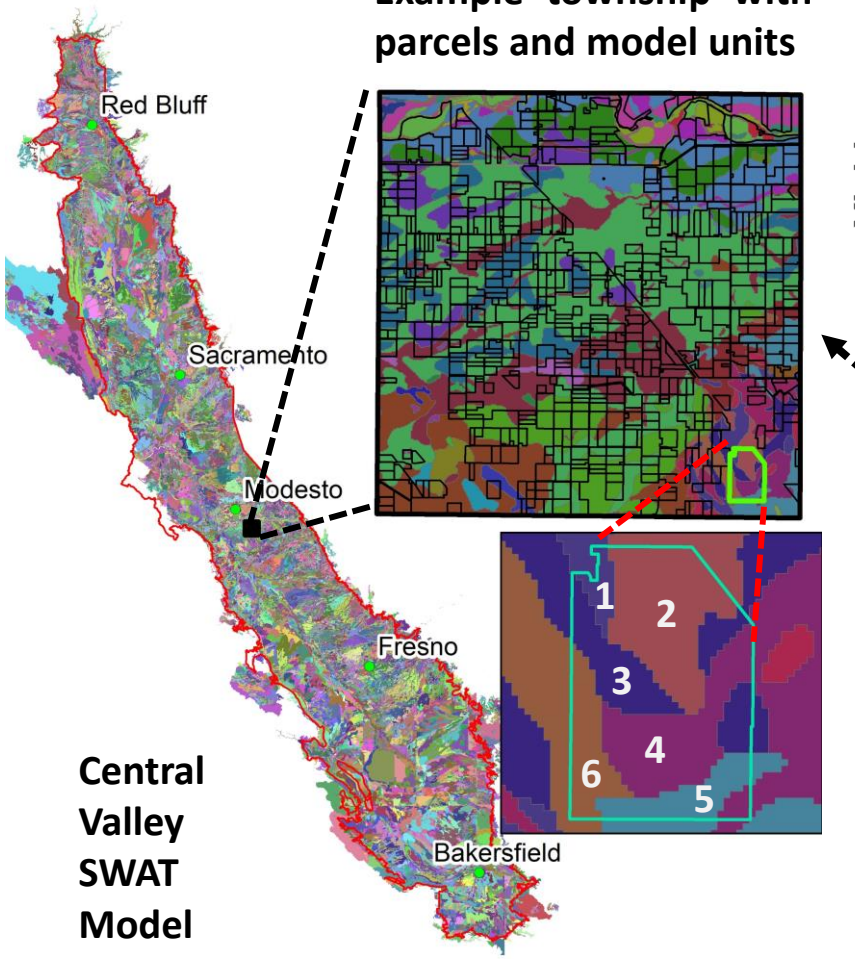
Rootzone Library

- 129 unique crop models developed across 3 watersheds
- 500 – 760 scenarios for each crop
- Range of grower-reported NMP data captured
- 6 million datapoints per crop
- More than ½ a billion results for the Central Valley

Example of range of applied nitrogen and yield for a crop. Datapoints are watershed averages for each scenario.

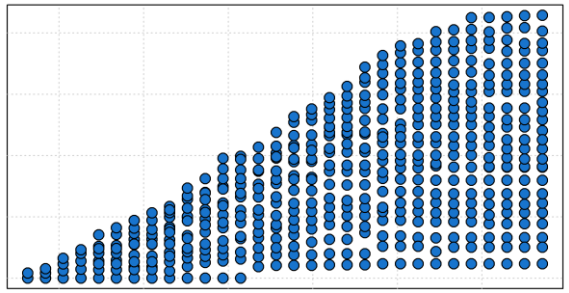


GWP Township Value Calculation



Central Valley SWAT Model

Example township with parcels and model units



Each model unit, for each crop, has simulations spanning range of grower-reported applied N and yield, along with modeled leaching estimate

GWP Value calculation workflow done for each parcel in township

INMP Report contains:
Respective APN (related to soil x climate)
Crop, N Applied, Yield

Find closest Root Zone Library match to crop, applied N, and yield for each soil

Acre-weight match results to calculate estimate for parcel

Calculate estimates for each parcel and aggregate to the Township

GWP Values Report:

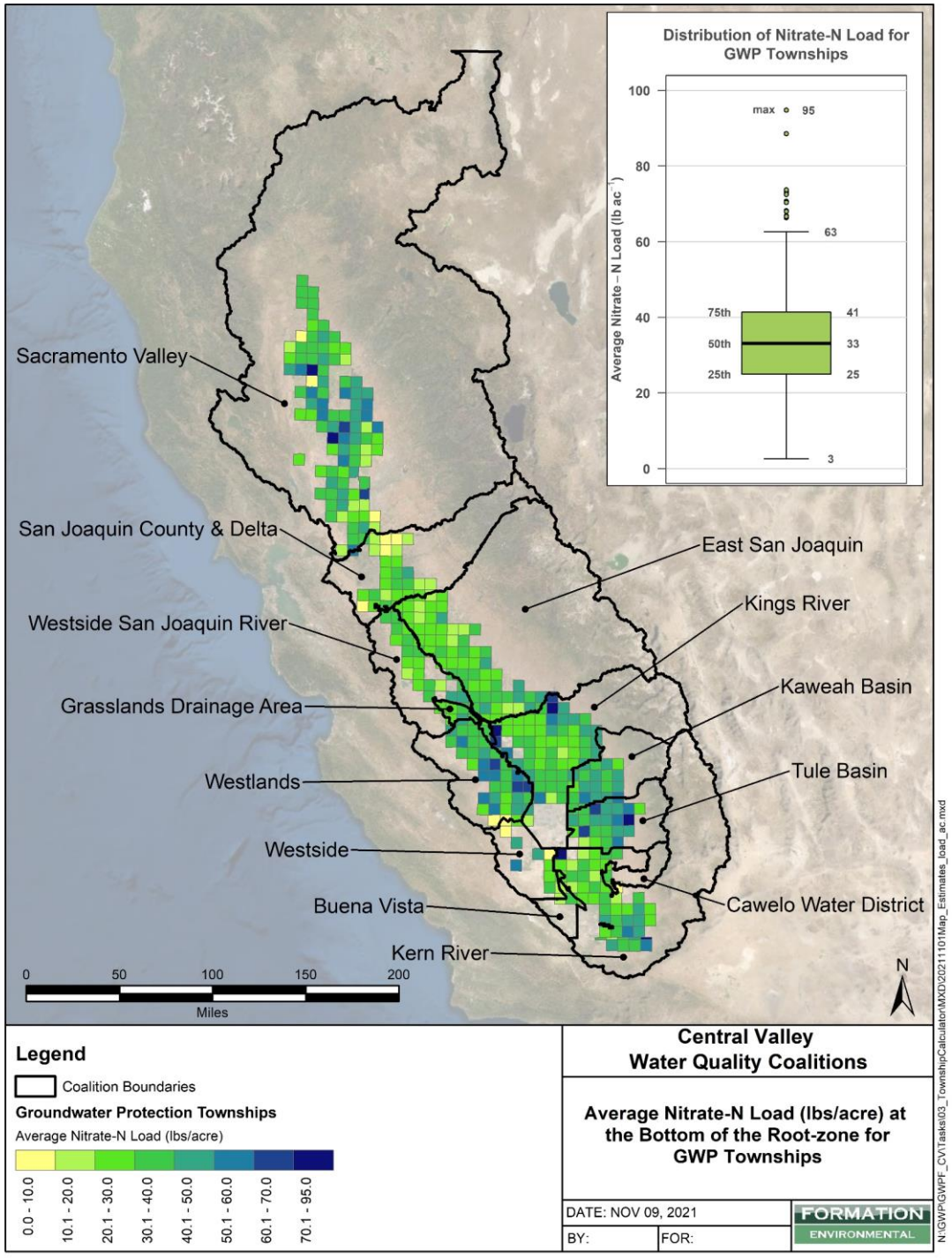
- Detailed township summary tables of modeling results
  - Nitrogen and water balances

- Summary of nitrogen pathways by crop by watershed (TLB/SJV/Sac Valley) for top 5 crops by acreage
  - Gaseous losses, runoff, perennial tissue, soil organic matter

- Comparisons to other sources of percolation and nitrate leaching estimates
  - Literature, other models

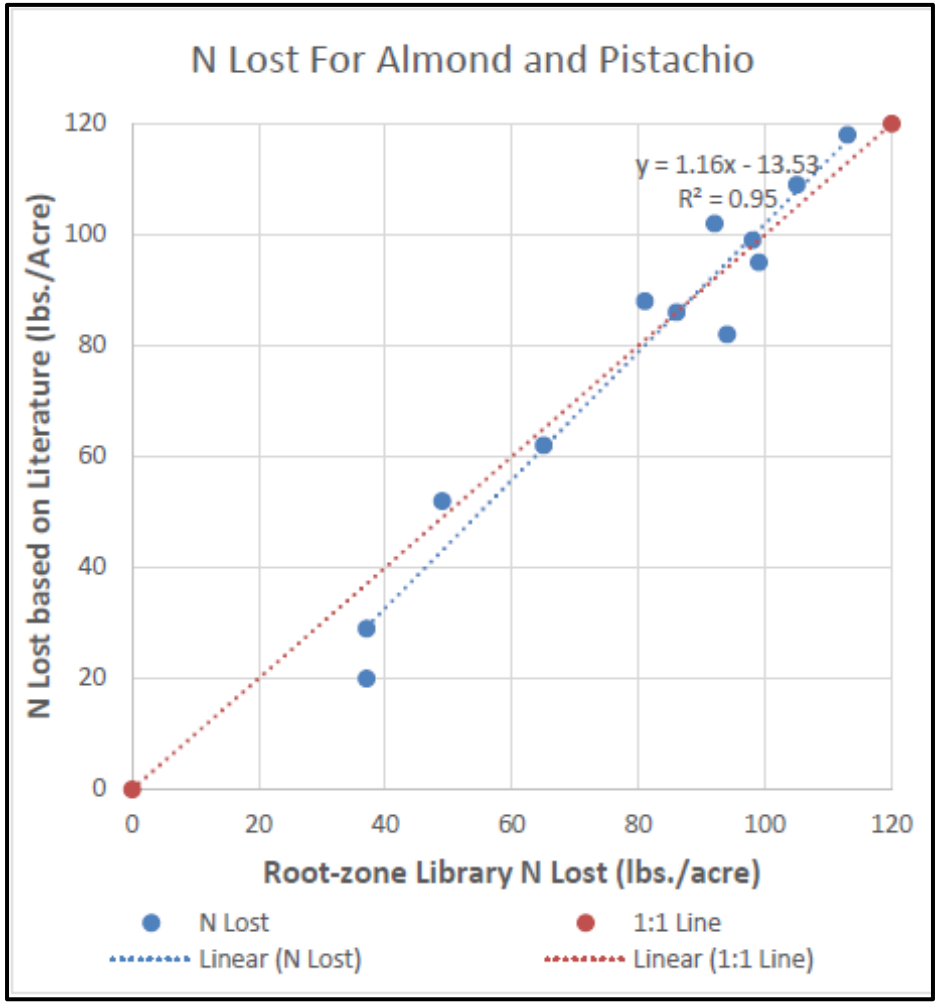
- Sensitivity Analysis on N pathways for top 5 crops by acreage

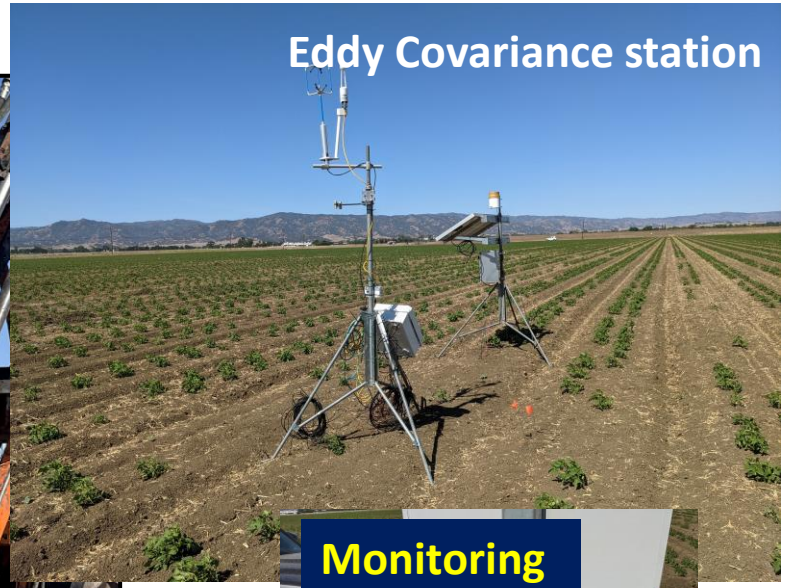
- Model and rootzone library documentation



CV-SWAT Validation

Comparison to CV field studies





Additional Applications of CV-SWAT Rootzone Library

- Resource for coalitions and growers to understand current state of agriculture regarding N loading and adapt as/where needed
- Support prioritization of outreach and education to achieve greatest near-term impact across the landscape

Salinity

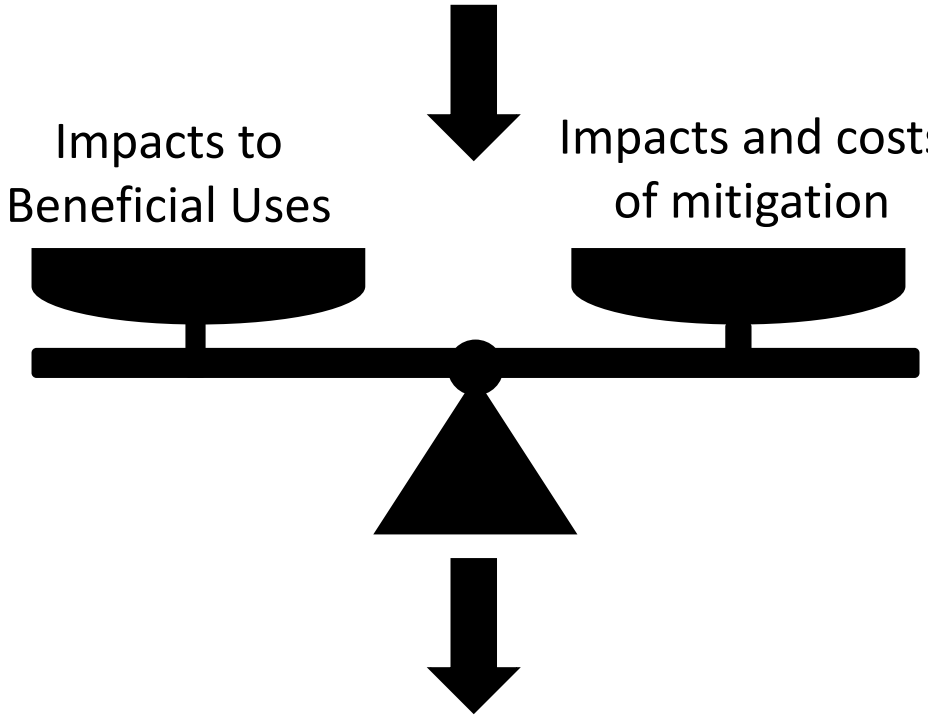
CV-SALTS Prioritization and Optimization Study Big Picture

Stakeholder driven process to develop Long-term salt management solutions to protect beneficial uses

<u>Key Information derived from analytical tools:</u>

- Understanding how the system works
  - Key drivers of salinization
  - What we can and can't manage/control
- Ability to impact salt accumulation and salinity concentrations.
  - Effectiveness of range of management and regulatory options

Management & Regulatory Alternatives



Project Prioritization & Optimization

CV-SWAT Augmentation to model salinity

- Collaboration with SWAT developers
  - Dr. Jeff Arnold, USDA ARS
  - Dr. Jaehak Jeong, Texas A&M
  - Dr. Ryan Bailey, Colorado State University

- Integrating/calibrating:
  - Surface hydrology, water management (based upon DWR's CalSim3)
  - Water allocation to assign irrigation sources to HRUs, conjunctive use based upon water availability
  - Rice module for ~500k of rice in the Sacramento Valley
  - Salinity module to simulate fate and transport of specific ions
  - Point and non-point source salt source information
    - Groundwater and surface water quality, fertilizers and amendments, POTWs, food processors, wineries, stormwater, oil & gas