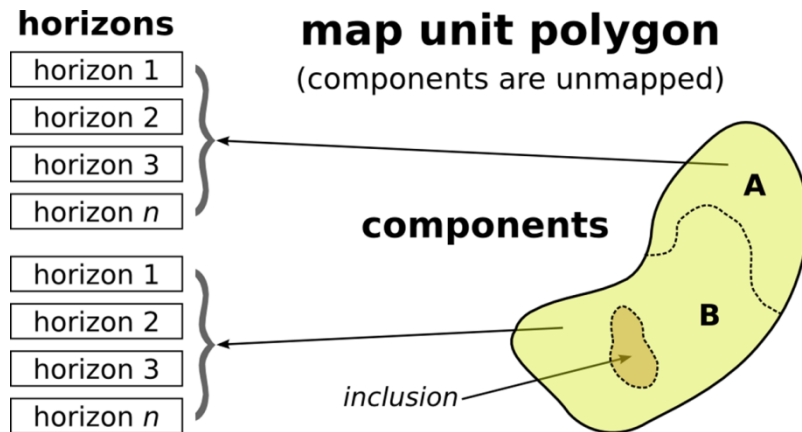


A Vision for a Revised Nitrate Hazard Leaching Index (NHI)



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NHI is a valuable tool to identify the relative differences in nitrate leaching hazard for soils, irrigation schemes, and cropping systems



Convenient
Easy
Representative of CA's
cropping systems and soils



Mapping the Risk of Nitrate Leaching from Irrigated Fields by Use of a Nitrate Hazard Index: Case Study in the San Joaquin Valley of California

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Introduction

Irrigated cropland accounts for 59% of groundwater nitrate concentrations in the southern San Joaquin and Salinas Valleys of California (Harris et al., 2011). Reducing nitrate leaching is primarily achieved by improving crop nitrogen use efficiency (NUE) by better matching application rates and timing of irrigation water and fertilizer to crop requirements.

The difficulty in limiting nitrate leaching from the root zone varies with the crop species, soil properties, and type of irrigation system. Under average management practices, the likelihood of high nitrate leaching loss is greater, e.g., for shallow-rooted and high-value crops that are sensitive to short-term N deficiencies, greater on highly permeable soils with low water-holding capacity, and greater under furrow irrigation compared to drip or microsprinkler irrigation.

Based on this concept, University of California scientists developed a Nitrate Groundwater Pollution Hazard Index (NI) for irrigated agriculture (We et al., 2005). This tool is available online to the public (see <http://www.water.ca.gov/nitrate/>). The NI assigns index values to crop species, soil texture, and irrigation system type, which are multiplied together to produce a composite risk value.

The method allows estimation of risk severity and identification of the major factors contributing to this risk without requiring the large data set needed for more complicated assessment methods (e.g., Delgado et al., 2008; Shaffer et al., 1991). However, the NI method does not consider depth to groundwater, amount of rainfall, or the management practices in actual use on fields, such as fertilizer N rate and irrigation water applied.

In this study, we used the NI to map the risk of nitrate leaching from crop production in a four-county area of the San Joaquin Valley of California. The total area analyzed was 1,318,000 ha of irrigated cropland, devoted mainly to production of grapes, deciduous tree fruits and nuts, citrus, cotton, forages, grains, and vegetables (Fig. 1).

Methods

- Crop species and irrigation type for agricultural parcels obtained from recent (1999-2006) California Department of Water Resources land use surveys for each of the four counties in the study area.
- Crop species index based on rooting depth, amount of N required, crop value, and market product quality sensitivity to N deficiencies. Examples: Lettuce=4, alfalfa=1.
- Drip/microsprinkler with fertigation=1, without fertigation=2, overhead sprinkler with fertigation=3, without fertigation=3, all surface gravity systems=4. For crops that are known to be typically established with overhead sprinklers (PE=4), they switched to drip with fertigation (NI=1), we use the irrigation NI to 2.
- Soil values based on predominant soil series in SSURGO polygons. Soil index values represent the consensus of three soil scientists who considered NRCS soil series, drainage and permeability characteristics, including typical pedon texture, sequence layers and root life (indicators of poor drainage).
- Multiply together index values for crop species, soil leaching potential, and irrigation system type to obtain composite NI value from 1 to 20 (low to high risk). Matrix is shown in Fig. 2.
- Fields with composite NI above 10 (yellow highlight in Fig. 2) are considered to be at high risk of nitrate leaching when managed with typical agricultural practices (We et al., 2005).
- Index values were compiled in a GIS using SSURGO polygons (soil NI values) and fields (agricultural parcels) in Department of Water Resources surveys (crop species/irrigation type NI values).

Acknowledgements

This work was funded in part by the California State Water Resources Control Board under agreement number C9-127-12N. We thank Dr. John Lacey and Dr. David Binkley for their helpful advice and comments in writing and some data were not included in the original UC Water Hazard Index.

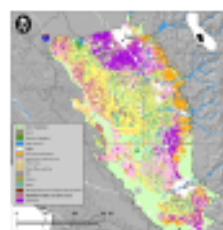


Fig. 1. Crop species in study area in southern San Joaquin Valley of California (Vera et al., 2002).

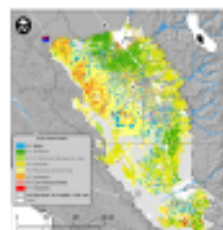


Fig. 2. Crop species by NI value. From Co., 2000; Tulare, 1999; Kings, 2000; Kern, 2000. Department of Water Resources surveys during summer months.

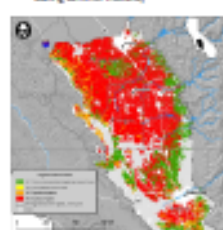


Fig. 3. Irrigation system hazard index value. Source = DM Fig. 6 (2005).

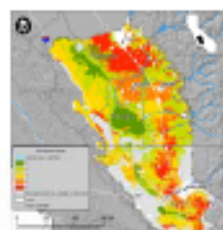


Fig. 4. Soil hazard index value for soil series in irrigated agriculture in NI.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

Fig. 5. The University of California nitrate hazard index multiplicative matrix, with highly vulnerable situations highlighted in yellow (adapted from We et al., 2005).

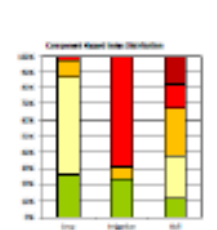


Fig. 6. Component NI values - distribution by percent of total area in study.

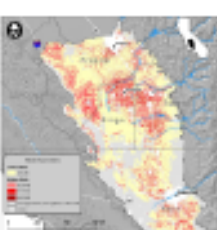


Fig. 7. Composite NI value hazard index map.

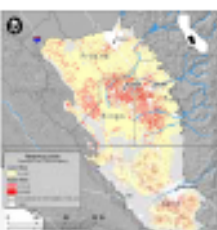


Fig. 8. NI hazard index map according to orchards, vineyards, and vegetable crop fields converted to drip or microsprinkler irrigation with fertigation.



Fig. 8. Decrease in total area with high nitrate leaching risk due to conversion to drip/microsprinkler irrigation with fertigation (see caption Fig. 8).

Results and Discussion

- Over half (13%, 435,372 ha of 1,317,966 ha) of the basin has a composite NI > 10 and therefore is vulnerable to significant nitrate leaching if not properly managed (Fig. 7).
- Much of the study area is cropped to lower risk crop species (Fig. 3), but prevalence of higher risk surface irrigation (Fig. 4) and medium-textured soils (Fig. 5) contribute to the overall 13% of area at risk (Fig. 5).
- Corn (mainly for silage) and vegetable production, as well as surface irrigated trees and field crops grown on high-risk soils account for the majority of this area.
- Conversion of fruit, nut, and vegetable crops to drip or microsprinkler irrigation from the earlier (1999-2006) adoption levels would decrease the area vulnerable from 13% to 22% of the area analyzed (Figs. 3 and 8).
- Significant conversion of cropland to drip/microsprinkler irrigation has occurred since the surveys used in this study were conducted in 1999-2006, and therefore the actual situation in 2012 falls between the two maps shown in Figs. 7 and 8.
- A large proportion of the cropped area remaining at risk of nitrate leaching less than such a conversion is used to produce silage corn and other forages, which typically receive applications of dairy manure and are irrigated by furrow or border methods. We note that in Tulare Co. (east-center of study area), dairy farmers raised approximately 500,000 cows (2010), which produced more milk than any other county in the US.

References

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- Wu, L., J. Lacey, C. French, V. Wertz, and D. Shultz. 2011. Nitrate leaching hazard index developed for regional operations. *Final State Water Resource Report*. <http://www.water.ca.gov/nitrate/>
- Wu, L., J. Lacey, C. French, V. Wertz, and D. Shultz. 2011. Nitrate leaching hazard index developed for regional operations. *Final State Water Resource Report*. <http://www.water.ca.gov/nitrate/>



Crop	Soil					Irrigation
	1	2	3	4	5	
1	1	2	3	4	5	1
1	2	4	6	8	10	2
1	3	6	9	12	15	3
1	4	8	12	16	20	4
2	2	4	6	8	10	1
2	4	8	12	16	20	2
2	6	12	18	24	30	3
2	8	16	24	32	40	4
3	3	6	9	12	15	1
3	6	12	18	24	30	2
3	9	18	27	36	45	3
3	12	24	36	48	60	4
4	4	8	12	16	20	1
4	8	16	24	32	40	2
4	12	24	36	48	60	3
4	16	32	48	64	80	4

Shortcomings of the Current NHI

- Soil index ratings have potential bias as they are based on the opinion of 3 individuals.
- Not all soils are rated.
- The experts have retired (1) and/or (2) moved on to other positions making updates challenging.
- NHI lacks transparency
- Does not consider climate
- NHI rates soil series not components of map units
 - soil series have a range in characteristics that is documented by map units e.g. Yolo silt loam; Yolo silty clay loam, Yolo loam; Yolo loam, clay substratum

Other Shortcomings of the Current NHI

- Masks the complexity of soil survey data

Map Unit Name: **Madera-Alamo complex,** Symbol: **195**
leveled, 0 to 1 percent slopes

▲ **Map Unit Composition**

65% - **Madera**
 Geomorphic Position: *terraces / Shoulder*

20% - **Alamo**
 Geomorphic Position: *terraces*

3% - ***Unnamed, ponded***
 Geomorphic Position: *depressions*
 Horizon data n/a

3% - ***San Joaquin***
 Horizon data n/a | [View Similar Data](#)

3% - ***Jahant***
 Horizon data n/a | [View Similar Data](#)

3% - ***Altered soils***
 Horizon data n/a

3% - ***Steeper slopes***
 Horizon data n/a

Map Unit Name: **Vina fine sandy loam, 0** Symbol: **272**
to 2 percent slopes

▲ **Map Unit Composition**

85% - **Vina**
 Geomorphic Position: *flood plains / Toeslope*

7% - ***Columbia***
 Geomorphic Position: *flood plains*
 Horizon data n/a | [View Similar Data](#)

4% - ***Coarse text overwash***
 Horizon data n/a

4% - ***Mod coarse text overwash***
 Horizon data n/a

▼ **Map Unit Data**

What do you choose?

Dominant soil

Limiting condition

Area weighted average

What do you choose?

Dominant soil

Limiting condition

Area weighted average

Dominant condition

Goal: Develop a Data-Driven, Revised Nitrate Leaching Hazard Index

- Parameterize HYDRUS with soil survey data to model nitrate flux over irrigation, crop, N-management and BMP scenarios.
- Develop a data-driven hazard rating based on model results.
- Create interactive web-based apps that report NHI ratings and place-based BMPs, and possibly nitrate flux estimates.

Outcomes of a Revised NHI

- Less subjectivity
- Greater transparency
- Will generate ratings for every soil component within soil map units. This is needed for watershed scale analysis.
- Wide spread adoption via interactive web-based apps
- Capability of generating nitrate flux beyond the root zone (quantity $\text{time}^{-1} \text{ area}^{-1}$) useful for evaluating BMP's and cropping system scenarios.
- Can be linked with groundwater models and other decision support tools.

What would it look like?

Integrate with SoilWeb: Easy to use and link with info.

The screenshot displays the SoilWeb interface, which is a web-based tool for soil data management and analysis. The interface is divided into several sections:

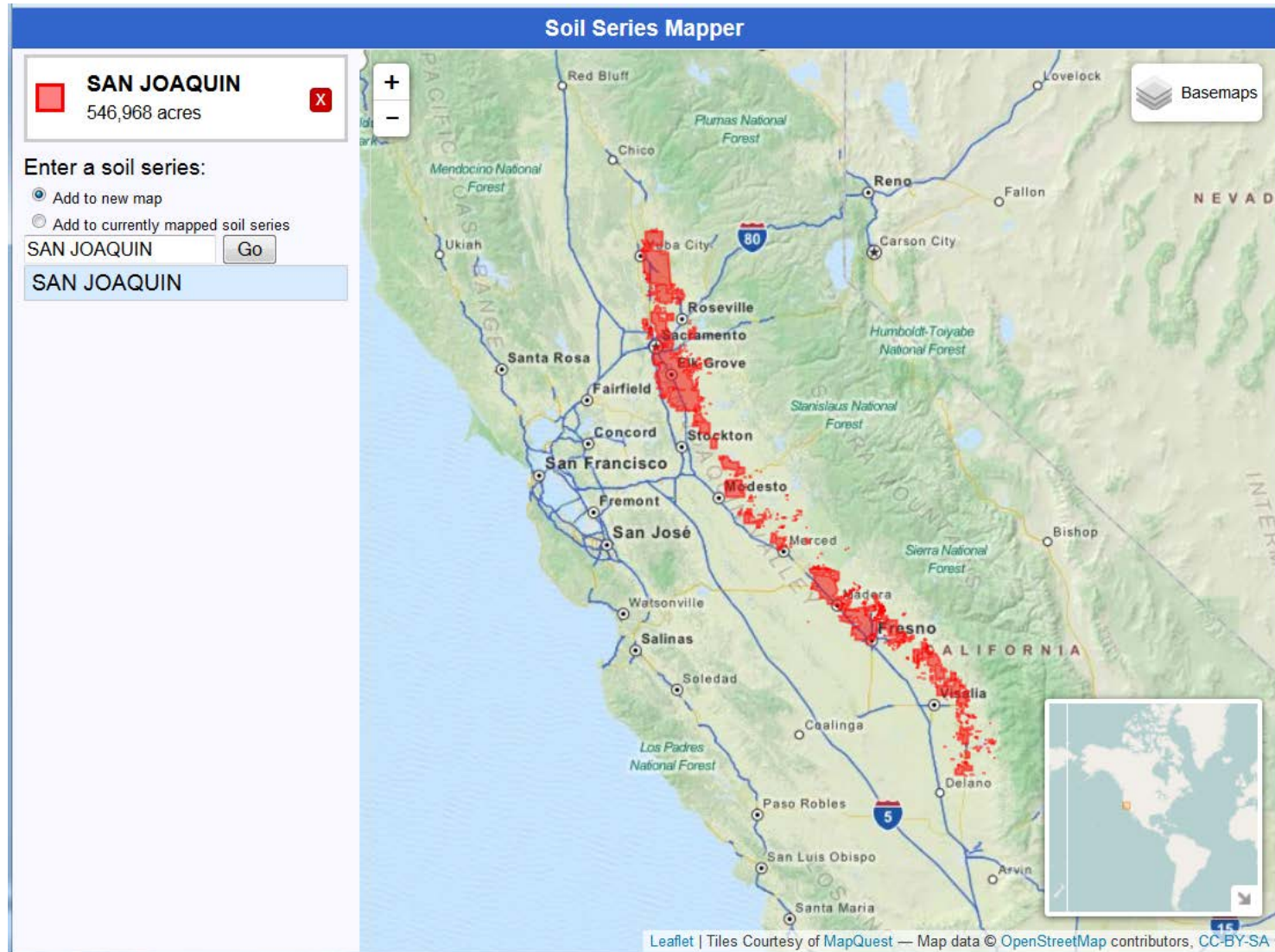
- Top Navigation:** Includes a "Close" button, the "SoilWeb" logo, and the "UC DAVIS NRCS University of California Agriculture and Natural Resources" logo.
- Map Unit Information:** Shows the "Map Unit Name: Yolo loam" and "Component Name: Yolo". A link to the "Official Series Description" is provided.
- Soil Profiles:** A section titled "Soil Profiles" with a "Typical Profile" dropdown. Below this, there are buttons for various soil properties: "Org. Matter", "Clay", "Sand", "Ksat", "pH", "Kf Factor", "EC", "SAR", "CaCO3", "Gypsum", "CEC @ pH7", and "Linear Ext.". A vertical soil profile diagram shows horizons Ap1, Ap2, A1, A2, C1, C2, Ab, and C3 with their respective depths (0cm to 165cm).
- Soil Taxonomy and Land Classification:** Sections for "Soil Taxonomy" and "Land Classification" are visible at the bottom left.
- Fertilization Guidelines:** A large section titled "Fertilization Guidelines for Major Crops Grown in California" is displayed. It includes text about the guidelines being based on research results and a list of crops: Cotton, Almonds, Processing Tomatoes, Broccoli, Lettuce, Wheat, Corn, and Rice. A "Soil and Plant Tissue Sampling" section provides links to "Soil Test Sampling Instructions", "Sampling for Soil Nitrate Determination", "Soil Sampling in Orchards", and "Plant Tissue Sampling". An "Additional Resources" section links to "Organized by Topic" and "Organized by Source".
- Map and Coordinates:** A map at the bottom right shows the location of the soil unit, with coordinates "Lat: 38.5201" and "Lon: -121.7251".

A red dashed circle highlights the "NHI" button in the "Soil Profiles" section.

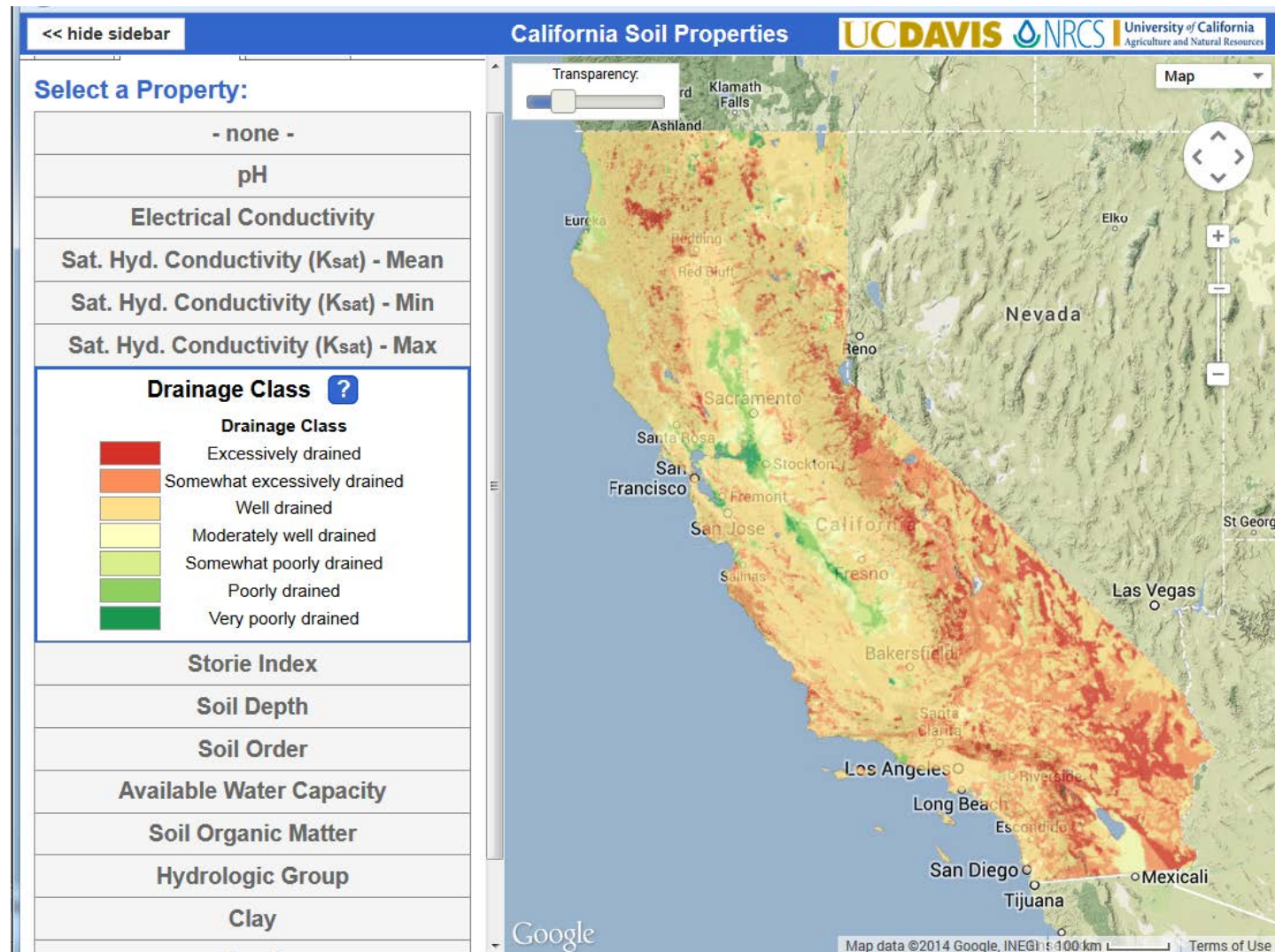
<http://casoilresource.lawr.ucdavis.edu/gmap/>

Flexibility in Data Delivery

Apps have interactive mapping capabilities that could display spatial extent of NHI.



Data for Multiple Scales: Field to Regional Scenarios



e.g. change in nitrate loss beyond the root zone considering 25% increase in adoption of improved irrigation technology.

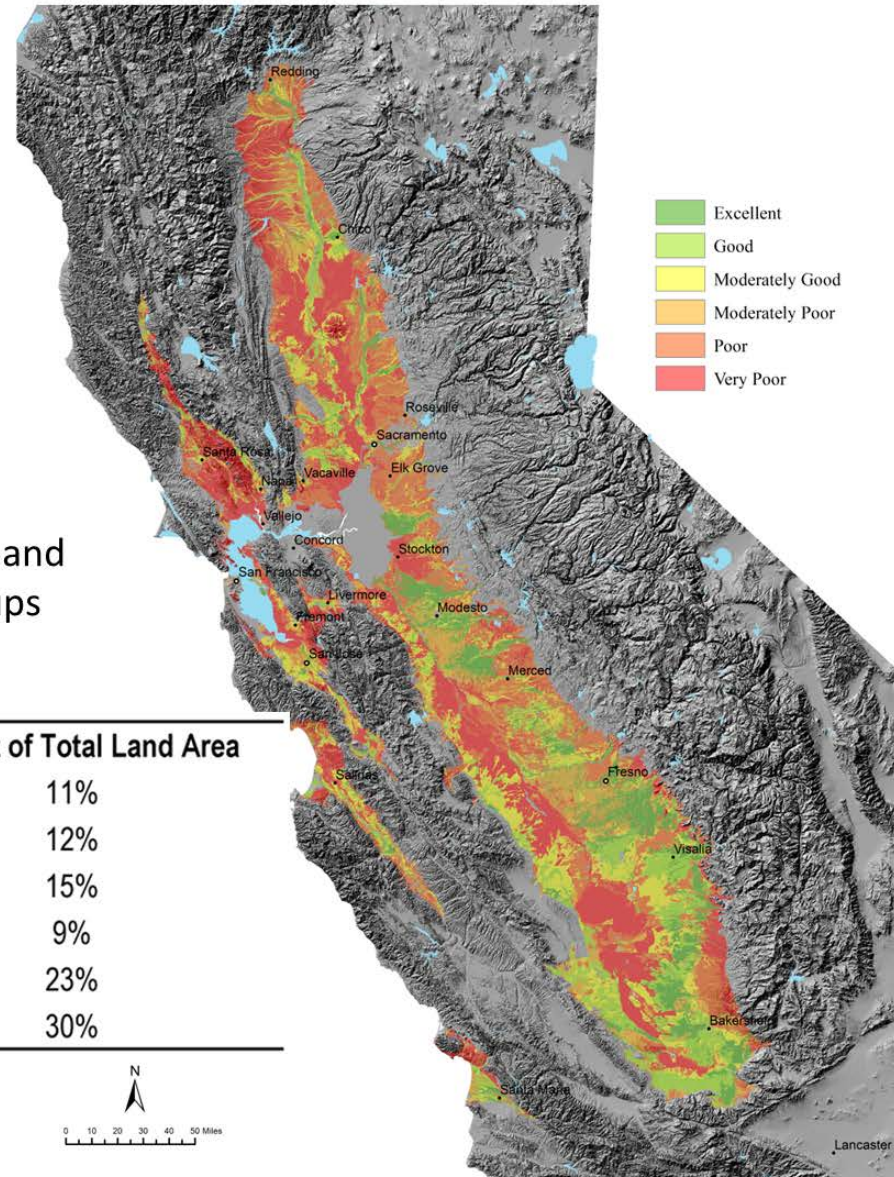
Soil Agricultural Groundwater Banking Index

Tradeoffs between maximizing water quantity and maintaining water quality need to be evaluated.


Tools need to harmonize

5 million acres in Excellent Good, and Moderately Good Suitability Groups

Suitability Group	Acreage	Percent of Total Land Area
Excellent	1,429,960	11%
Good	1,644,922	12%
Moderately Good	1,953,304	15%
Moderately Poor	1,196,257	9%
Poor	3,092,531	23%
Very Poor	4,016,445	30%



Thank You



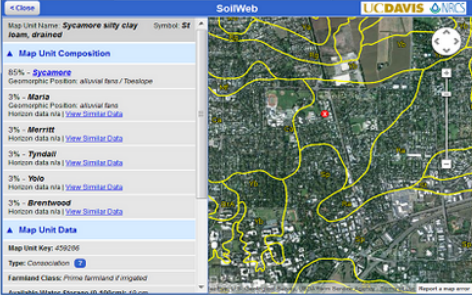
[Home](#) [Links](#) [Online Soil Survey](#) [People](#) [Projects](#) [Software](#) [Site Map](#)

SoilWeb: An Online Soil Survey Browser

Our online soil survey can be used to access USDA-NCSS detailed soil survey data (SSURGO) for most of the United States. Please choose an interface to SoilWeb:

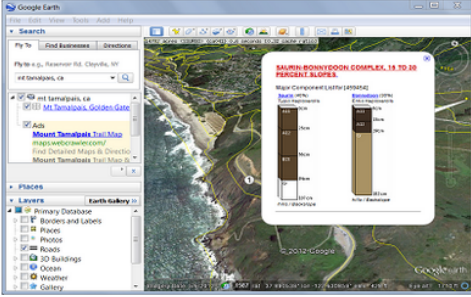
[SoilWeb](#)

Explore mapped soil survey areas using an interactive Google map and view detailed information about map units and their components. This app runs in your web browser and is compatible with desktop computers, tablets, and smartphones.



[SoilWeb Earth](#)

Soil survey data are delivered dynamically in a [KML](#) file, allowing you to view mapped areas in a 3-D display. You must have [Google Earth](#) or some other means of viewing KML files installed on your desktop computer, tablet, or smartphone.



[iPhone and Android apps](#)

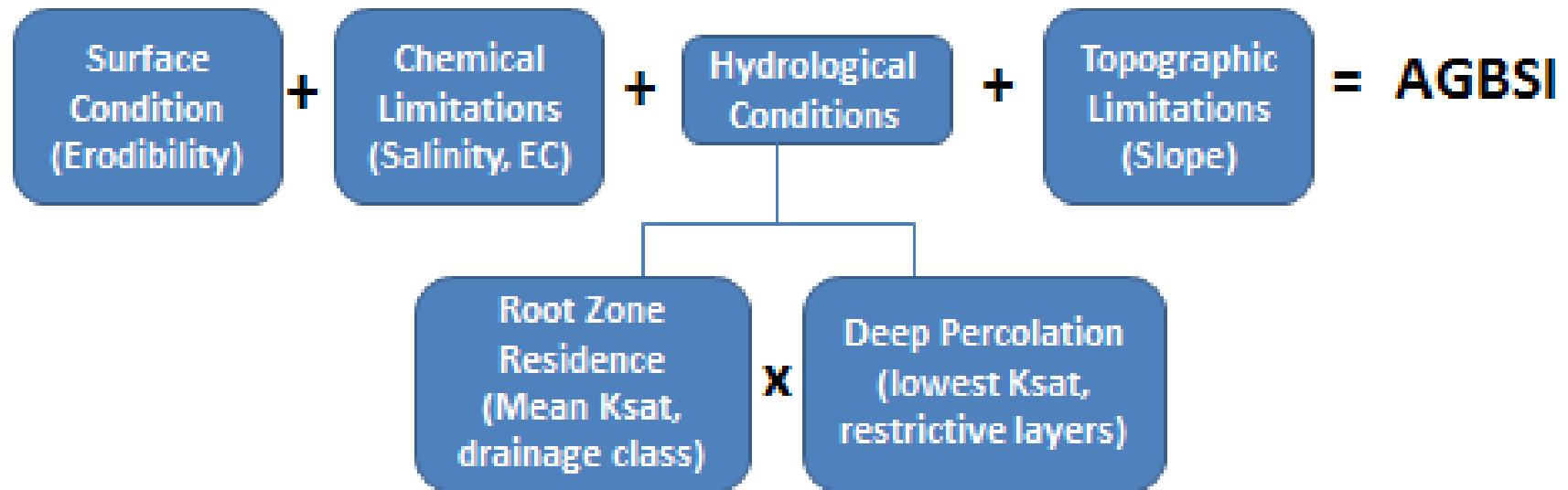
These are native smartphone apps that use your device's GPS to give soil information for your current location.

[Text Interface](#)

Choose from a list of available survey areas and map units to view the soil information of interest to you.

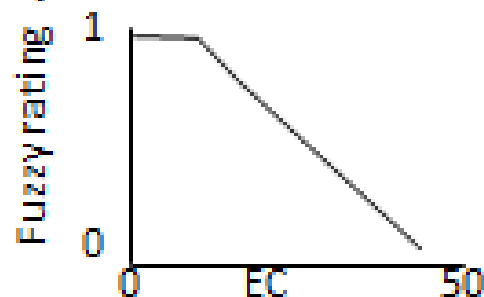
<http://casoilresource.lawr.ucdavis.edu/soilweb/>

Repackaging Soil Survey for an Ag. Groundwater Banking Suitability Index

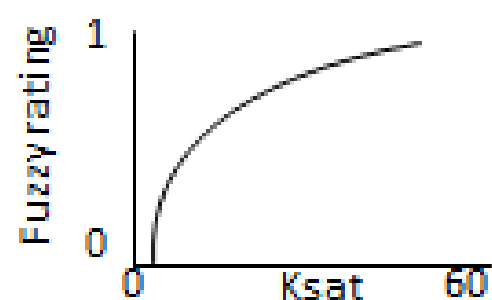


Fuzzy Logic Rating System

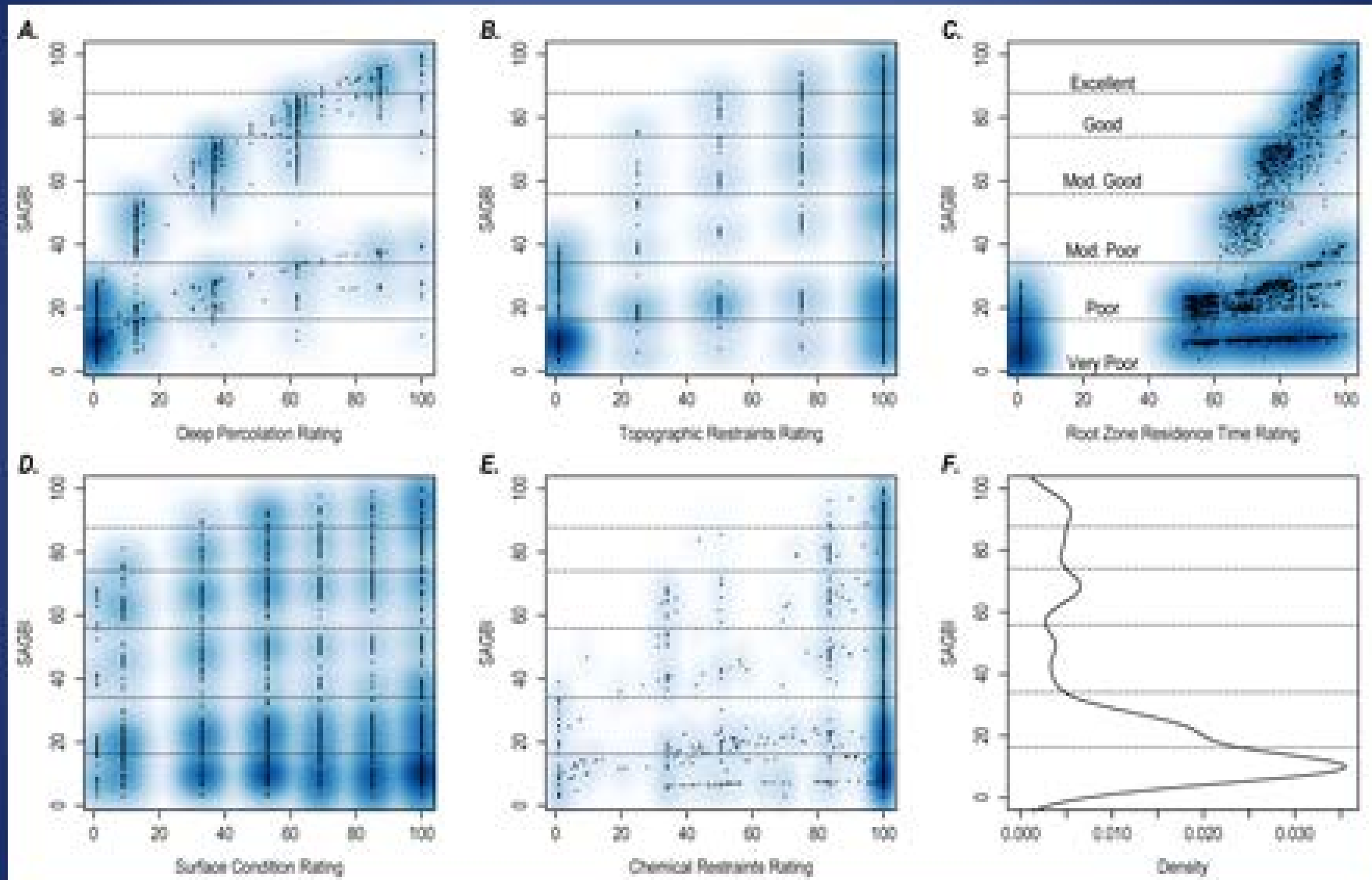
Optimum & less is better



More is better



Distribution of SAGBI Scores



N = 6394

[illegible]

A map of California showing water quality distribution by county. The map uses a color-coded legend to indicate water quality levels: Excellent (dark green), Good (light green), Moderately Good (yellow), Moderately Poor (orange), Poor (red-orange), and Very Poor (red). Major cities like Sacramento, San Francisco, San Jose, Los Angeles, and San Diego are labeled. A scale bar at the bottom left indicates distances from 0 to 60 miles, and a north arrow is also present.

