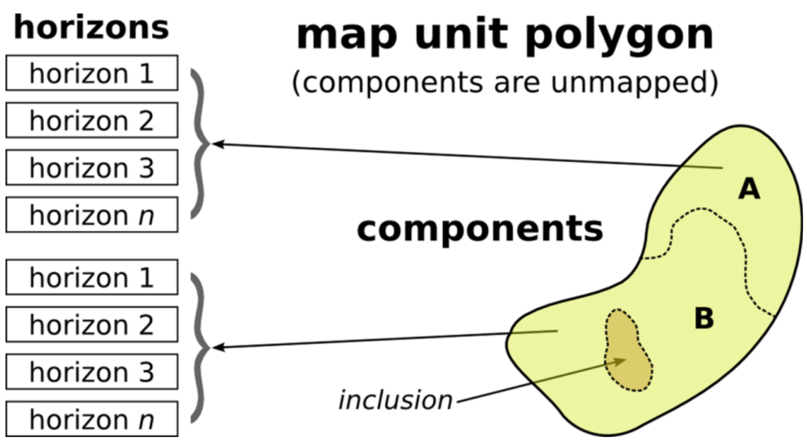
A Vision for a Revised Nitrate Hazard Leaching Index (NHI)



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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

Convent
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 96% of groundwater nitrate contamination in the southern San Joaquin and Salinas Valleys of California (Harter et al., 2012). 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 (HI) for irrigated agriculture (Wu et al., 2005). This tool is available online to the public (see Wu et al. for web address). The HI assigns index values to crop species, soil series, 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 HI 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 HI 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= 2, without fertigation =3, all surface gravity systems = 4. For crops that we know are typically established with overhead sprinklers (HI=4), then switched to drip with fertigation (HI=1), we set the irrigation HI 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, restrictive layers and mottles (indicators of poor drainage).
- Multiply together index values for crop species, soil leaching potential, and irrigation system type to obtain composite HI value from 1 to 80 (low to high risk). Matrix is shown in Fig. 2.
- Fields with composite HI above 20 (yellow highlight in Fig. 2) are considered to be at high risk of nitrate leaching when managed with typical agronomic practices (Wu et al. 2005).
- Index values were compiled in a GIS using SSURGO polygons (soil HI values) and fields (agricultural parcels) in Department of Water Resources surveys (crop species/irrigation type HI values).

Acknowledgements

This work was funded in part by the California State Water Resources Control Board under agreement number 09-122-250. We thank Dr. John Letey and Dr. David Rolston for their helpful advice and assistance in rating soil series that were not included in the original UC Nitrate Hazard Index.

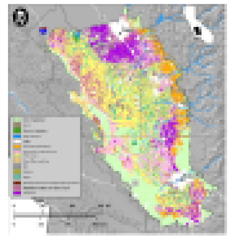

Fig. 1. Crop species in study area in southern San Joaquin Valley of California (Wu et al. 2005)

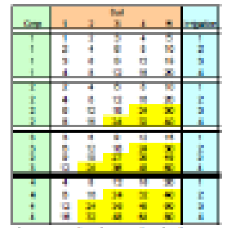

Fig. 2. The University of California nitrate hazard index multiplicative matrix, with highly vulnerable situations highlighted in yellow (adapted from Wu et al. 2005)

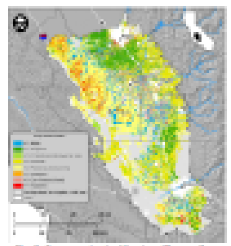

Fig. 3. Crop species by HI value. (Fresno Co. 2000; Tulare, 1999; Kings 2003; Kern 2006; Department of Water Resources surveys during summer months)

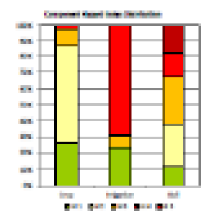

Fig. 6. Component HI values: distribution by percent of total land area in study.

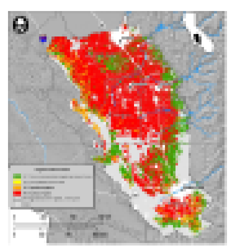

Fig. 4. Irrigation system hazard index value. Source – see Fig. 3 caption.

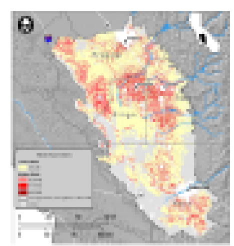

Fig. 7. Composite nitrate hazard index map.

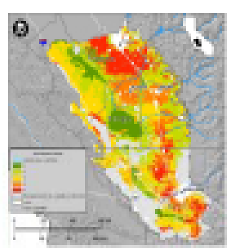

Fig. 5. Soil hazard index value for soil series in irrigated agricultural land.

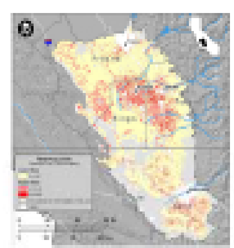

Fig. 8. Hazard index map assuming all orchards, vineyards, and vegetable crop fields converted to drip or microsprinkler irrigation with fertigation.

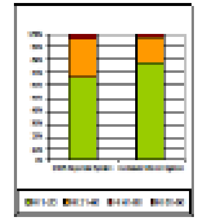

Fig. 9. Decrease in land area with high nitrate leaching risk due to conversion to drip/microsprinkler irrigation (see caption Fig. 8)

Results and Discussion

- One third (33%, 435,372 ha of 1,317,906 ha) of the basin has a composite HI > 20 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 well-drained soils (Fig. 5) contribute to the overall 33% of area at risk (Fig. 6).
- 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 33% to 22% of the area analyzed (Figs. 8 and 9).
- 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 loss after 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 milked approximately 500,000 cows (2010), which produced more milk than any other county in the US.

References

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Wu, L., J. Letey, C. French, Y. Wood, and D. Birkle. 2005. Nitrate leaching hazard index developed for irrigated agriculture. J Soil Water Conservation 60(4): 90-95. Online version of UC nitrate hazard index: [illegible]

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, leveled, 0 to 1 percent slopes*** Symbol: ***195***

▲ Map Unit Composition

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

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

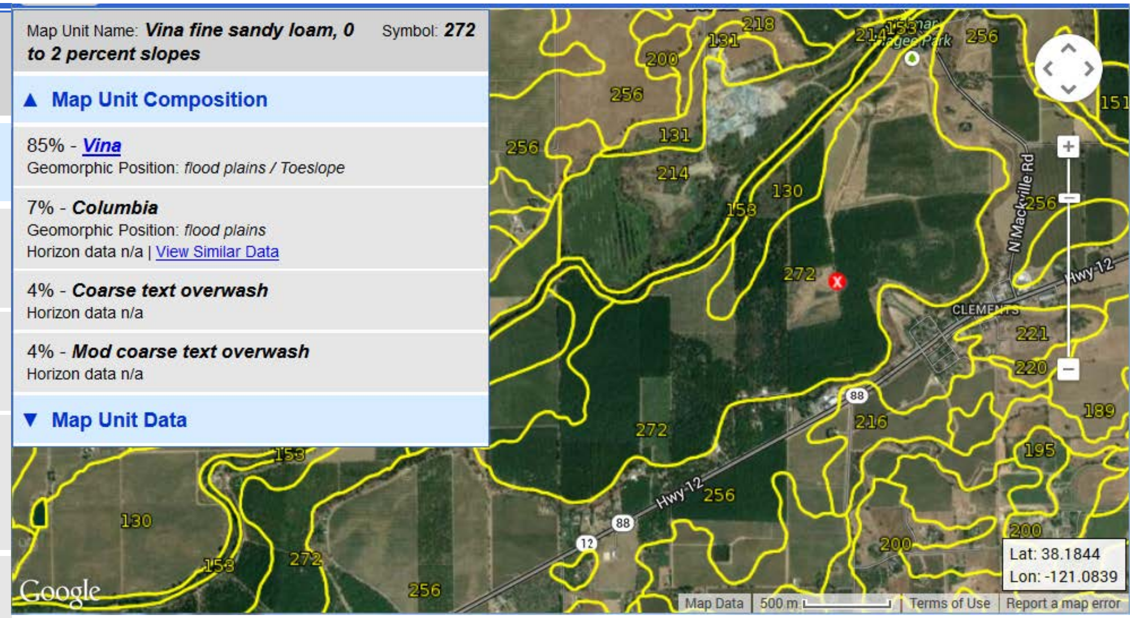
3% - ***Unnamed, ponded***
Geomorphic Position: *depressions*
Horizon data n/a

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



What do you choose?
Dominant soil
Limiting condition
Area weighted average
Dominant condition

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

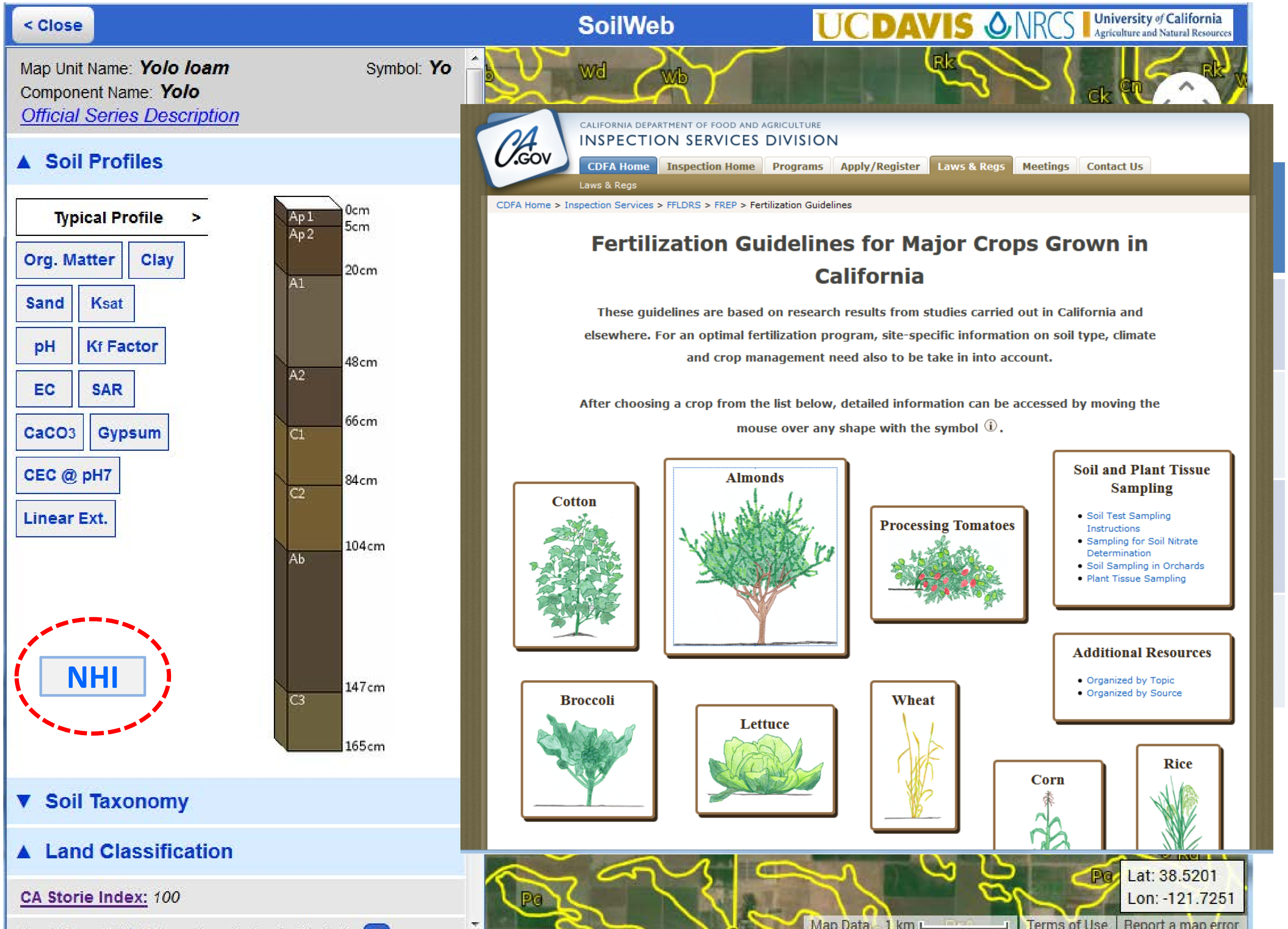
- Parameterize HYDRUS with soil survey data to model nitrate flux over irrigation, crop, N-management and BMP scenarios.
- Develop a data-driven hazard rating based on model results.
- Create interactive web-based apps that report NHI ratings and place-based BMPs, and possibly nitrate flux estimates.

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 time^{-1} 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?

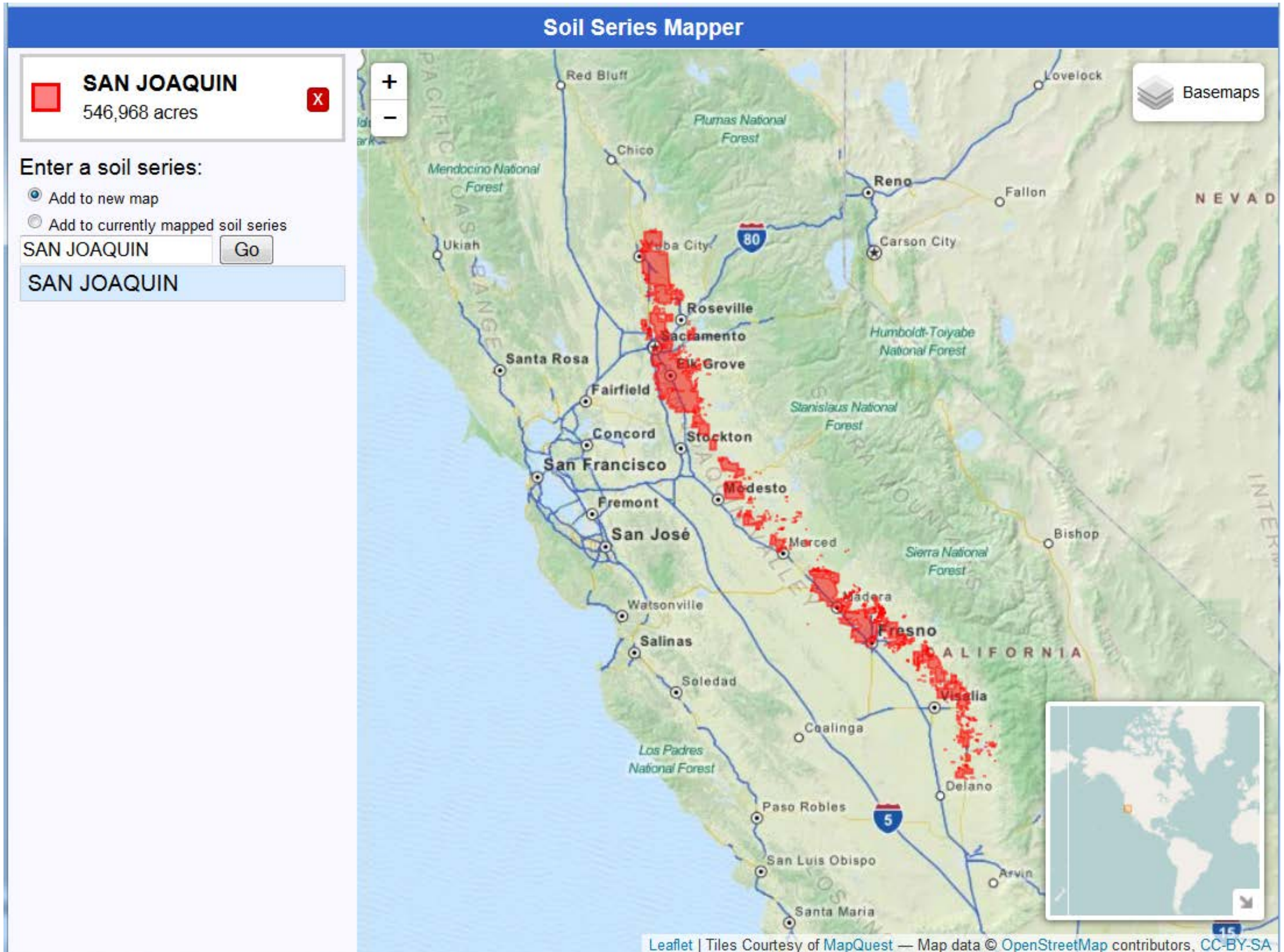
Integrate with SoilWeb: Easy to use and link with info.



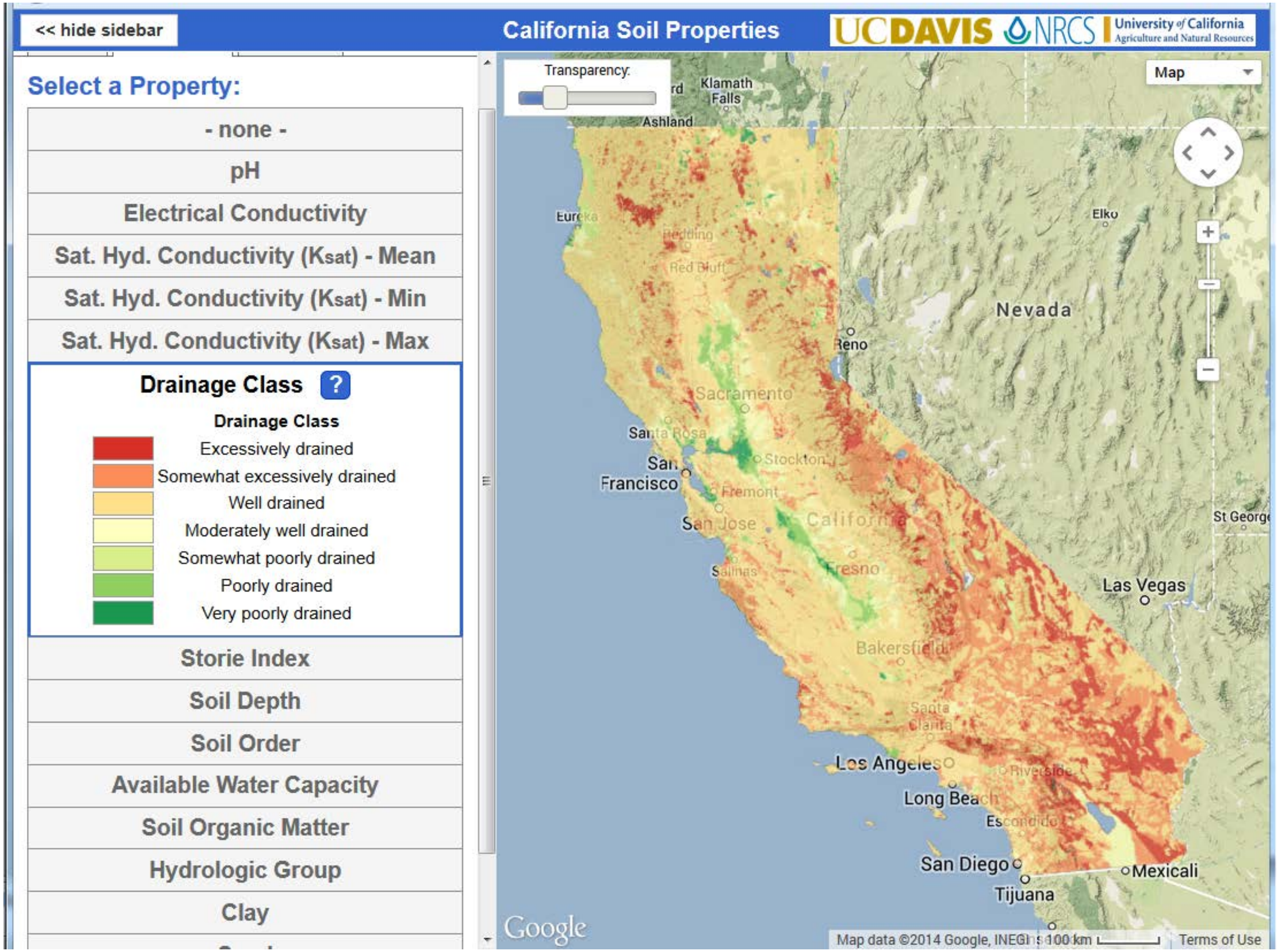
http://casoilresource.lawr.ucdavis.edu/gmap/

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.

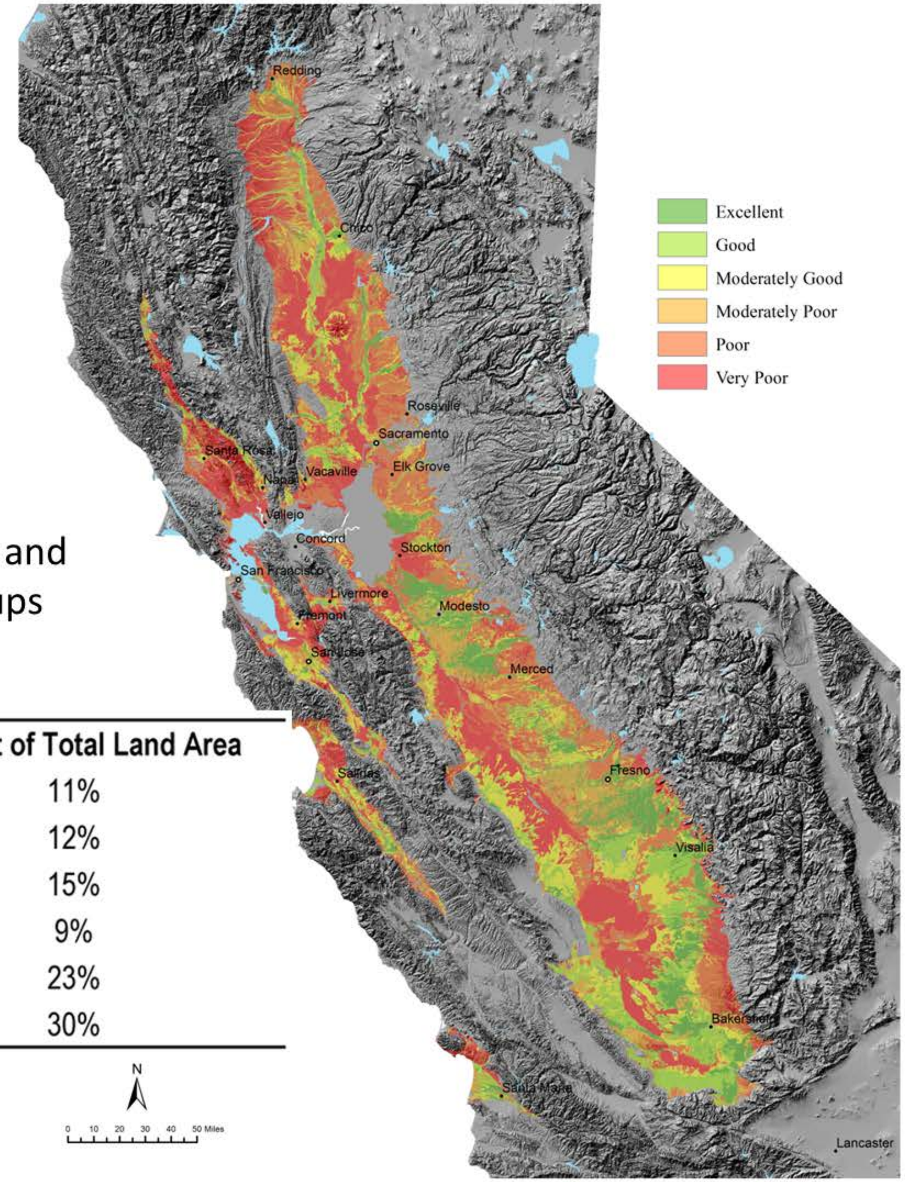
Soil Agricultural Groundwater Banking Index

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

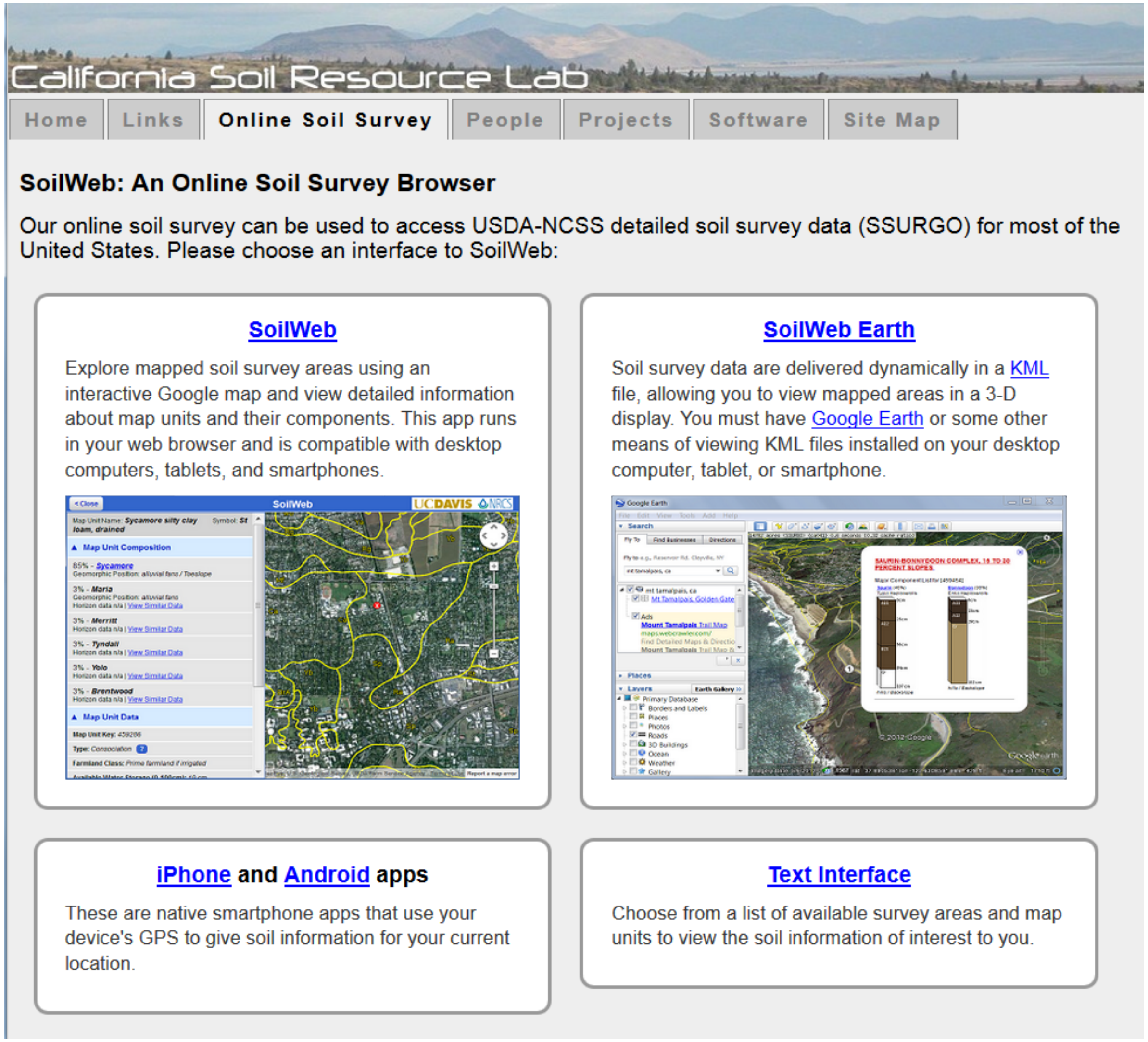
Tools need to harmonize

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%

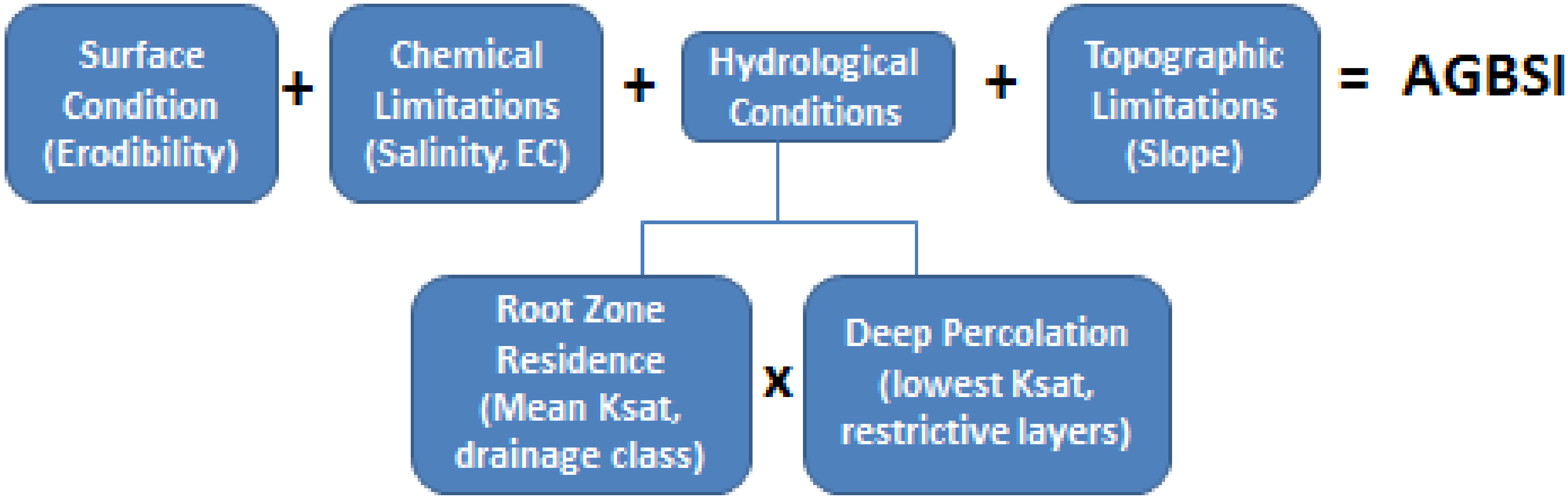


Thank You



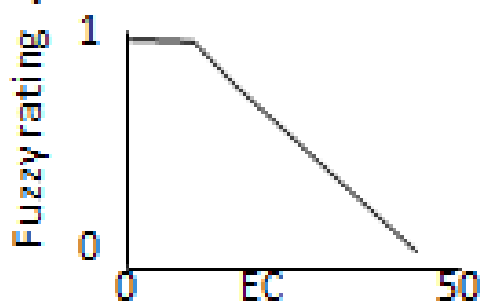
http://casoilresource.lawr.ucdavis.edu/soilweb/

Repackaging Soil Survey for an Ag. Groundwater Banking Suitability Index

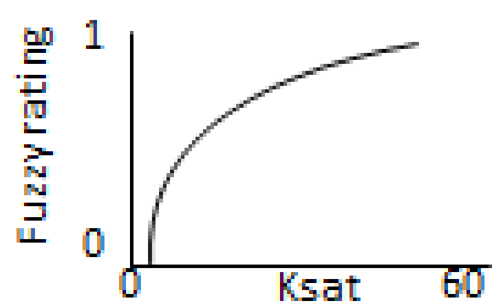


Fuzzy Logic Rating System

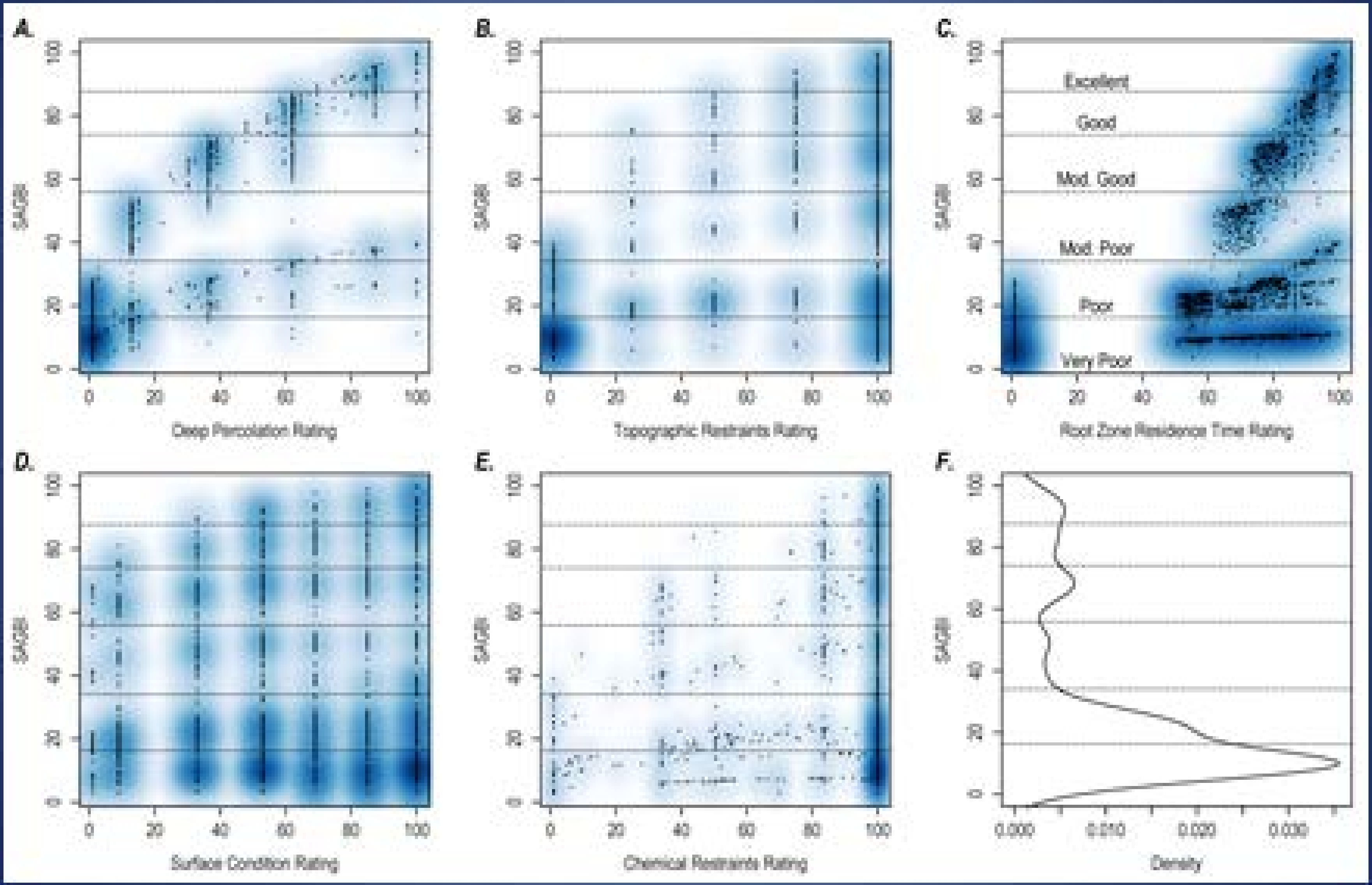
Optimum & less is better



More is better



Distribution of SAGBI Scores



N = 6394

Soils Modified by Deep Tillage

Many soils that contain water-restrictive horizons have been modified by deep tillage. This information has not been updated in most soil surveys.