Irrigated Lands Regulatory Program Agricultural Expert Panel Testimony

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Outline

- Introduction and technical background
- Involvement in ILRP process
- Charges to the Expert Panel
- Statements about risk and variability
- Preview select Expert Panel themes/questions
  - Discuss approaches:
    - N ratio and balance approaches – advantages and challenges
    - Index approach – advantages and challenges
- Conclusions

Introduction and Technical Background

- Lifelong upbringing in California irrigated agriculture and current land owner
- BS, MS, and PhD in Soil Science
  - Graduate research focused on N dynamics in agricultural systems – specifically mineralization, denitrification and transport to surface and groundwater as influenced by irrigation and drainage management
- Agricultural consultant for 18 years
  - Specializing in nutrient, salinity, irrigation, drainage and agricultural systems management

Involvement in ILRP process

- Technical consultant for commodity and coalition organizations (e.g. Almond Board and KRWCA)
- CDFA N Tracking and Reporting System Task Force member
- Provided testimony before RWQCB and CDFA
- Attendance and participation in various CDFA and SWRCB public meetings
- Attendance and participation in coalition meetings throughout state
- Current SWRCB Advisory Committee member for this Expert Panel

Charges to the Expert Panel

- **Assess existing agricultural nitrate control programs and develop recommendations**, as needed, to ensure that ongoing efforts are protective of groundwater quality. (Recommendations Addressing Nitrates in Groundwater, State Water Board's Report to the Legislature, February 20, 2013)

- and -

- Provide a more thorough analysis and long-term statewide recommendations regarding many of the issues implicated in State Water Board Order WQ 2013-0101, including indicators and **methodologies for determining risk** to surface and groundwater quality, **targets for measuring reductions in risk**, and the use of monitoring to evaluate practice effectiveness.

Variability and Change vs. Risk and Vulnerability

- Variability and change in California agriculture

  (Intrinsic variables)
  - Hundreds of miles of change (N to S and W to E)
  - Hundreds of unique soil types dictating performance
  - Significant variation in climatic regimes that is changing

  (Extrinsic variables)
  - Hundreds of crop types that are constantly changing
  - Significant variation/implementation in management practices (e.g. irrigation types/methods)
- Regional approaches must be considered and attempts to group too broadly will likely result in less effective outcomes. What works one place may not in another
- All can significantly impact the risk and vulnerability of the system
- Science and engineering should dictate approaches to addressing these variables and change

Theme of questions 1-4

- Vulnerability and Risk Assessment
  - Regulatory programs are most effective when they are able to focus attention and requirements on those discharges or dischargers (i.e. growers) **that pose the highest risk or threat** because of the characteristics of their discharge or the environment into which the discharge occurs. …

Questions 1-4 – Risk Assessment and Vulnerability

1. How can **<u>risk to or vulnerability of groundwater best be determined</u>** … ?
2. Evaluate and develop recommendations for the current approaches taken to assessing risk to, or vulnerability of, groundwater:

   a. Nitrate Hazard Index (as developed by the University of California Center for Water Resources, 1995),

   b. Nitrate Loading Risk Factor (as developed by the CCRWQCB),

   c. Nitrogen Consumption Ratio,

   d. Size of the farming operation,

   e. High Vulnerability Areas Methodology (as developed by the CVRWQCB).

3 & 4. Questions addressing surface water, but again focused on current risk, vulnerability and approaches.

High Vulnerability Areas Methodology as developed by the CVRWQCB

- Developed through the SWRCB HVAs, DPR Groundwater Protection Areas (GPA's), and measured Nitrate Exceedances
  - Depth to groundwater
  - Soil type
  - Pesticide exceedance
- Does not take into account crop type (which determines rooting zone and fertilizer N practices) or irrigation type
- Proposed as regional basis classification which is convenient in application, but challenging in lack of granularity necessary to optimize regulation and achieve efficient impact

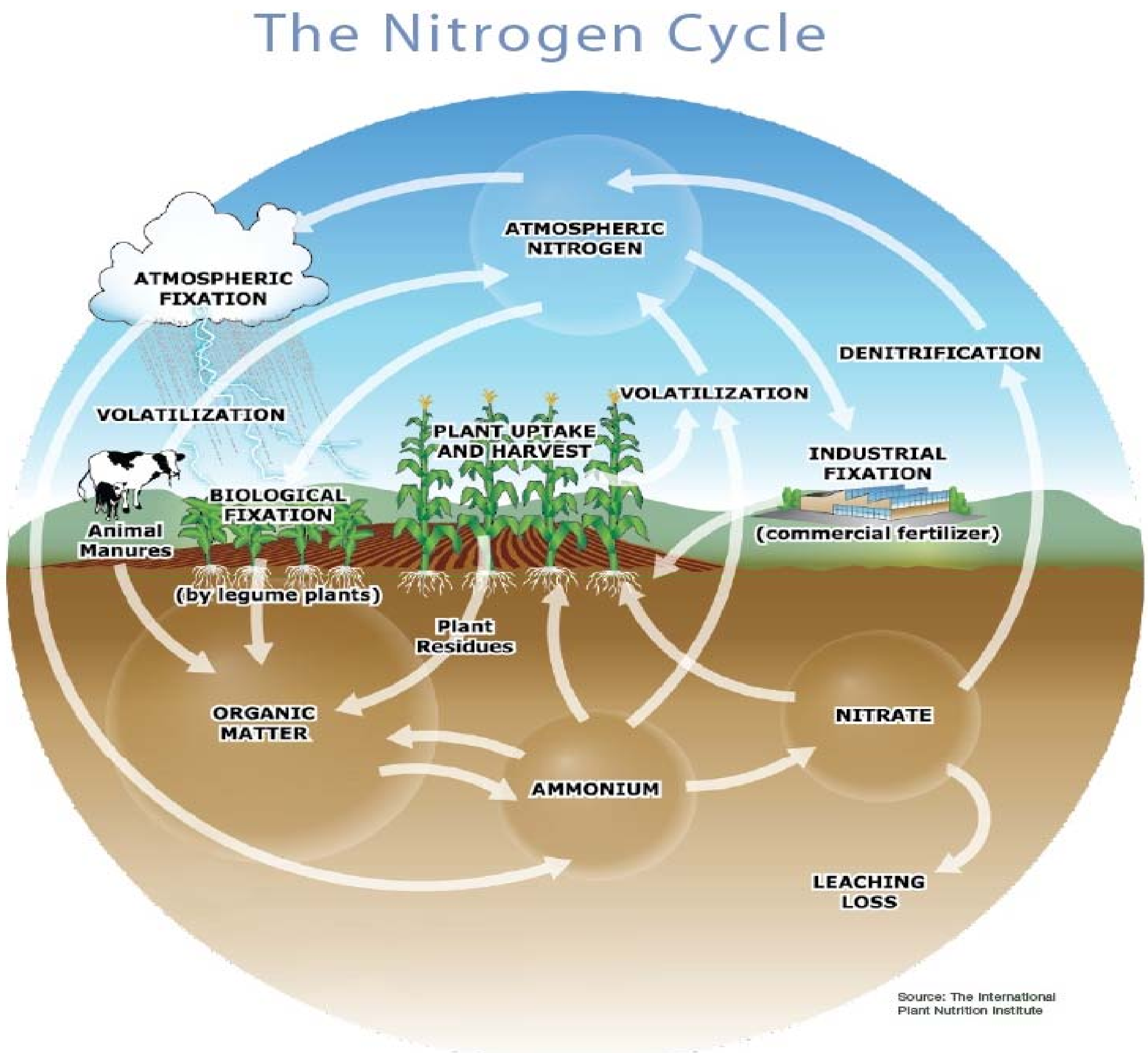
Additional Considerations of CVRWQCB High Vulnerability Areas

- Nature of groundwater movement precludes straightforward interpretation of monitoring results
- Transport times vary widely and in some cases are poorly understood
- Monitoring results may reflect several different soils, crops etc. if used in conjunction with a general classification approach

Nitrogen Consumption Ratio

- Also known as:
  - Partial mass balance
  - Farm-gate mass balance
  - “N in” versus “N out” approach
- Intent is to focus on applied N and assumes less applied N results in less N losses
- If system is not in N deficit, and all things remaining static, the easiest way to improve a ratio is to apply less N
- Does not account for internal and variable components of the soil/plant N cycle that are impacted by management practices

A Nitrogen Mass Balance Approach



Variability of the N Cycle

- Range of losses (validated in literature)
  - Denitrification (0-60+% of applied N)
  - Volatilization (0-40+% of applied N)
  - Plant Uptake (0-80+% of applied N)
  - Biological Immobilization (0-50+% of applied N)
  - Leaching (0-70+% of applied N)
- Degree of loss is dictated by intrinsic factors and management variables
- Spatial and temporal variability are additionally complicating

N Ratios vs. Leaching Potential

Field	N applied	N Removed	Ratio	Biological/Biomass Assimilation	Volatilization	Denitrification	Leaching
	#N/acre			#N/acre			
A	150	100	**1.5**	10	8	22	**10**
B	150	100	**1.5**	10	10	10	**20**
C	150	100	**1.5**	12	5	3	**30**

Field	N applied	N Removed	Ratio	Biological/Biomass Assimilation	Volatilization	Denitrification	Leaching
	#N/acre			#N/acre			
A	200	100	**2.0**	15	5	60	**20**
B	150	100	**1.5**	10	10	10	**20**
C	130	100	**1.3**	5	3	2	**20**

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Understanding Management Impacts

- Irrigation management: Nitrate leaching more highly correlated with water moving beyond root zone than with total amount of N applied (Letey et al., 1977; Pratt et al., 1984; Letey et al., 2013; and others)
- Fertilizer management: 4 R's – right source, right rate, right time, right place (IPNI, 2012)
- Compendium: (e.g. Dzurella, 2012) – Technical Report 3 – Addressing Nitrate in California's Drinking Water – Explains both management practices and integration of the Nitrate Hazard Index (NHI)

Nitrate Hazard Index (NHI)

- Assigns a relative index value to each field based on three basic pieces of information
  - Soil type
  - Crop type
  - Irrigation method
- Developed as assessment tool, but may be used as an interpretive tool to gain insight into the causative factors of N budget results
- May serve as means of validating, verifying, and providing context for N budgeting results

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

Stuart Pettygrove[1], Kristin Dzurella[1], Anna Fryjoff-Hung[2] and Allan Hollander[2],
Departments of Land, Air & Water Resources[1] and Environmental Science & Policy[2], University of California, Davis, CA

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 rootzones 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=3), 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 Birkle for their helpful advice and assistance in rating soil series that were not included in the original UC Nitrate Hazard Index.

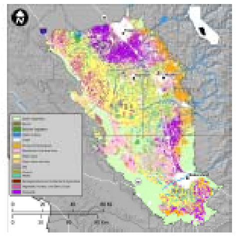

Fig. 1. Crop species in study area in southern San Joaquin Valley of California (Viers et al. 2012)

Crop	Soil 1	2	3	4	5	Irrigation
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

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

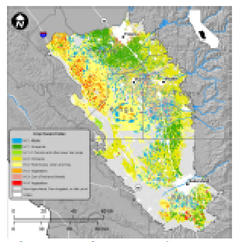

Fig. 3. Crop species by HI value. (Fresno Co., 2000; Tulare, 1999; Kings 2003; Kern 2006, Department of Water Resources surveys during summer months)

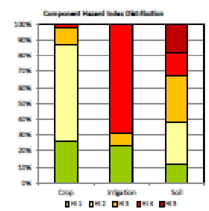

Fig. 6. Component HI values- distribution by percent of total land area in study.

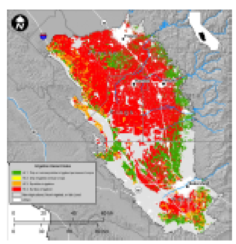

Fig. 4. Irrigation system hazard index value. Source – see Fig. 3 caption.

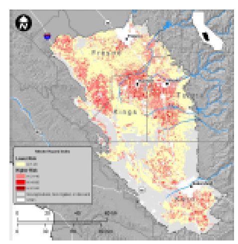

Fig. 7. Composite nitrate hazard index map.

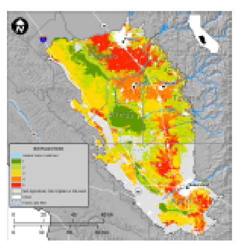

Fig. 5. Soil hazard index value for soil series in irrigated agricultural land.

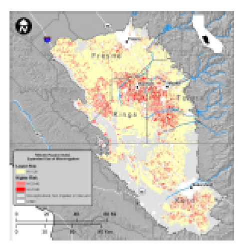

Fig. 8. Hazard index map assuming all orchards, vineyards, and vegetable crop fields converted to drip or microsprinkler irrigation with fertigation.

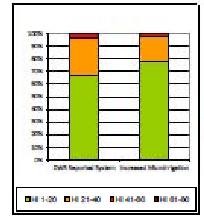

Fig. 9. Decrease in land area with high nitrate leaching risk due to conversion to drip/microsprinkler irrigation (see caption Fig. 8)

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.

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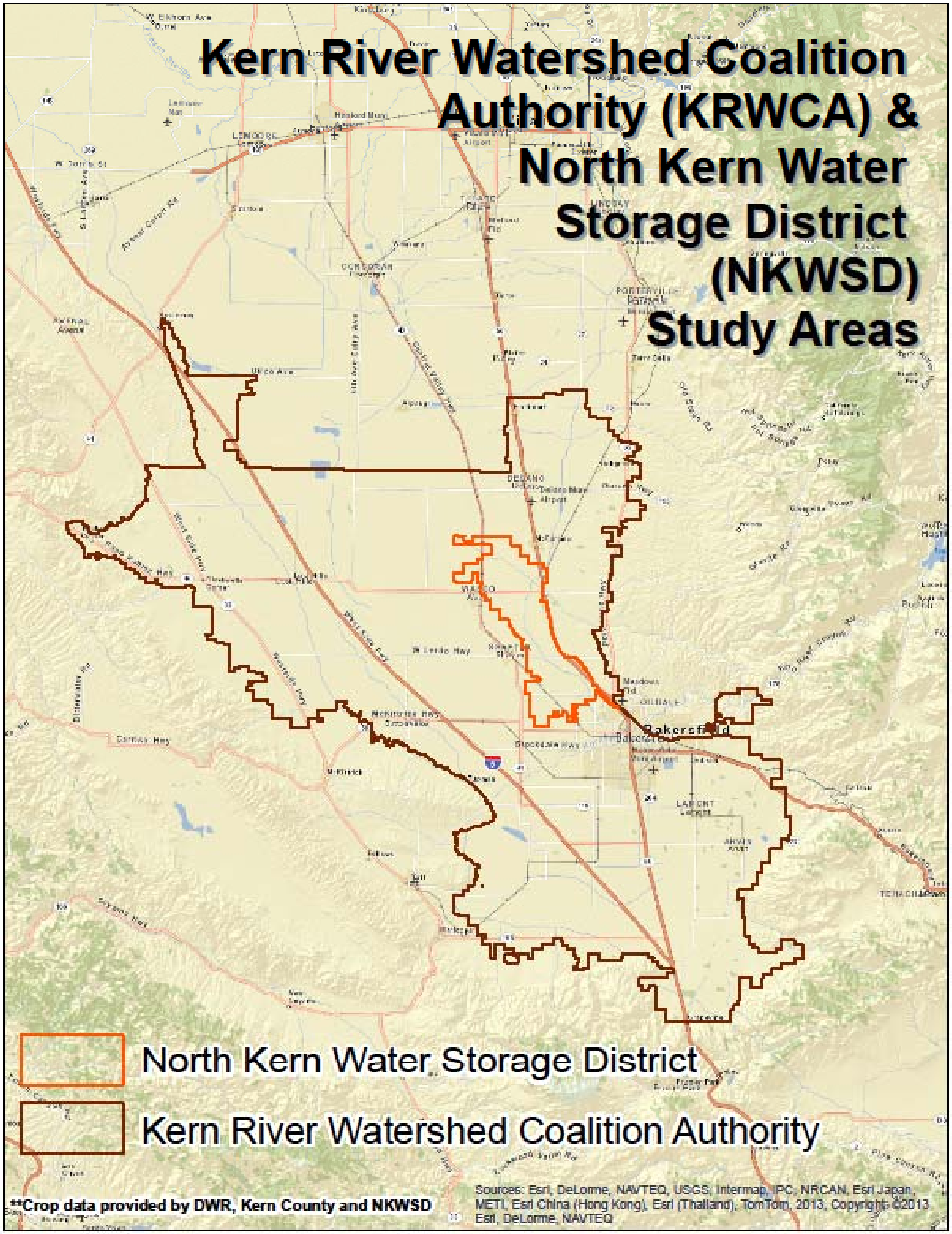
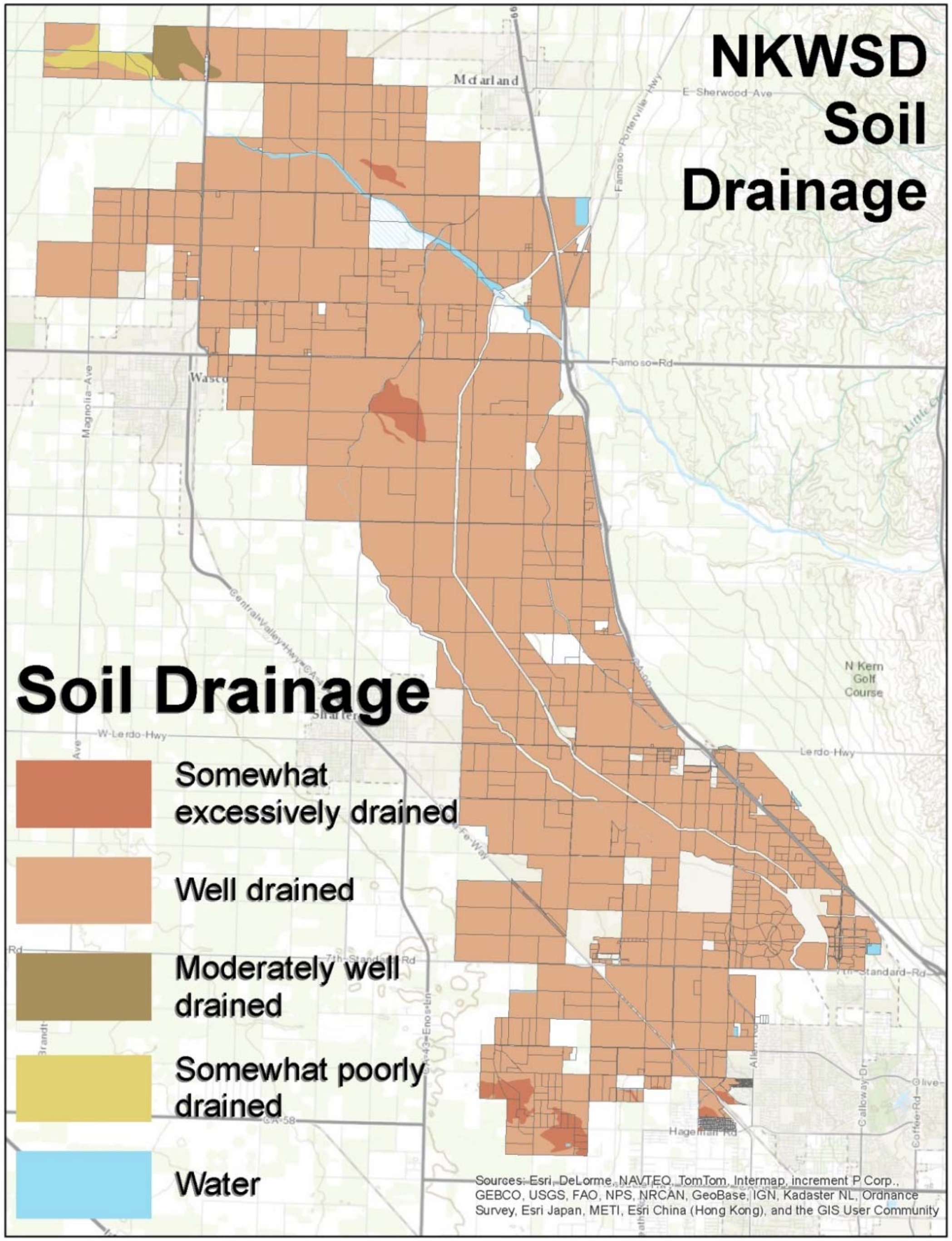
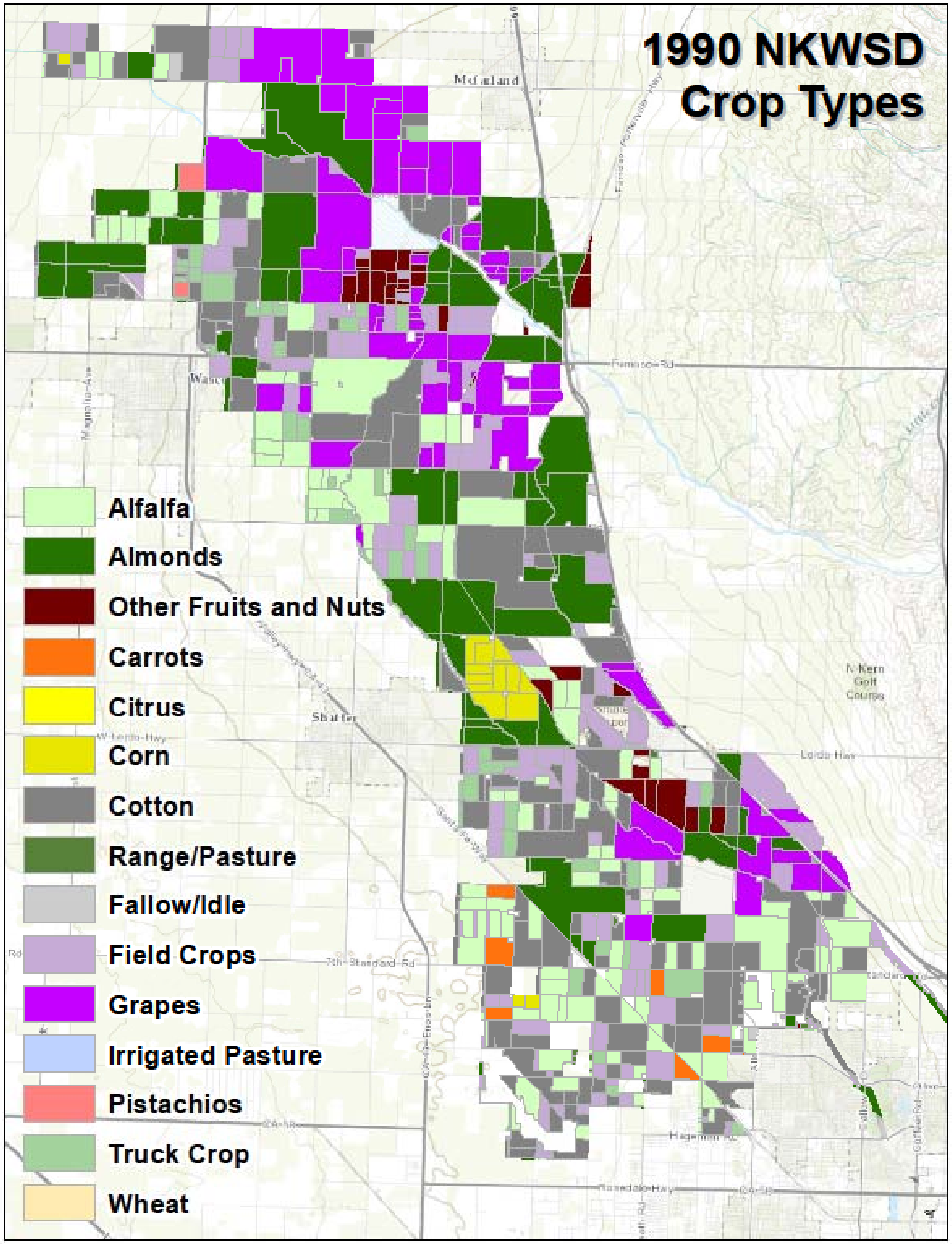
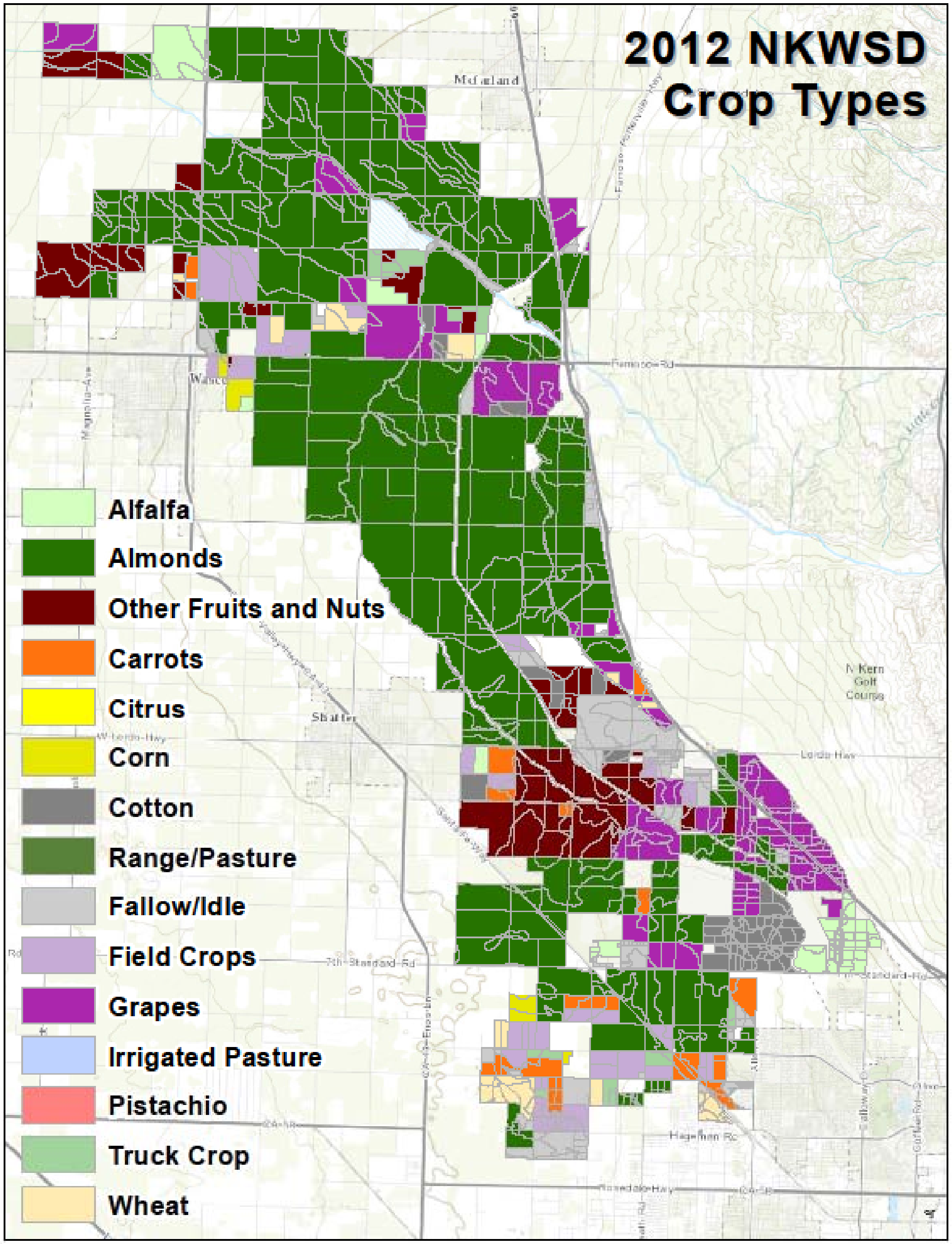
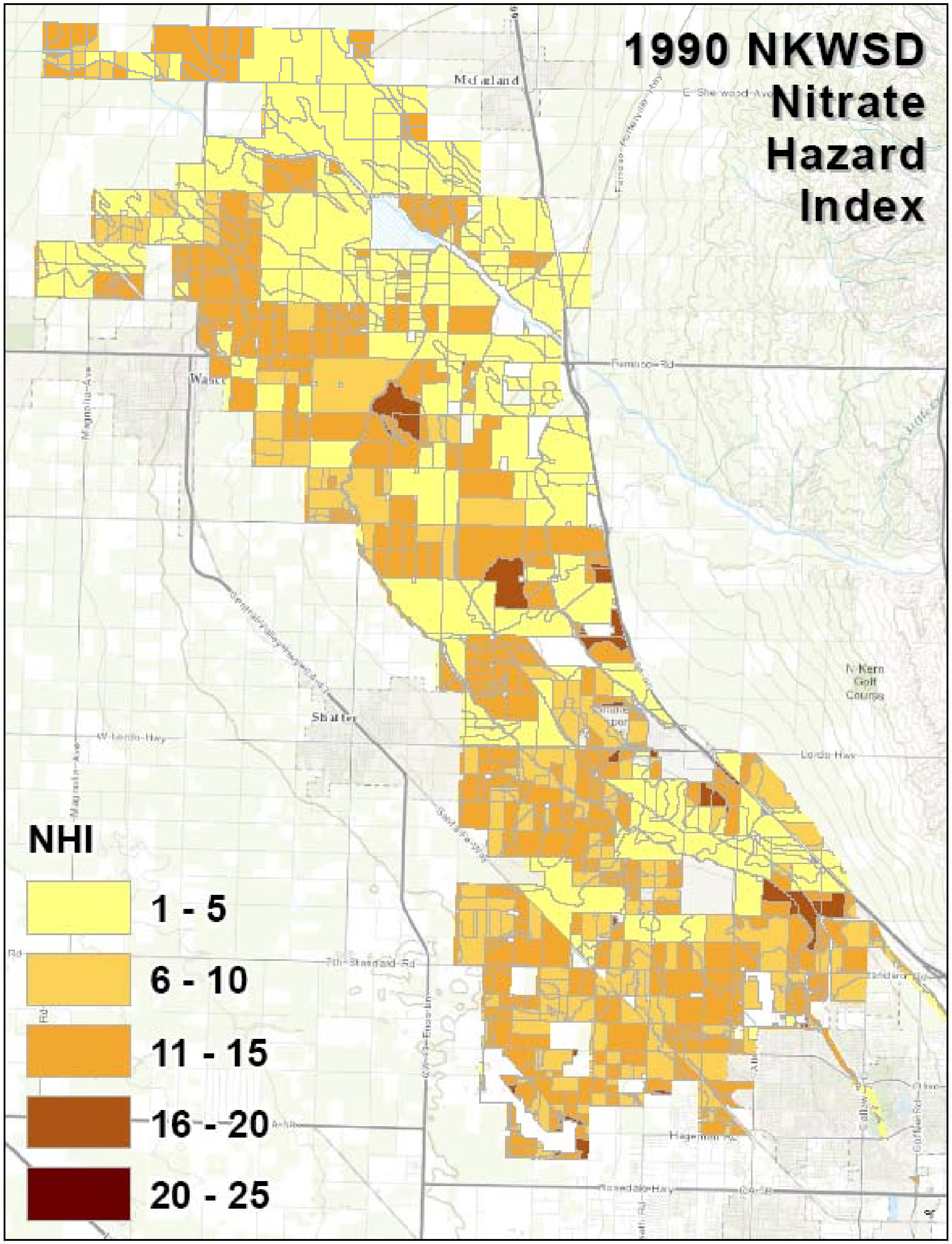

Kern River Watershed Coalition Authority (KRWCA) & North Kern Water Storage District (NKWSD) Study Areas
North Kern Water Storage District
Kern River Watershed Coalition Authority
**Crop data provided by DWR, Kern County and NKWSD
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, IPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013, Copyright: ©2013 Esri, DeLorme, NAVTEQ


NKWSD
Soil
Drainage
Soil Drainage
Somewhat excessively drained
Well drained
Moderately well drained
Somewhat poorly drained
Water
Mcfarland
E-Sherwood-Ave
Famoso-Rd
Wasco
Lerdo-Hwy
W-Lerdo-Hwy
Shafter
7th-Standard-Rd
Hageman Rd
N Kern Golf Course
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community


1990 NKWSD
Crop Types
Alfalfa
Almonds
Other Fruits and Nuts
Carrots
Citrus
Corn
Cotton
Range/Pasture
Fallow/Idle
Field Crops
Grapes
Irrigated Pasture
Pistachios
Truck Crop
Wheat


2012 NKWSD
Crop Types
Alfalfa
Almonds
Other Fruits and Nuts
Carrots
Citrus
Corn
Cotton
Range/Pasture
Fallow/Idle
Field Crops
Grapes
Irrigated Pasture
Pistachio
Truck Crop
Wheat


1990 NKWSD
Nitrate
Hazard
Index
NHI
1 - 5
6 - 10
11 - 15
16 - 20
20 - 25
McFarland
Wasco
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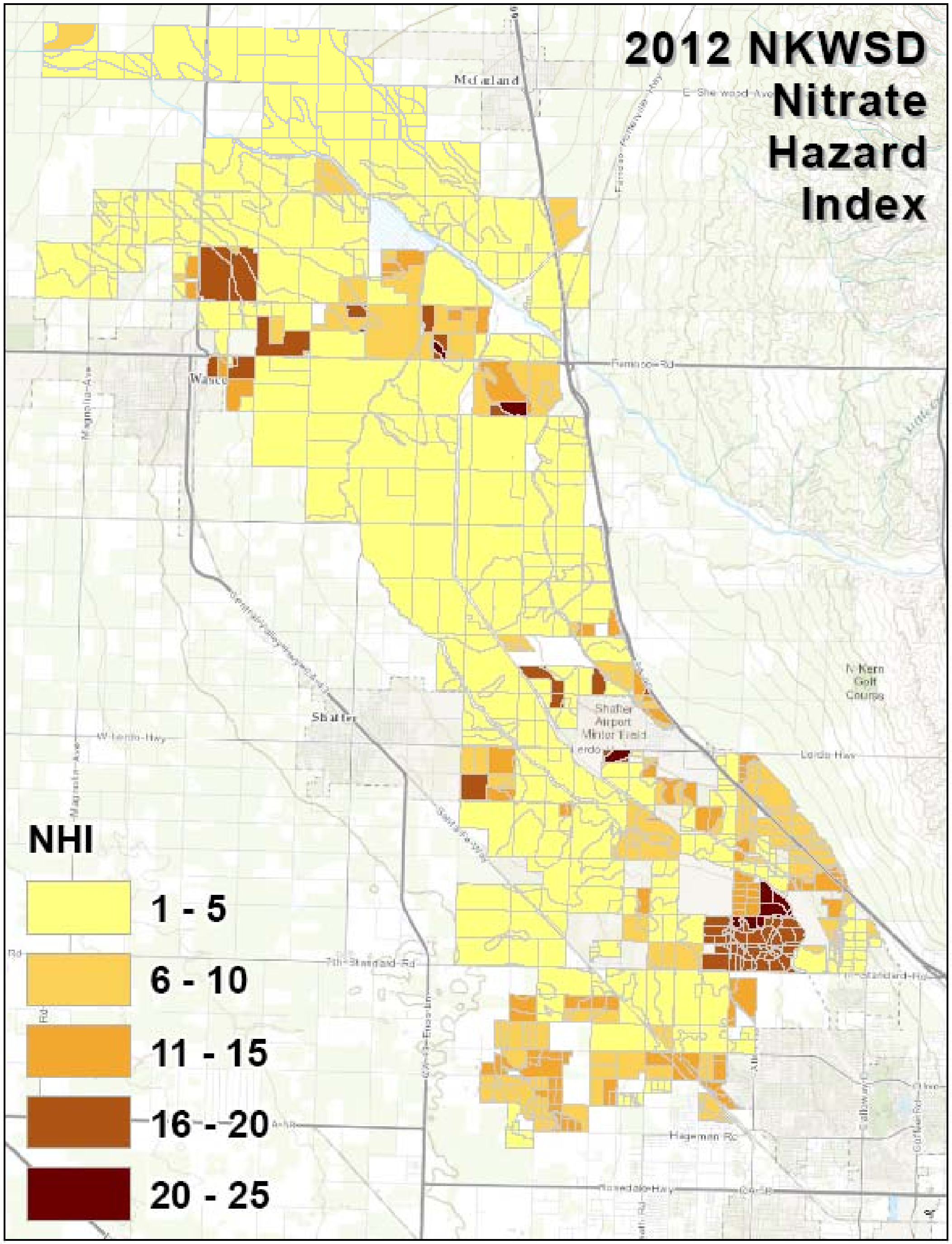
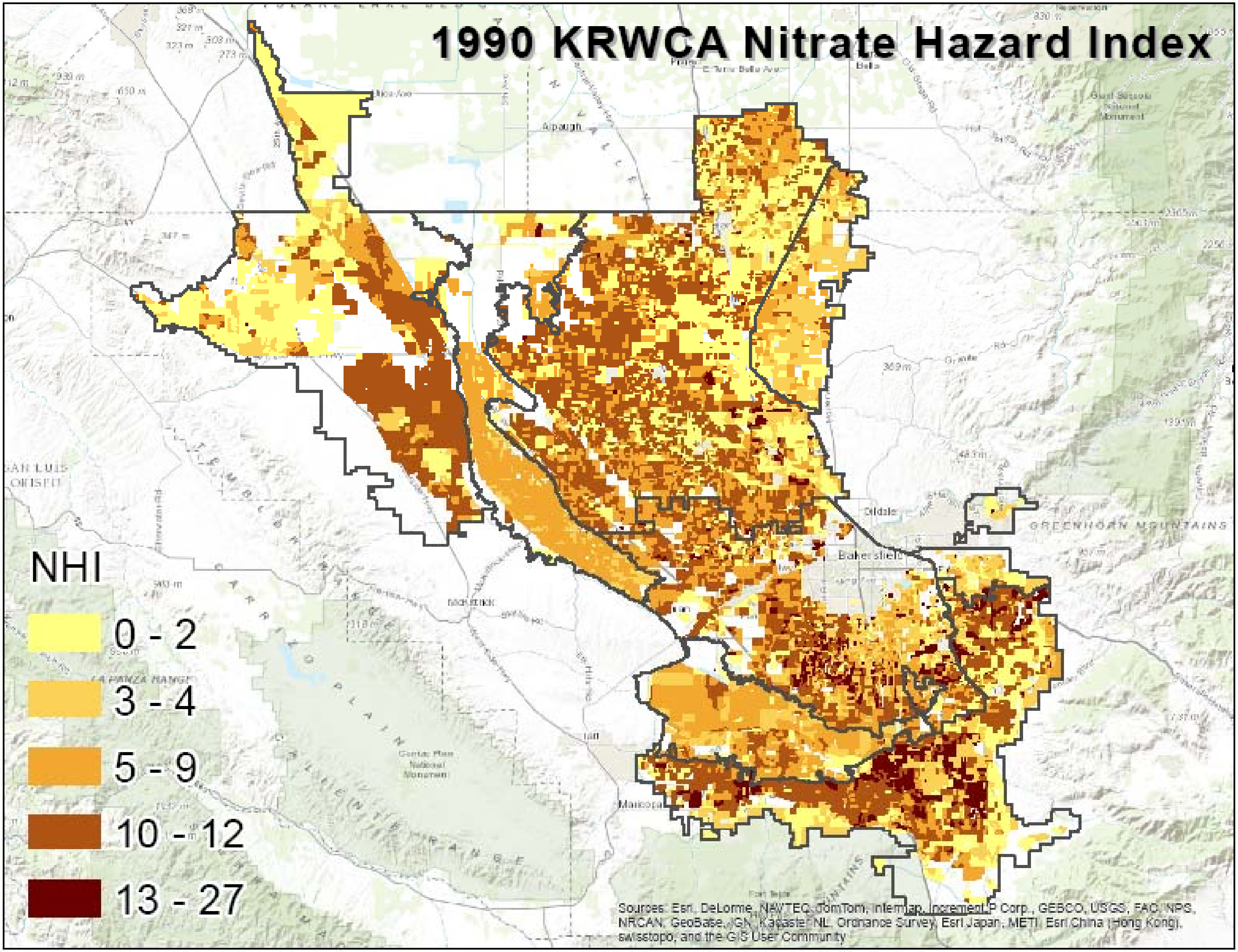
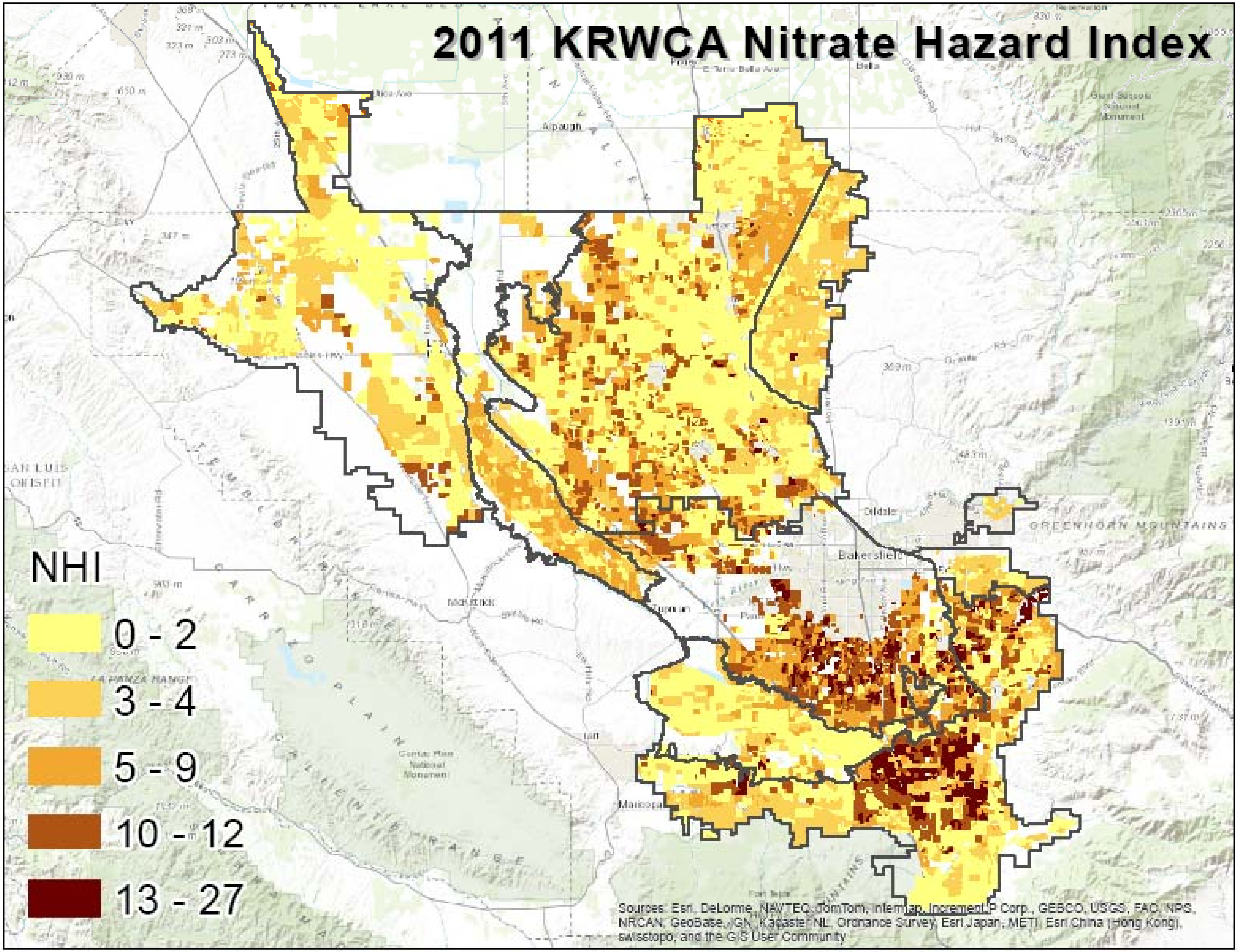
N Kern
Golf
Course
Lerdo Hwy
7th Standard Rd
Hageman Rd
Rosedale Hwy



2012 NKWSD
Nitrate
Hazard
Index
NHI
1 - 5
6 - 10
11 - 15
16 - 20
20 - 25
McFarland
Wasco
Shafter
Shafter Airport Minter Field
N Kern Golf Course
Fumoso Rd
Lerdo Hwy
7th Standard Rd
Hageman Rd
Rosedale Hwy


1990 KRWCA Nitrate Hazard Index
NHI
0 - 2
3 - 4
5 - 9
10 - 12
13 - 27
Bakersfield
Oildale
Maricopa
Alpaugh
GREENHORN MOUNTAINS
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community


2011 KRWCA Nitrate Hazard Index
NHI
0 - 2
3 - 4
5 - 9
10 - 12
13 - 27
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Nitrate Hazard Index

- Advantages
  - Simple – Does not require numerical data, but more beneficial when available
  - Flexible – Can be used on as large or small scale as desired, or in combination with other assessment methods
  - Additional – More parameters (e.g. N Use Efficiency (NUE), effective precipitation, depth to groundwater, etc.) can be included and weighted to better represent the areas being classified
  - Valid – Developed by multidisciplinary group of experts and approved by SWRCB. Has been replicated
  - Satisfies SWRCB desire to prioritize regulation in an even more refined way
  - Satisfies agricultural interests in achieving “customized” rather than “one-size fits all” approach to agricultural regulation

Nitrate Hazard Index

- Challenges
  - Does not provide absolute values, therefore difficult to be used as a quantitative benchmark
  - Needs completion/updating – hazard values for soils, unique crop combinations, new irrigation system technologies, regional differences
  - Needs consideration/development of additionality (e.g. consumptive N ratio?, depth to groundwater?, effective precipitation?)
  - Requires more analysis up front, but purpose would be to strategically focus monitoring and regulatory efforts overall for more effective results, management and cost savings

Theme of questions 5-7

Application of Management Practices

- **The application and use of management practices for the control of nonpoint source pollution is a fundamental approach** taken by many Water Board orders, and considered a key element in the State Water Board's *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program, May 20, 2004.*
- **Management practices that are cost-effective and are easy to implement have the best chance of being adopted** and successful. However, when comparing management practices, **consideration should also be given to the likelihood that a management practice will be effective** in reducing nitrogen loading to surface and groundwater.

Questions 5-7 – Application of Management Practices

5. What management practices are expected to be implemented and under what circumstances for the control of nitrogen?

6. What management practices are recommended for consideration by growers when they are selecting practices to put in place for the control of nitrogen?

7. Evaluate and make recommendations regarding the usage of the following management practices:

a. **<u>Nitrogen mass balance calculations and tracking of nitrogen applied to fields</u>**. This should include consideration of measuring and tracking Nitrogen:

i. Applied to crops or fields

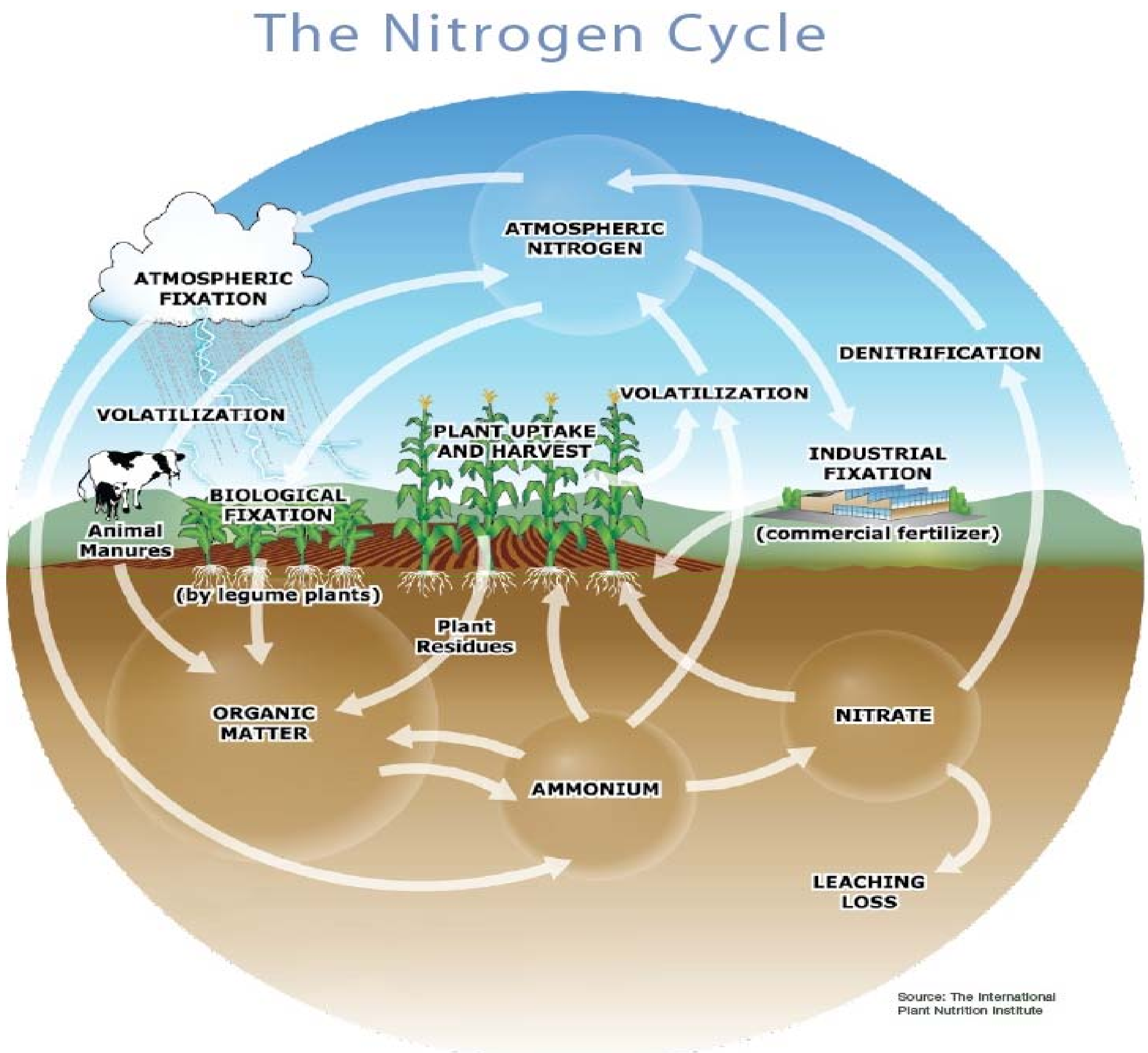
ii. In soil

iii. In irrigation water

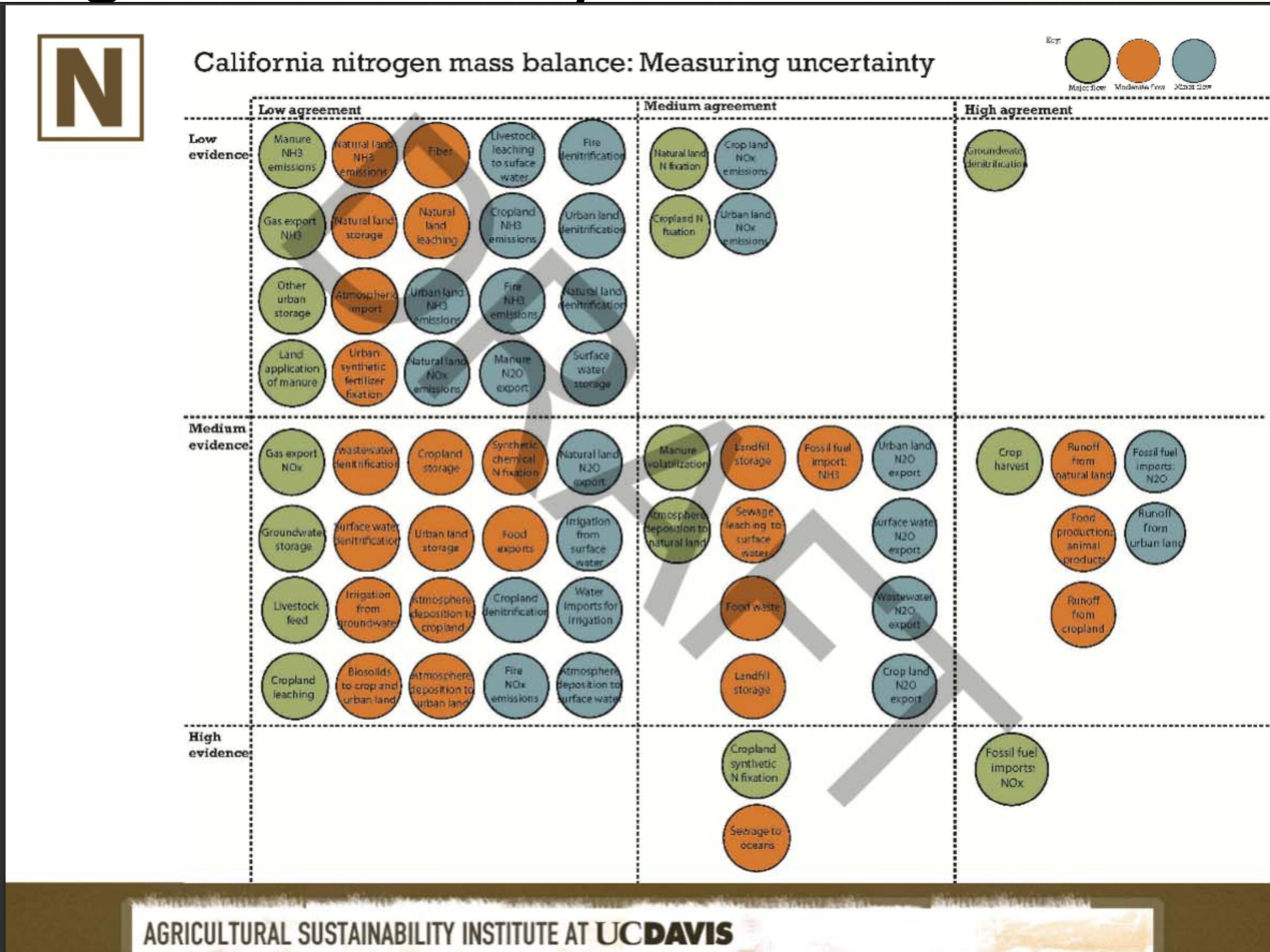
iv. Removed from the field

v. **<u>Estimation of losses</u>**

A Nitrogen Mass Balance Approach



The California Nitrogen Assessment – Ag Sustainability Institute – UC Davis



Main theme of questions 9-10

- Verification Measures
  - Utilization of verification measures to determine whether management practices are being properly implemented and achieving their stated purpose is another key element to the success of a nonpoint source control program. **<u>Because of the nature of nonpoint source discharges, direct measurements are often difficult or impossible to obtain</u>** and other means of verifications may be required.

Conclusions

- Program intent
  - Management practice based regulatory process
  - Scientifically informed
- Perspective
  - Great diversity in agriculture in California
  - Groundwater data and its interpretation represent only one part of puzzle
  - Surficial agricultural management practices are key to understanding: variability & change vs vulnerability & risk
  - Mine the existing science (e.g. Technical Report 3 – Addressing Nitrates in California's Drinking Water)

Conclusions

- Goal: Provide N leaching estimates on diverse cropping soils
  - Complexity necessitates results as broad ranges rather than absolute values
  - Highly diverse results from different cropping scenarios – substantiated by multiple studies
  - Ag systems are dissimilar in their potential to leach N and contaminate groundwater
- Necessitates the need for a more granular, management-based approach

Conclusions

- N budgeting alone cannot accurately capture the variability of N dynamics in California agriculture across the wide range of geography, climate and cultural practices throughout the state.
- N budgeting alone cannot necessarily provide information on what is contributing to or causing high or low nitrates in groundwater in any given scenario

Questions

Additional Points

Advantages of Approach and Recommendations

- Results from partial N balance approach provide some absolute, discrete values to work with (benchmarks)
- Measurements provide an indication of status of groundwater contamination
- Relative proportions of N pools can be portrayed at gross scale to improve understanding of N dynamics
- Provides methodical approach for estimating amount of N that should be applied

Challenges with Suggested Approach

- Uncertainties associated with partial N balance approach:
  - Requires even more data for interpretation
    - Even if a partial N balances were accurate in determining amount of N leached, we would still not know *why*
  - Does not capture differences that irrigation and other management practices exert on N leaching
    - Partial N balance does not capture changes in N transport and transformation caused by influencing factors

Challenges with Suggested Approach

- Uncertainties associated with partial N balance approach:
  - Results not necessarily correlated to groundwater quality monitoring results, especially where groundwater is deep and complicated hydrogeologic factors influence nitrate movement
  - Does not address historic groundwater nitrate and differences in nitrate leaching over time that result from improved management practices and irrigation systems

Challenges with Suggested Approach (cont.)

- Uncertainties associated with data collection
  - Specific uses were not clarified
  - Great diversity of agricultural infrastructure in California = inefficient data collection
  - Lack of protocol when there are significant data gaps and limitations
  - Lack of clear understanding of relationship between data types, such as irrigation and N fertilizer application
  - Complexity of relating surface data to groundwater quality data

Key Findings from Research

1. Residual N and/or N fertilizer applied is not necessarily related to amount of N leached and/or other losses

   Broadbent and Rauschkolb 1977; Olson 1982, Burrow et al. 1998; Hoben et al. 2011; Linquist et al. 2012; Van Groenigen et al. 2010; Hart et al. 1993.

2. Reducing N fertilizer application does not necessarily reduce N leaching

   Pang et al. 1997; Rosenstock et al. 2013; Altman et al. 1995; Jego et al. 2008; Fix and Piekielek 1983.

3. Nitrate leaching is more highly correlated with water moving beyond root zone than with total amount of N applied

   Letey et al. 1977; Pratt et al. 1984; Feaga et al. 2004; Aschmann et al. 1992; Randall and Iragavarapu 1995; Gaines and Gaines 1994; Tindall et al 1995; La Follie 2000; Letey and Vaughan 2013.

4. Management practices change groundwater nitrate status

   Letey and Vaughan, 2013; Haslauer et al. 2004; Broadbent and Rauschkilb 1977

Questions 9-10 – Verification Measures

9. What measurements can be used to verify that the implementations of management practices for nitrogen are as effective as possible?

10. Evaluate and make recommendations regarding the usage of the following verification measurements of nitrogen control:

a. Sampling first encountered groundwater via shallow monitoring wells.

b. Direct sampling of groundwater from existing wells, such as an irrigation well or domestic drinking water well, near the field(s) where management practices for nitrogen are being implemented.

c. Sampling of the soil profile to determine the extent to which nitrogen applied to a field moved below the root zone.

d. Representative sampling of a limited area and applying the results broadly.

e. Sampling water in surface water containment structures for their potential discharge to groundwater.