NewFields Agricultural & Environmental Resources
2020 L Street, Suite 110
Sacramento, CA 95811
T: 916.265.6350
www.newfields.com

Kern River Watershed Coalition Authority
Assessment of Potential for Nitrate Migration in Kern Sub-Basin
Documentation Submittal for Preliminary Review Only

TO:

Ernest Conant/Young Wooldridge

John Schaap/Provost & Pritchard

FROM:

Joel Kimmelshue, PhD, CPSS/NewFields Agricultural & Environmental Resources

Stephanie Tillman, MS, CPSS/Ag/NewFields Agricultural & Environmental Resources

April 11, 2013

Executive Summary

Background

The California Regional Water Quality Control Board – Central Valley Region (CVRWQCB) has issued Tentative Order R5-2013-XXXX titled, Waste Discharge Requirements General Order for growers within the Tulare Lake Basin Area that are members of a Third Party Group, dated March 15, 2013,"Tentative Order". This technical memorandum has been developed in support of the comments submitted by the Kern River Watershed Coalition Authority (KRWCA).

The purpose of this technical memorandum is two-fold: (1) to document on-going technical work that addresses the unique nature of the Kern Sub-Basin area, and (2) to provide an explanation of an alternative and modified methodology (using a Nitrate Hazard Index, or "NHI") to rank, track, and manage the potential for nitrate leaching to groundwater.

Approach

The overall approach of the work performed for the KRWCA was to:

- Develop and explain representative leaching conditions using a Soil Moisture Root Zone Balance (SMB) and understand the inherent variability associated with those estimates with specific conditions related to the Kern Sub-Basin area.

- Develop a unique Nitrate Hazard Index (NHI) as a comprehensive tool to use in assessing large landscape areas on a field by field basis in order to estimate relative potential nitrate contributions to groundwater based on surface agricultural activities and conditions unique to the Kern Sub-Basin area.

Results and Conclusions

The results and conclusions listed below, while part of an on-going investigation, are consistent with the conclusions from various researchers and approaches. NewFields used specific information applicable to the Kern Sub-Basin area.

- Currently, the Tentative Order suggests that agriculture in the Kern sub-basin is to be regulated similarly across all cropping systems in large areas regardless of irrigation method, N management, soil type, crop type, location, etc. The results of this preliminary evaluation indicate that within the Kern Sub-Basin there are significant differences between crop types and resultant potential contributions of N to groundwater resources which will require more flexible and perhaps crop- or area-specific considerations in order to develop effective regulations.

- For a variety of reasons (e.g. water availability, water cost, soil type, crop mix, market conditions, effective rainfall, etc.) the relative water use and nitrogen use in the Kern Sub-Basin is generally more efficient as compared to other areas of the Southern San Joaquin Valley and the remainder of the Central Valley as a whole. This is also supported by research conducted by others (Pettygrove, et al, 2012) (Boyle, et al, 2011) as contracted by the State Water Quality Control Board.

- Regardless of the methodology employed, estimating nitrate leaching, even under specified conditions, is a highly complex task with many variables. Therefore, the results of any N leaching estimating method should be interpreted as precisely that – estimates only – and are subject to modification with new information.

- The most significant effort related to broad land-based estimates of nitrate leaching potential to date focused on assessing nitrate contamination in groundwater from agricultural sources in California and resulted in the UC Nitrate Hazard Index. This effort intentionally avoided any attempt to place absolute values on total amounts of nitrate leached, due to the known variability (Wu et al, 1995). This work was developed and reviewed by some of the foremost experts in this multi-disciplinary subject, and should serve as an indication of the caution with which estimates of nitrate leaching must be interpreted and how variable they can be.

- A preliminary NHI was developed for the Kern Sub-Basin (specific to its conditions) and compared to previous years. In relative comparisons, the potential for nitrate leaching has decreased significantly over the past 20 years and in many areas is negligible due to the rapid conversion to highly-efficient irrigated perennial crops from historic surface irrigated row and field crops. The NHI approach allows for comprehensive assessment for the potential of nitrate leaching on large landscapes at the field level.

- From a hydraulic perspective, for purposes of our investigations, the Kern Sub Basin area was successfully separated into 6 regions that offered like soil, crop, water supply and overall production system similarities and a spatial dataset was developed from recent crop mapping (Kern Co., 2011) as the basis for analysis.

- This spatial dataset coupled with detailed literature resources and local expert knowledge specific to the Kern Sub-Basin was used in creation of inputs used for the analysis performed.

- Major crop type systems were evaluated from both a hydraulic (agronomic water balance focusing on return flows to groundwater) and nutrient use efficiency standpoint.

- In general, results confirm that perennial crops on high efficiency irrigation systems (common to the Kern sub basin) result in limited return flows to groundwater.

- Largest return flows occur under corn/wheat, sudan/wheat or other forage crop rotations that are commonly associated with feeding operations for dairies. The majority of these systems are currently regulated under the Dairy General Order (2007-035).

- Other row crops such as cotton/wheat and carrot/potato rotations result in moderate return flow estimates mostly because of the types of irrigation methods and management employed.

- The variation in nitrate leaching estimates for diverse cropping scenarios is significant, as irrigation method and soil combinations result in a wide range of nitrate leaching estimates. This finding is substantiated by numerous authors, whose work contributes to the scientific literature on N dynamics in cropping scenarios (Viers et al., 2012), and reinforces the point that nitrate leaching from various cropping systems cannot be considered or treated as similar systems.

- As a result of this preliminary evaluation, it is evident that a continued significant contributor to nitrate concentrations in groundwater is forage cropping systems predominantly used for dairy feed sources. The conclusion is supported by work performed by UC Davis (Pettygrove, et al., 2012). Much of this forage crop production is currently regulated under the existing Dairy General Order 2007-035 (the "Dairy Order").

- As a result of our preliminary NHI evaluation, drip/micro irrigated perennials have a low risk due to limited return flow and effective precipitation. These results also agree with work performed by UC Davis (Pettygrove, et al., 2012) that also show that the nitrate risks to groundwater in the Kern Sub-Basin is significantly less than other areas to the North.

- Development and utilization of a modified, Kern Sub Basin-specific NHI as a comprehensive tool to use in assessing large landscape areas on a field by field basis is a preferred methodology in estimating relative potential nitrate contributions to groundwater based on surface agricultural activities and conditions. The NHI should be employed within the proposed Waste Discharge Requirements Tentative Order for members of a third-party group within the Tulare Lake Basin, at least for the Kern Sub-Basin, as a means of simplifying and prioritizing the regulatory scheme.

General Introduction

The subject of this review is the proposed California Regional Water Quality Control Board – Central Valley Region (CVRWQCB) Order R5-2013-XXXX titled, Waste Discharge Requirements Tentative Order.

NewFields Agricultural & Environmental Resources has been retained by Young Wooldridge, LLP, on behalf of the Kern River Watershed Coalition Authority, to assist in development of scientific-based, comments and suggestions to the Tentative Order. Some focus areas will include:

- irrigation and drainage management
- nutrient use efficiencies
- soil/nutrient dynamics
- crop production
- root zone moisture management
- other related scientific approaches

Our project team has focused efforts on estimated hydraulic and nitrogen components of the varied agricultural systems within the Kern Sub-Basin of the Southern San Joaquin Water Quality Coalition (SSJWQC). A comparison to other directly applicable published work will also be provided.

More specifically, the technical tasks that have been completed include:

- Review of the Tentative Order and Other Appropriate Literature
- Development of Spatial Data Resources
- Development of Representative Scenarios and Soil Moisture Budgets
- Development of a Preliminary NHI for the entire Kern Sub-Basin

In addition to these tasks, an attempt to compare existing agronomic conditions to past trends has been developed both from a water use efficiency and nitrogen (N) use efficiency standpoint.

Finally, the results of this work were compared to agronomic-focused research in the same area conducted by other researchers (e.g. Pettygrove, et al., 2012 and Boyle, et al, 2011). These researchers and others have developed components of an overall study performed by UC Davis (Harter, et. al. 2012) and support the work performed here.

Development of Spatial Data Resources

Introduction

The first step in assessing a region of this size is to partition “like” or more “manageable” areas that may be similar in soil type, crop type, irrigation supply and management, climate, etc. The information below provides the detailed documentation as to the methods used to separate the Kern sub-basin into six regional components for the purpose of our investigations.

Methods

Determination of Regions

The following descriptions outline the features that were used to determine the boundaries between each region. Names of KRWCA agencies (water districts, irrigation districts and water storage districts) are also included to ensure all KRWCA agencies are accounted for in a region or multiple regions. Final results indicate six distinct areas with similar characteristics (Figure 1).

Clay Rim Region

This region was created in response to two dominant zones of fine-textured clay present within the valley. The region encompasses all of the Buena Vista WSD and Henry Miller WD, portions of the Wheeler Ridge-Maricopa WSD (from the districts northern border to Copus Rd), southwest portions of the Kern Delta WD (from I-5 west and Herring Rd south), the northwestern portion of the Semitropic WSD (from Gun Club Rd. west and CA-46 north) and the northeastern corner of the Lost Hills WD (East of I-5).

Foothills Region

The Foothills region contains portions of the Southern San Joaquin MUD (east of the Famoso-Porterville Hwy), a portion of the Delano-Earlimart ID, Kern-Tulare WD, the Olcese WD, the Cawelo WD and a portion of the Arvin-Edison WSD. The eastern boundary of the region follows the Kern-Tulare WD and the Cawelo WD boundaries. The western boundary was determined based on the distribution of crop types due to the limited difference between soil mapping units found. A noticeable shift in crop types occurs immediately to the east of the city of Delano and the Famoso-Porterville Hwy/Richgrove Dr. from Vestal south to Famoso. This shift along Famoso-Porterville Hwy/Richgrove Dr from predominantly annuals, almonds, and grapes to the west and predominantly citrus to the east necessitates deviating from coalition agency boundaries to define the western edge of the Foothill region. The eastern and western boundaries head south along Poso Creek until it reaches the eastern border of Cawelo WD. The inclusion of a northern portion of the Arvin-Edison WSD is due to the density of citrus in this area. The northern boundary is formed by the Kern-Tulare WD northern border south of the city of Ducor near Vestal.

Kern Fan Region

The Kern Fan region contains the Rosedale-Rio Bravo WSD and the Kern Delta WD. The boundary was determined using differences in soil texture from the USGS SSURGO soil database and WSD boundaries. The orientation of soil map units (directionality of sediment deposition based on historic water flow characteristics) and the horizontal stratification associated with alluvial fans (coarse textured soils near the mouth of the stream and finer textured soils as distance increases away from the mouth of the stream) clearly shows the extent of the Kern River Fan. The southern boundary is formed along the Clay Rim region and a small section of the Arvin-Edison WSD The northern boundary is found along the Rosedale-Rio Bravo WSD northern border. The eastern edge is found along the Kern Delta WD and Arvin-Edison WSD boundary and extends north along CA-99 to Oildale. The western boundary is found running south from the Clay Rim region at Buttonwillow to the California Aqueduct at the Tule Elk State Reserve and south along the Aqueduct to Ironback Rd.

Westside Region

The Westside region contains the Belridge WSD, Dudley Ridge WD, Lost Hills WD and Berrenda Mesa WD. The boundary extends west to the edge of the Kern Sub-Basin, down to the bottom of Belridge WSD. The Eastern boundary follows the Clay Rim region which closely coincides with the Semitropic WSD and Buena Vista WSD western boundaries. More specifically, the eastern boundary mirrors that of the Clay Rim region to the bottom of Belridge WSD. The northern boundary extends to the northern most portion of the Dudley Ridge WD. The southern boundary of the region is shared by the southern boundary of the Belridge WSD and terminates near Lokern Rd by Missouri Triangle. The southern end of this region neighbors land that is not cropped and was therefore excluded. The interface between all of these coalition agency boundaries also corresponds closely with differences in soil texture distribution with the north end of this region being more heterogeneous in the textures found and the neighboring region (Northern region) being more homogeneous.

Northern Region

The North region contains portions of the Semitropic WSD (with the exception of the northwest corner from approx. CA-46, north and Gun Club Rd, west), the Southern San Joaquin MUD (west of Famoso-Porterville Hwy), Shafter-Wasco ID and the majority of the North Kern WSD (omitting the portion of the North Kern WSD that follows the Kern River). The western boundary respects the border established by the Clay Rim region. The eastern boundary follows the Famoso-Porterville Hwy to near the city of Famoso where it then follows Poso Creek and meets the Cawelo WD. The southern boundary lies along the northern border of the Rosedale-Rio Bravo WSD which happens to follow differences in soil texture found between the Northern region and Kern Fan region. The northern boundary is shared with the northern boundary of the Delano-Earlimart ID. The distinguishing characteristics that merit including this area as a separate region are the widespread presence of almonds and the divergent soil textures when compared to neighboring WSD's and regions.

Wheeler Ridge/Arvin-Edison Region

The Wheeler Ridge/Arvin–Edison region contains both of these water districts. The boundary follows the Arvin-Edison WSD and Wheeler Ridge-Maricopa WSD borders. Slight modifications to the boundary were made based on differences in soil texture and crop distribution when compared to surrounding areas, specifically coarser textured soils and citrus establishment. As a result, a portion of the northeastern section of Arvin-Edison WSD has been included in the Foothills WSD. Additionally, the dominant crop type in the area differed from other zones and overall crop diversity was increased in this region versus others. Furthermore, because of differences in soil texture and crop type in the northern part of the Wheeler Ridge-Maricopa WSD, the section from Copus Rd north to the district boundary is included in the Clay Rim region.

Approximately 935,000 acres were irrigated within the Kern Sub-Basin in 2011 (Table 1).

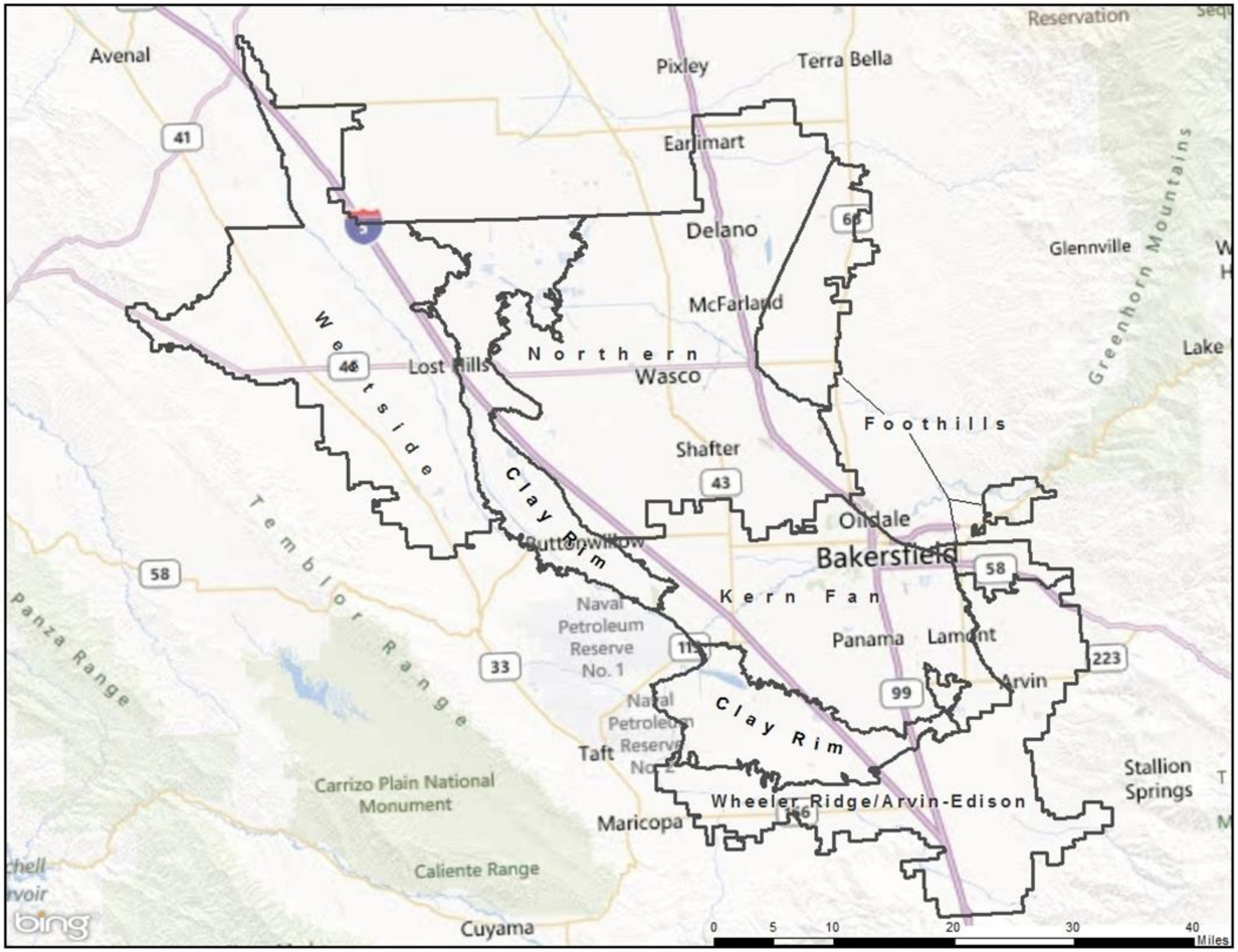


Figure 1. Six distinct regions based on differences in soil type, crop types and management

Table 1. Acreage summary for each region (includes irrigated lands only)

Region (AOI) Name	Acres
Clay Rim	114,809
Foothills	68,861
Kern Fan	106,032
Northern	321,360
Westside	152,013
Wheeler Ridge/Arvin-Edison	172,290
Total	935,365

Determination of Soil Type

The complexity and diversity of soil type over approximately 935,000 irrigated acres in the Kern sub-basin is substantial. The main driving force behind determining soil type was for the purpose of accounting for soil water holding capacities and relationships to crop types and modifications in irrigation management practices. The national SURRGO spatial soils database was initially used to partition the multitude of map unit classifications into three main categories (fine, medium and coarse) based on dominant surface texture within the expected rooting zone of the crops (Figure 2). It should be noted that soil types may also be categorized by drainage classification. Fine textured soils included mostly clays and any sandy clays and silty clays as defined by USDA textural classifications. Coarse textured soils included sands, loamy sands and coarse sandy loams. For the purposes of this evaluation, all other sandy loams (e.g. medium and fine sandy loams) were grouped with the medium classification due to similar water holding capacities and other hydraulic characteristics. Soil type and drainage classification was ultimately used as a variable in the calculation of both SMB and NHI.

Determination of Crop Type

Crop type was determined predominantly through the use of the Kern County crop distribution spatial data resources (Figure 3) for 2011 (Kern County, 2011). This annual data resource is detailed by crop type and even within various crop rotations within a single field. It offers a recent summary of existing crop distribution in an area of the state that is rapidly changing from lower water use efficiency annual row crops to higher water use efficiency perennial crops. In this regard, there is plentiful and timely data and as compared to other counties. Kern County has excellent crop distribution spatial data as do many of the water service entities within the county. In some areas, however, annual and forage crops still persist. This is especially true in areas within the Clay Rim and locations associated with dairy operations. The following figures represent all crop distribution within the Kern sub basin (Figure 3) as well as individual major crop types (Figures 4-11).

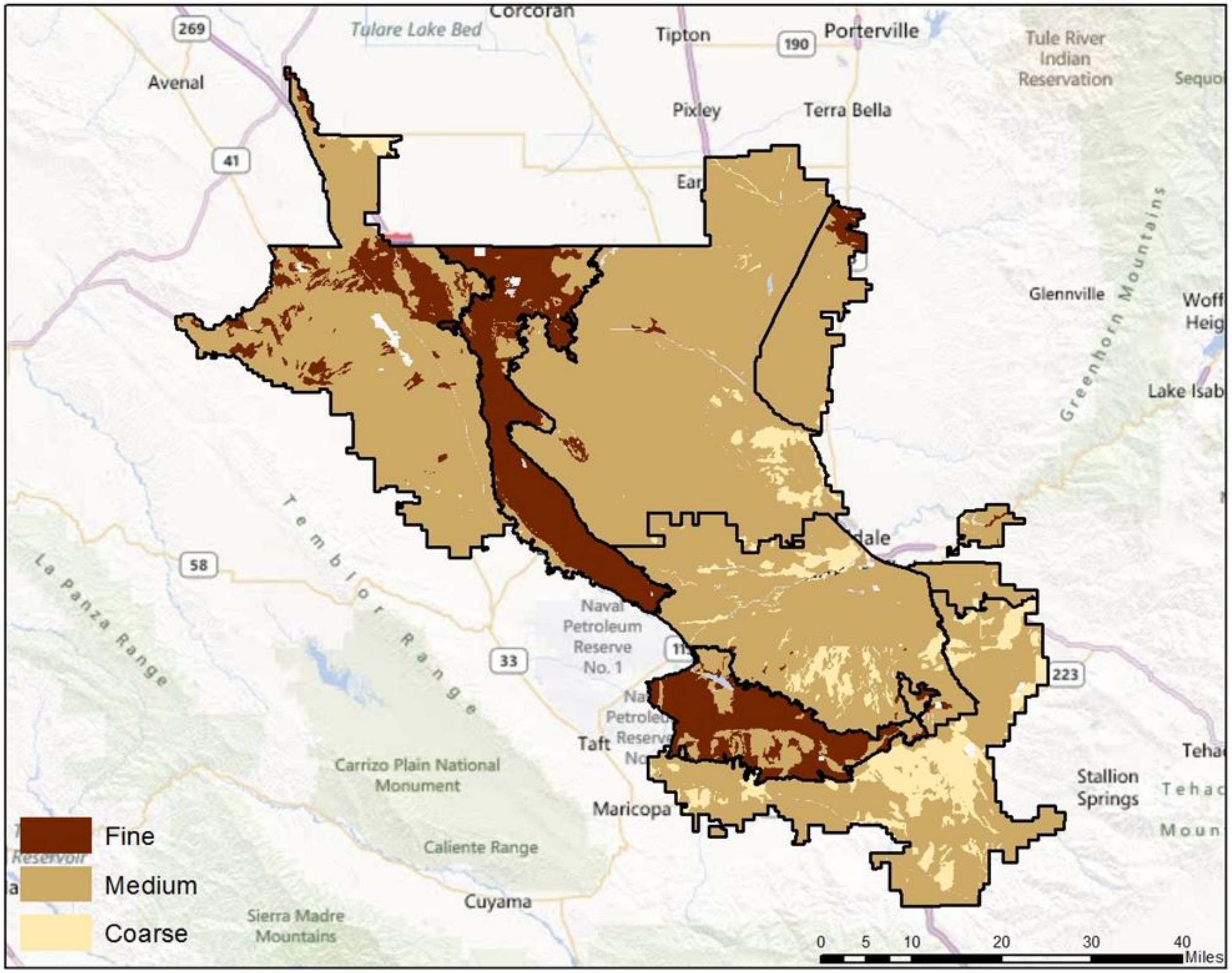


Figure 2. Generalized soil texture groupings derived from USDA SURRGO spatial soil data.

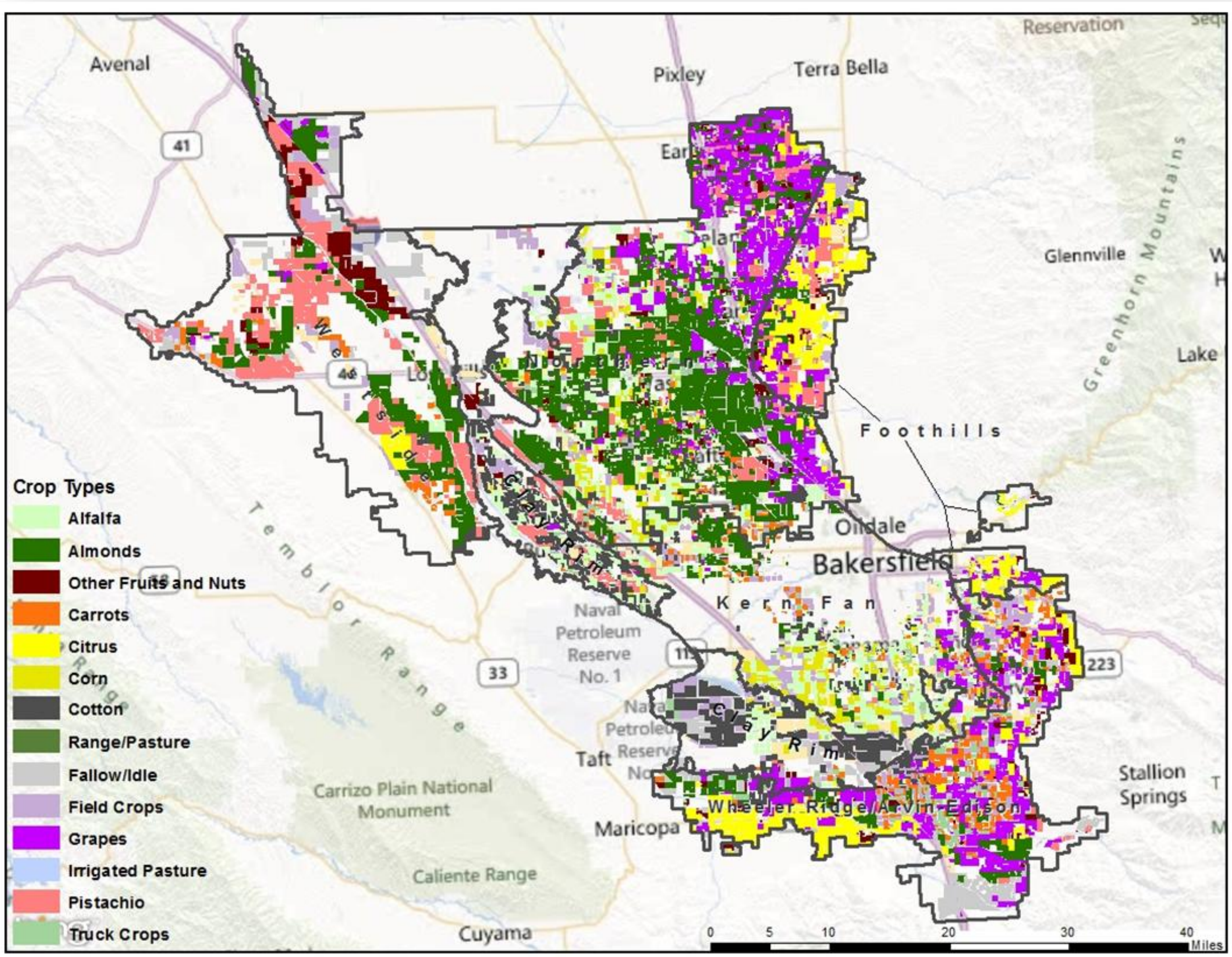


Figure 3. Comprehensive crop types and crop groupings in the KRWCA Sub-Basin.

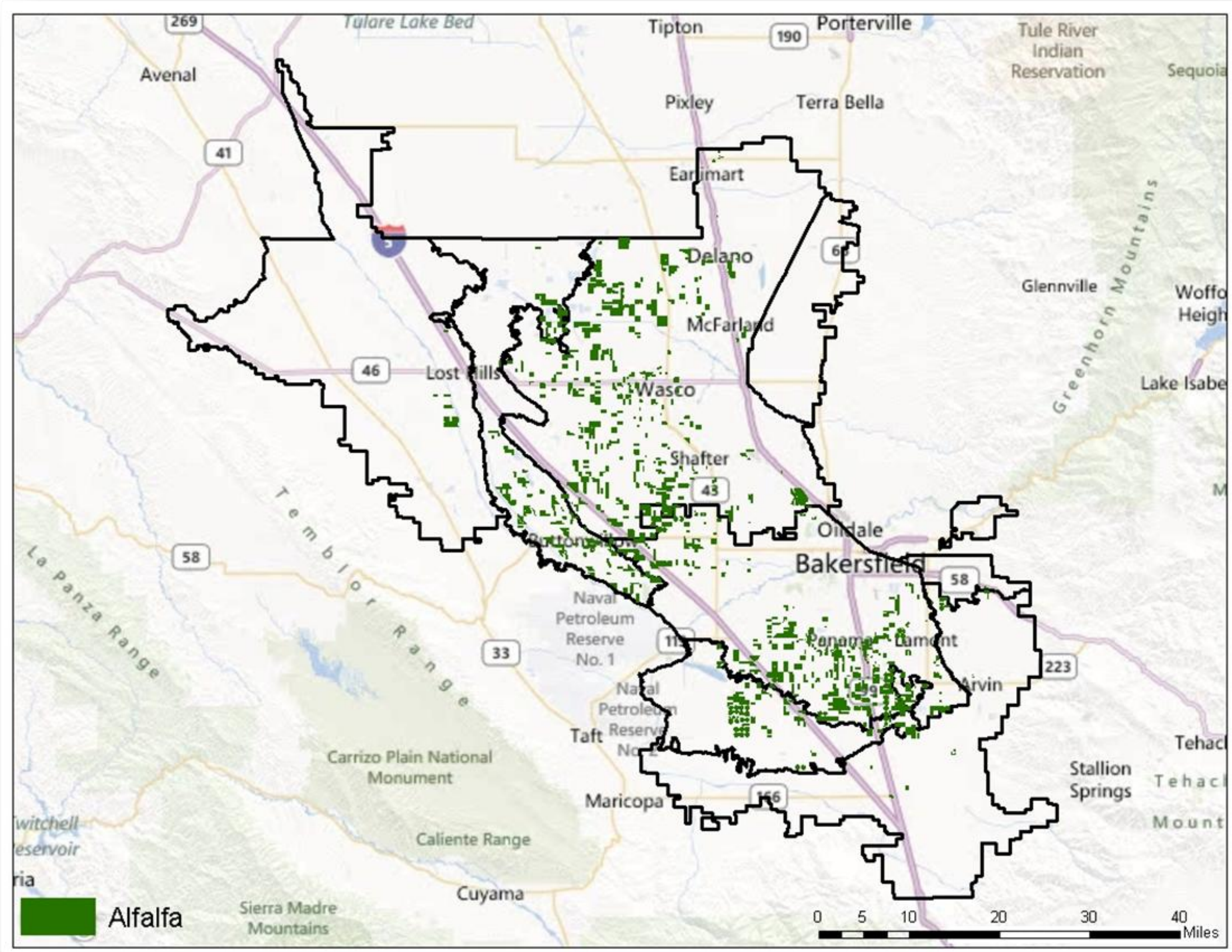


Figure 4. Alfalfa production within the KRWCA Sub-Basin.

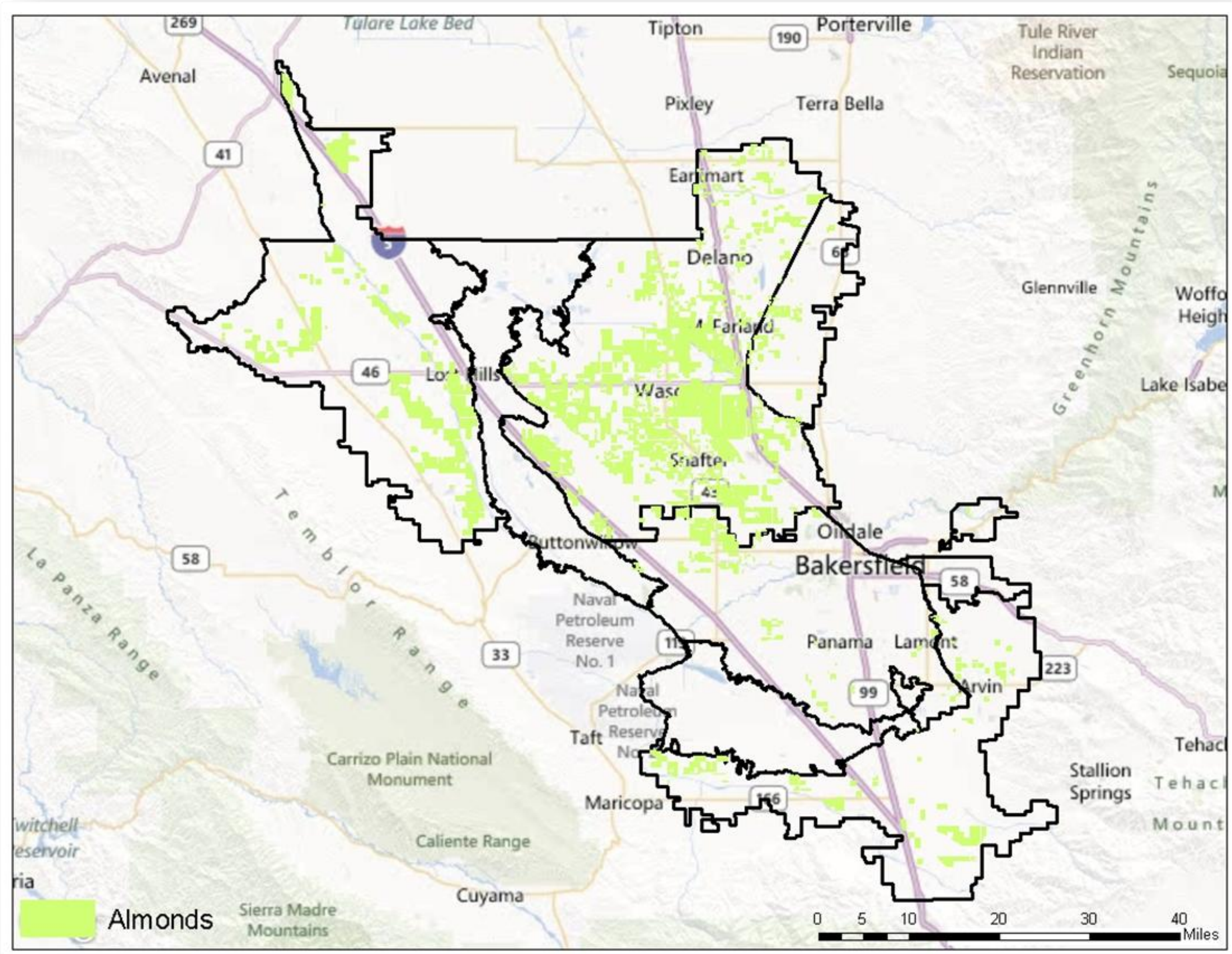


Figure 5. Almond production within the KRWCA Sub-Basin.

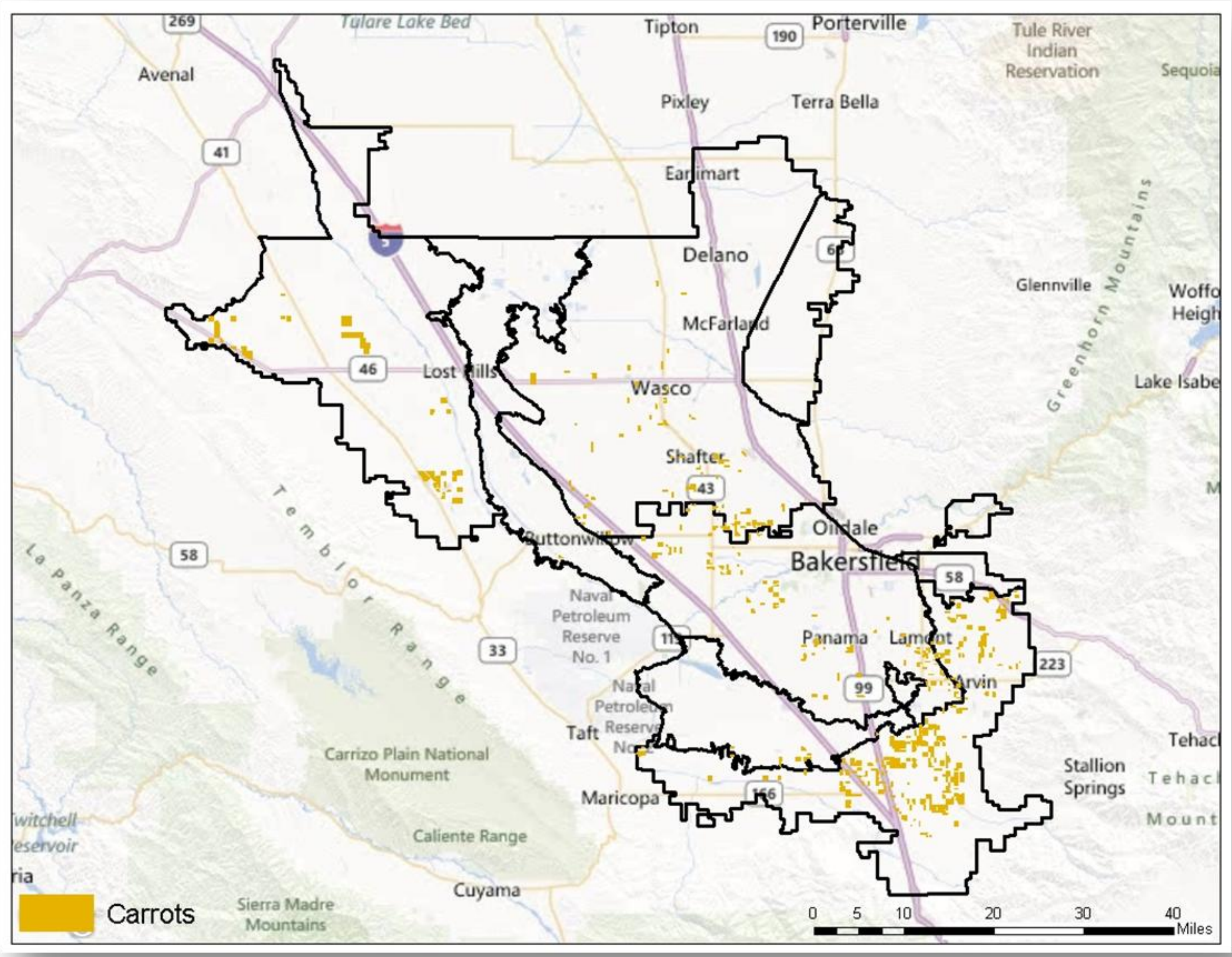


Figure 6. Carrot production within the KRWCA Sub-Basin.

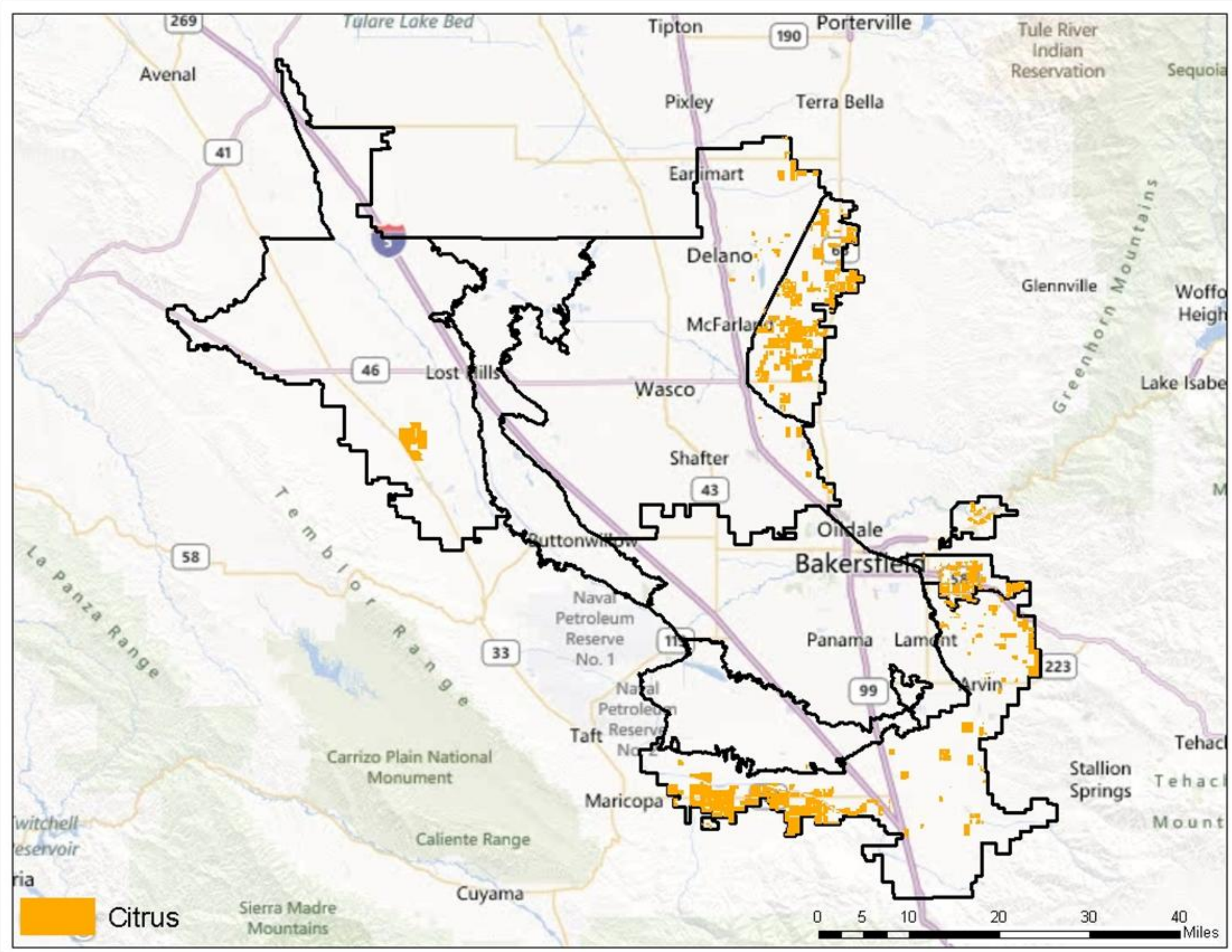


Figure 7. Citrus production within the KRWCA Sub-Basin.

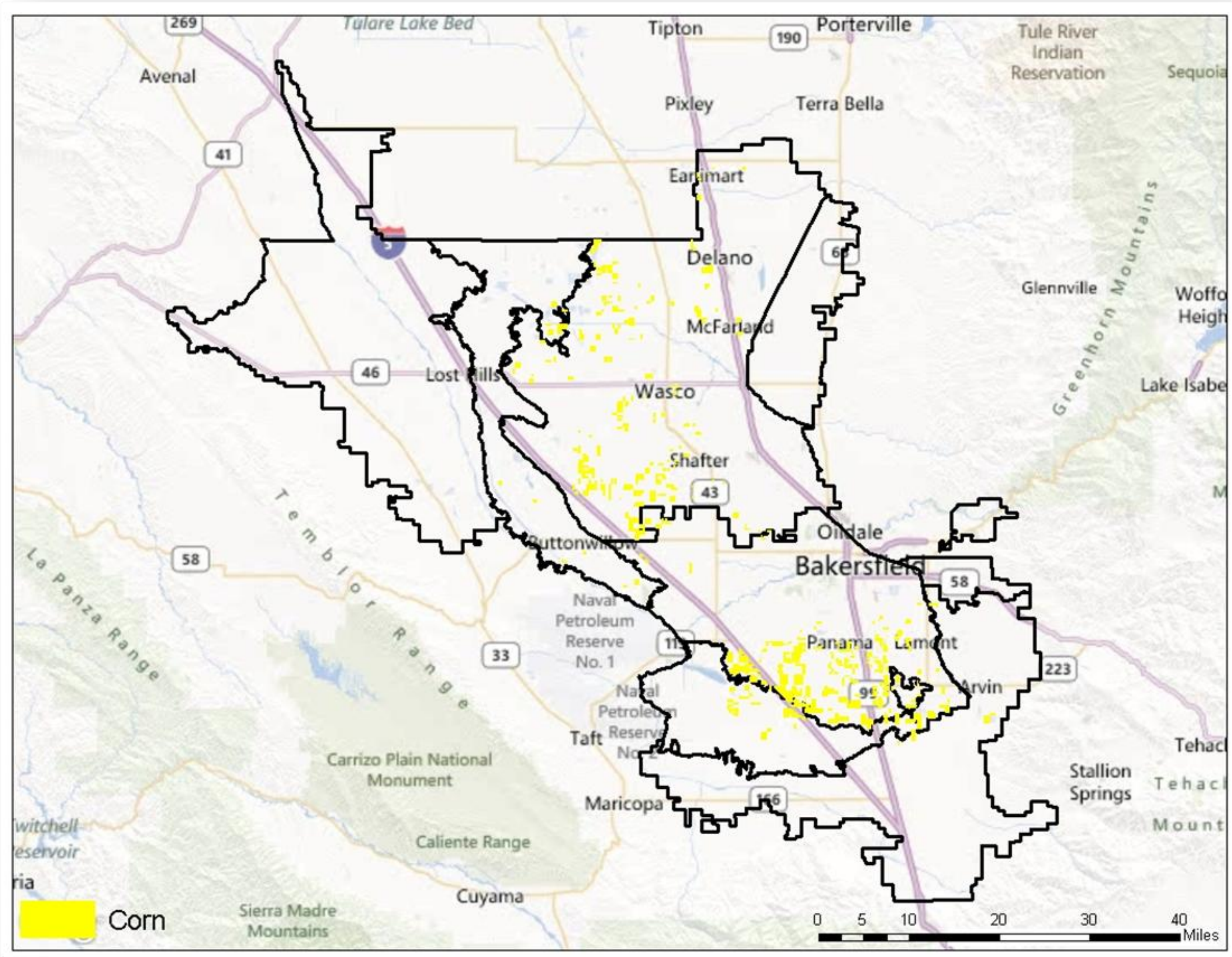


Figure 8. Corn production within the KRWCA Sub-Basin.

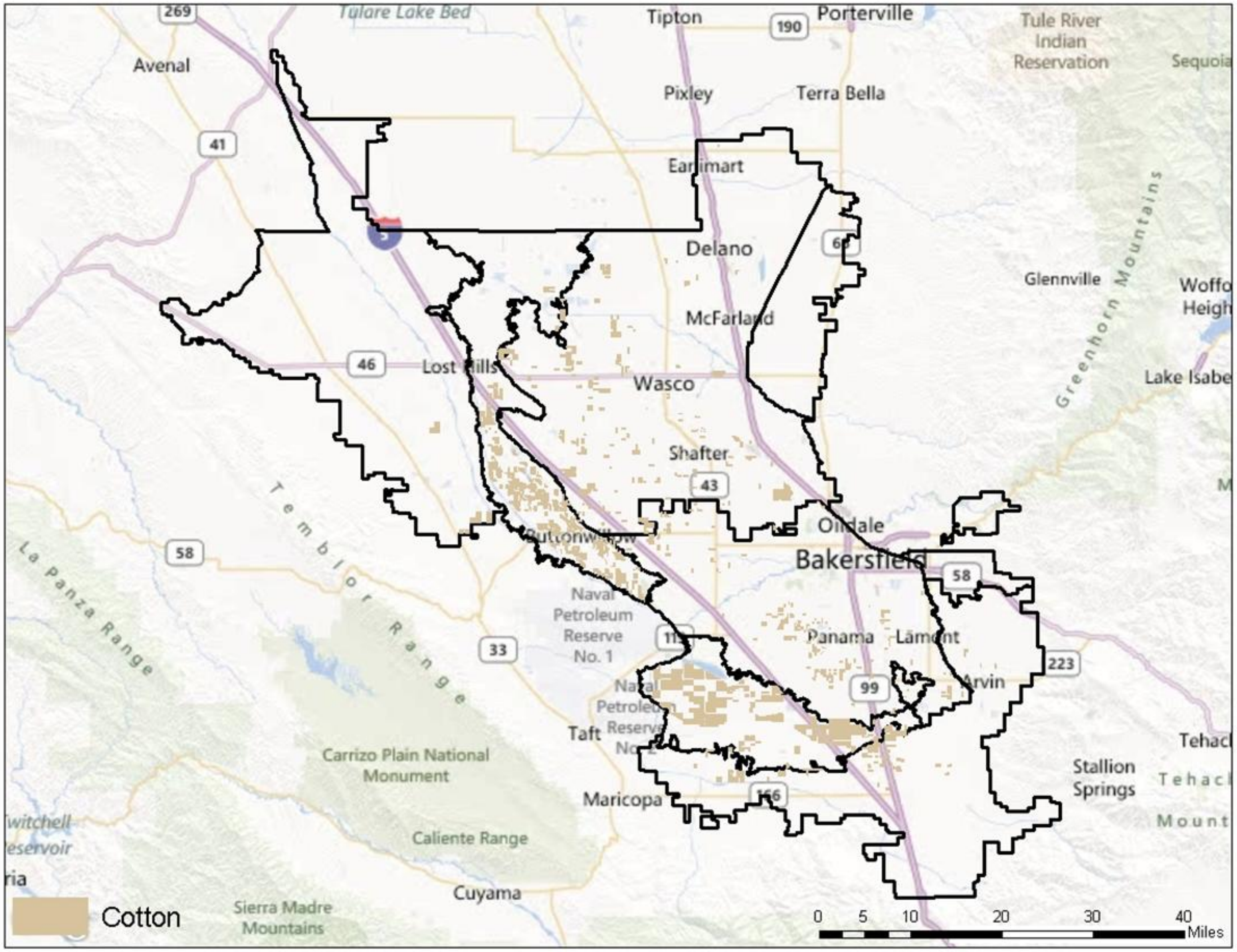


Figure 9. Cotton production within the KRWCA Sub-Basin.

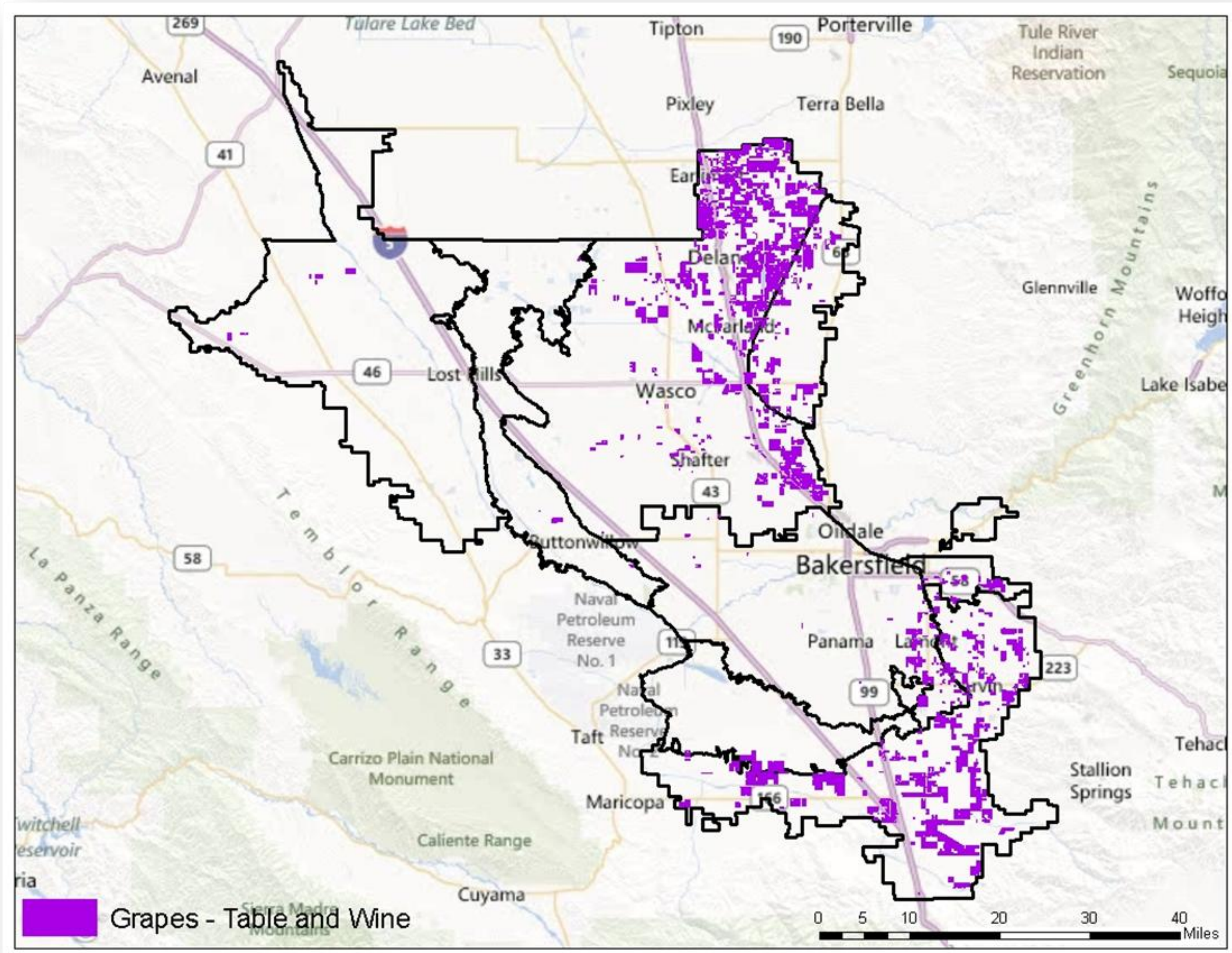


Figure 10. Grape production within the KRWCA Sub-Basin.

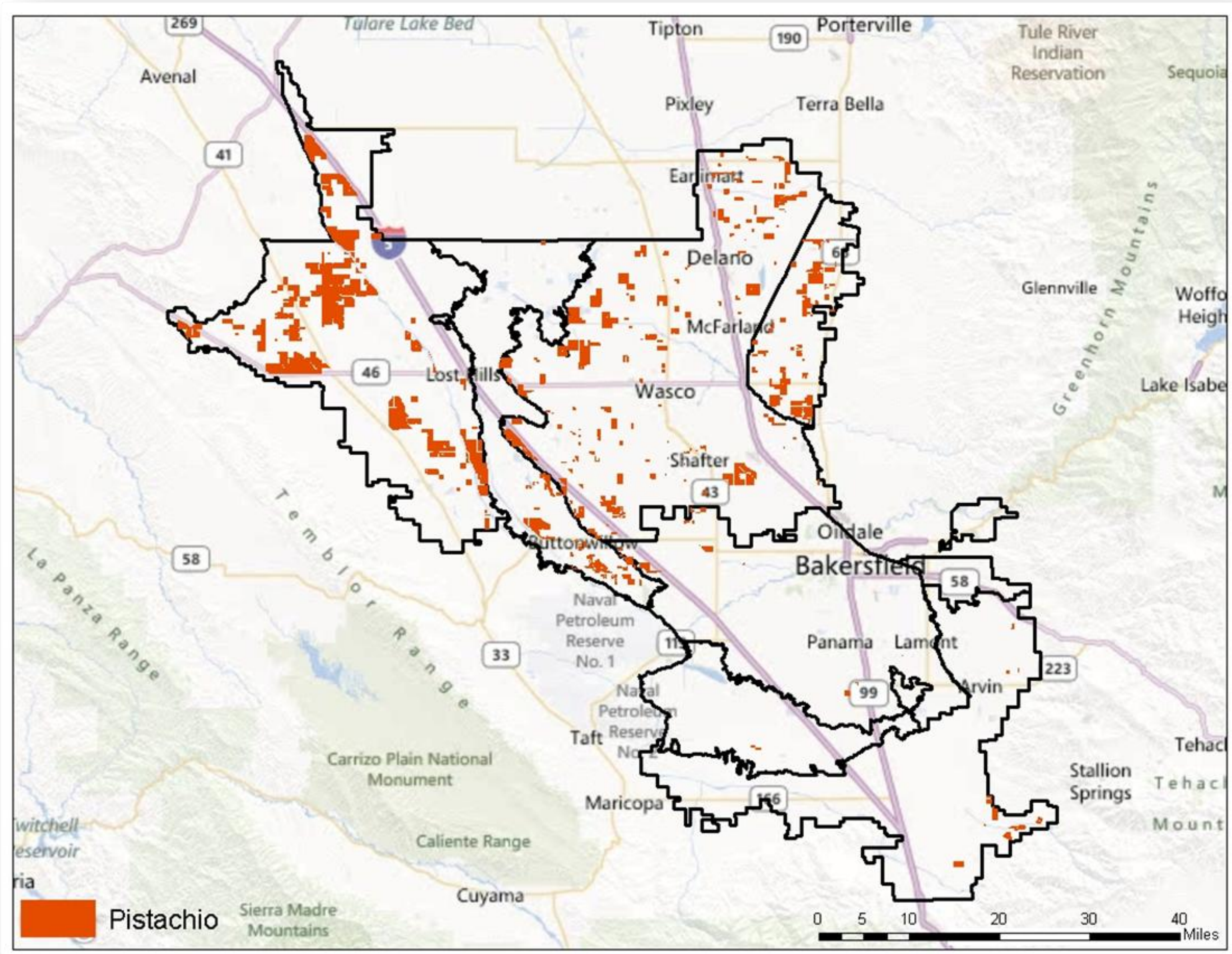


Figure 11. Pistachio production within the KRWCA Sub-Basin.

Historic Cropping Trends and Conversions

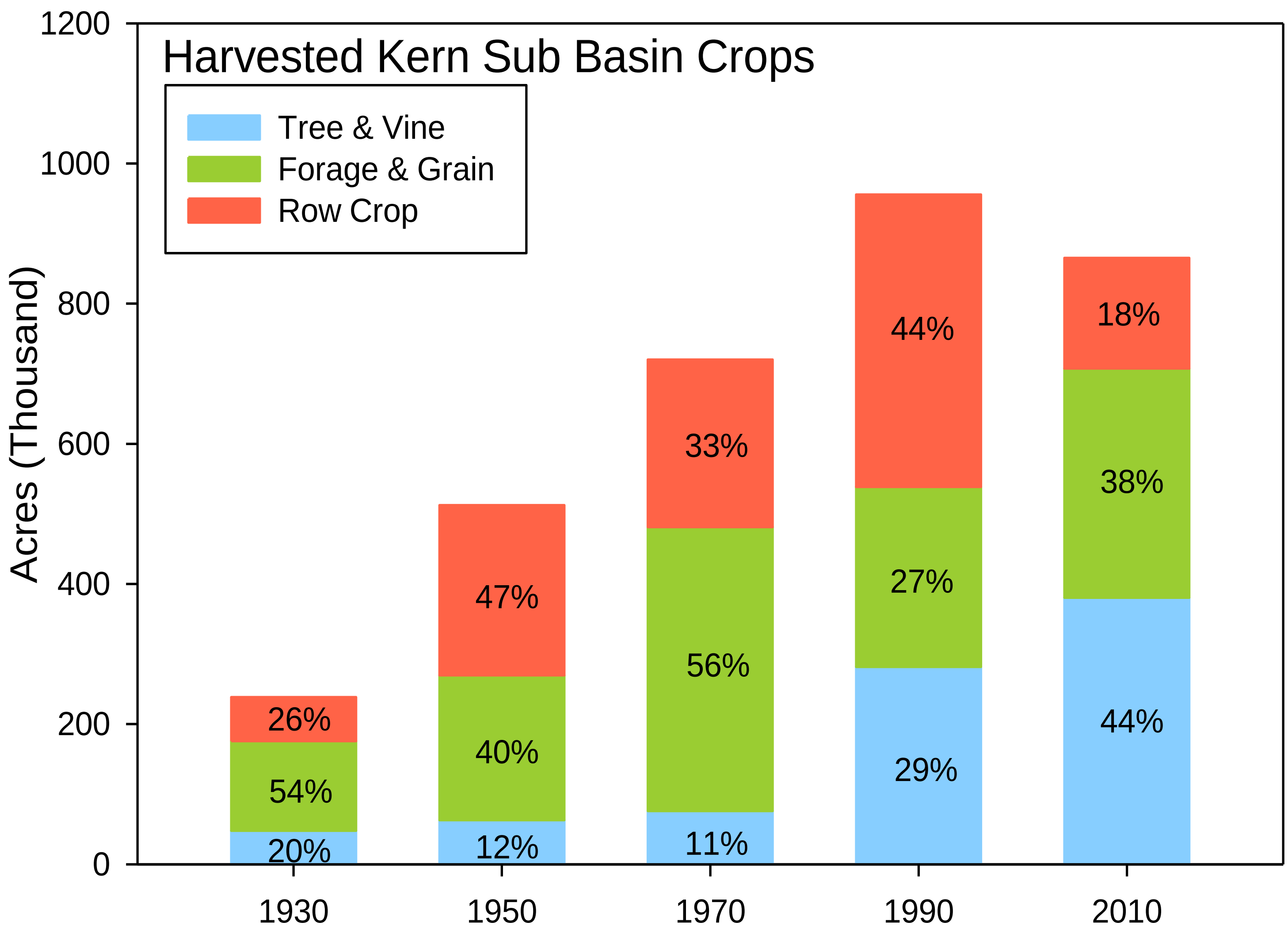
Historic crop trends for Kern Sub-Basin were summarized (Ag Commissioner Records) once every 20 years (1930-2010) to show the growth of agriculture in the county as well as the transition to permanent crops and also the recent (1990-2010) increase in forage crops associated with diaries (Figure 12). Cotton and to a lesser extent other row crops, have significantly been replaced by almonds and other permanent tree crops. This also has resulted in a corresponding shift in irrigation practices from gravity (mostly furrow) to pressurized (mostly drip/micro) systems. This has undoubtedly resulted in a significant reduction of return flows to groundwater and also associated nitrate contributions. The nitrate is allowed to remain in the deeper root zone for longer periods of time with a greater potential uptake by the crop. It is likely that Kern County is utilizing most of its irrigable land at this point. In fact, the total irrigated acreage actually dropped in 2010 as compared to 1990. Kern County does stretch into agricultural areas of the Antelope Valley; however this area is only sparsely irrigated as related to the remaining part of Kern County within the San Joaquin Valley.

Dairy production has also increased in Kern County over the past 20 years and, as a result so has a significant amount of forage crop production land (Figure 12). For the most part, the lands associated with dairy production are receiving manure as a nutrient source and are, therefore regulated by the CVRWQCB through the Dairy Order. There is, however, forage producing ground that is not regulated under the Dairy Order due the fact that it does not receive manure but does serve as a feed source.

Permanent Crop Irrigation Efficiencies

Irrigation efficiencies in the Kern Sub-Basin are, overall, some of the highest in the entire Central Valley. Various resources were used to show the increase in drip/micro irrigation systems in permanent crops (Figure 13). Overall, permanent crops are increasing significantly in the Sub-Basin and in nearly all cases are developed with highly efficient drip and/or micro spray irrigation systems.

This corresponding increase in highly efficient irrigation systems on permanent crops (e.g. grapes) is somewhat similar in other counties (Figure 14), however not to the degree as it has developed in Kern County. This is likely due to the scarcity and expense of water as well as a more dynamic and recent change to permanent crops in Kern County.



Source: Kern County Agricultural Commissioner Crop Reports – Does not include fallow land,1st leaf orchards and is Kern County only

Figure 12. Kern Sub-Basin harvested crop groupings.

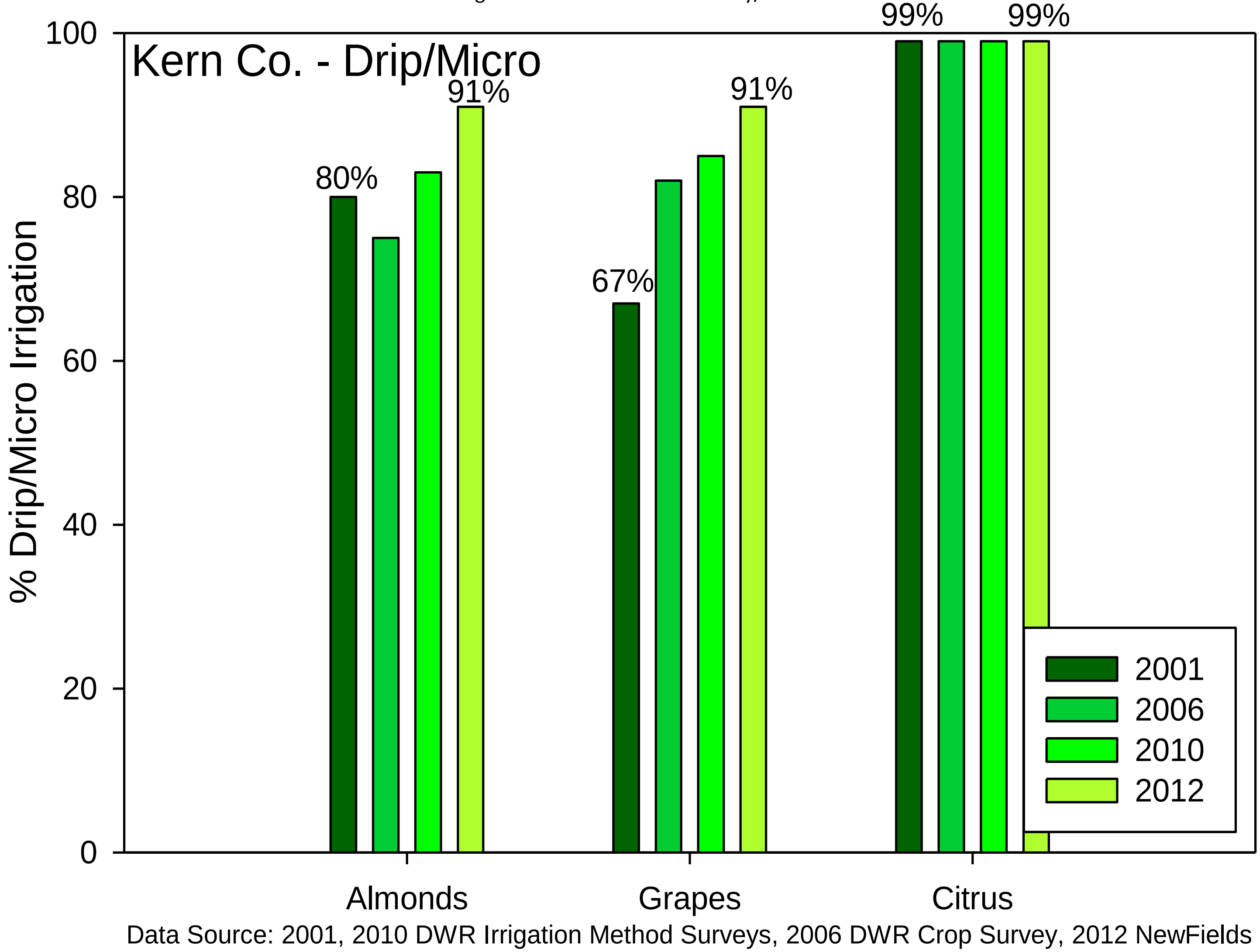


Figure 13. Increase in drip/micro irrigation systems on various permanent crops in Kern

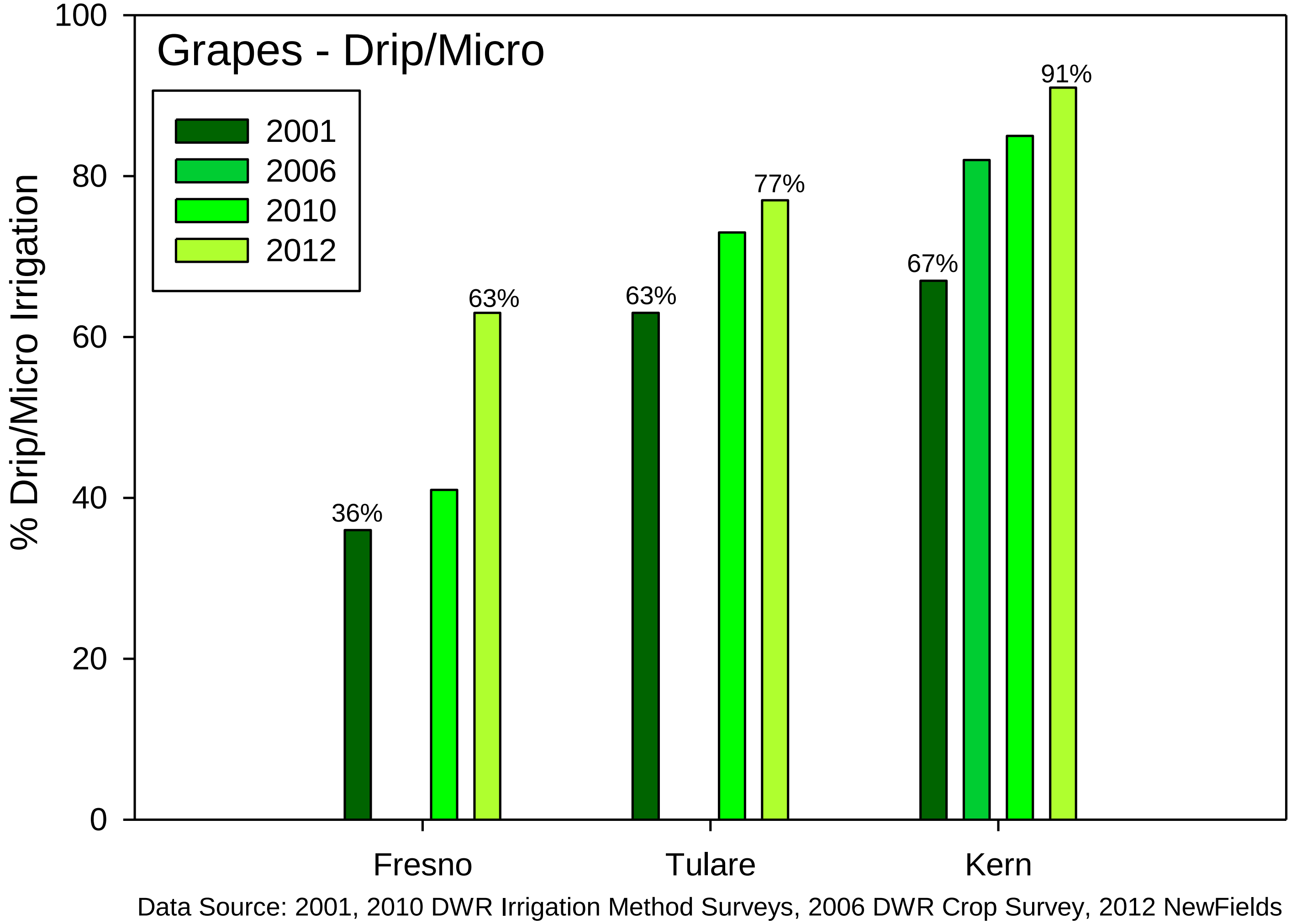


Figure 14. Example (in grapes) of shift to higher efficiency irrigation systems in Fresno, Tulare and Kern Counties County.

General Concepts of Nitrogen Fertilizer Recovery and Losses

Introduction

It is imperative to note that estimating nitrate leaching, even under specified conditions, is a highly complex task. Therefore, the results of any N leaching estimating method should be interpreted as precisely that – estimates only – and are subject to modification with new information.

The significance of the nitrate leaching estimates for diverse cropping scenarios is simply that they are different; crop, irrigation method and soil factors in combination with one another result in a wide range of nitrate leaching estimates. This finding is substantiated by numerous authors whose work contributes to the scientific literature on N dynamics in cropping scenarios (Viers, 2012), and implies that nitrate leaching from various cropping systems cannot be considered or treated as similar systems.

The most significant effort to date focused on assessing nitrate contamination in groundwater from agricultural sources in California resulted in the UC Nitrate Hazard Index (NHI). This effort intentionally avoided any attempt to place absolute values on total amounts of nitrate leached, for the reasons stated above (Wu et al., 2005). This work was developed and reviewed by experts in this multi-disciplinary subject, and should serve as an indication of the caution with which estimates of nitrate leaching must be interpreted. This approach was subsequently modified and used to identify agricultural areas in the Tulare Lake Basin and Salinas Valley that are vulnerable to nitrate contamination in groundwater (Dzurella et al., 2012).

A general description of nitrogen fertilizer recovery and losses from the literature and applied to the Kern Sub-Basin is provided (Appendix A) as background. The appendix was developed from reviewing scientific literature from peer-reviewed journals, extension publications, personal communications and privately-developed publications. No simulation models or statistical methods were used. The purpose of this information is to show the variability in the literature and impactful parameters that can significantly influence potential nitrate leaching.

Root Zone Soil Moisture Balance (SMB) Approach

Introduction and Purpose

Soil moisture conditions and nitrate leaching in agricultural systems can vary significantly throughout a year and are impacted primarily by irrigation practices and not necessarily rainfall in the Kern Sub-Basin area. This is because effective rainfall (1-3 inches) in this area is essentially insignificant as compared to the magnitude of irrigation water applied to meet crop and environmental demands (28-60 inches - depending on crop type, soil conditions and management practices).

A root zone soil moisture balance (SMB) calculator was used to model and predict potential leaching of available nitrate below the root zone. This was assumed to be nitrate that ultimately would be transported to the first encountered groundwater. It was assumed that any nitrate leached below the specified root zone of the crop was not recoverable by the crop and therefore transportable to groundwater.

The advantages of using a SMB approach include:

- a field- or smaller region-specific tool, commonly used to quantify hydraulic leaching below the root zone
- defensible and quantifiable results that can be used as input parameters for groundwater modeling purposes
- inclusion of various input parameters designed to optimize the results for a specific field, scenario, or a smaller area

The disadvantages of using the SMB approach for the Kern Sub-Basin include:

- relatively inaccurate representation of larger areas, thus why only representative scenarios can be developed
- difficultly in spatial application
- unwieldy number of iterations/options due to numerous and detailed input parameters
- complicated numerical applications and summary of results
- variable results over larger areas of land

The purpose of this effort was predominantly for:

- Development of representative scenarios (return flows) as input parameters for modeling work conducted by Rob Gailey/SGI Consultants.
- A better understanding of the unique nature of agricultural practices in the Kern Sub-Basin.
- A better understanding of the diversity of potential results for Basin-wide agricultural practices.

Approach

Twenty one scenarios were developed that represented major cropping systems across all six regions within the Kern sub basin. Ground truthing efforts were conducted throughout this area that documented irrigation practices on approximately 20% of all irrigated fields. This information was obtained spatially and overlain on the regional areas. When an irrigation practice on a certain crop type was documented greater than 90% of the time, that irrigation method was assigned to that crop type within a specified region. Where irrigation methods varied within crop type, a mix of methods was assumed. This resulted in correspondingly lower irrigation application efficiencies as well. Otherwise irrigation application efficiencies were used based on various sources including local knowledge (Sanden, personal communication, 2012) (Paramount Farms, 2012) and irrigation district reporting (Arvin Edison Water Use Report, 2012)

Representative scenarios were developed for common crop systems and soil types and represent the majority of cropping systems in the Kern Sub-Basin. For example, much of the Clay Rim area is cropped with cotton and to a much lesser relative extent, almonds. Therefore a "cotton on fine textured soils" scenario was developed for this area as was an "almond on medium textured soils" for other areas. A variety of other representative scenarios including other SMB inputs are summarized (Table 2). These scenarios were developed in conjunction with Blake Sanden, UC Cooperative Extension, Kern County and deemed as representative for the area.

It should be noted that certain set assumptions were developed for the 21 scenarios developed and modeled. Due to the variation in cropping systems, soil types, irrigation practice and management, rooting depths, etc., results for total return flow and to a lesser extent total applied water, should be considered as estimates only and specifically for the input parameters of each scenario only. It is entirely possible to find a combination of input parameters somewhere over the nearly 1,000,000 acres of irrigated land in the Kern Sub-Basin that result in less or more return flows or applied water. Again, this work was performed for the purpose of providing reasonable estimates as input parameters for the groundwater modeling work that are representative of the present-day Kern Sub-Basin, based on the best available data.

Results and Conclusions

In general, results indicate that perennial crops on high efficiency irrigation systems (common to the Kern Sub-Basin), result in limited return flows to groundwater. The largest return flows occur under corn/wheat, sudan/wheat or alfalfa crop rotations that are commonly associated with feeding operations for dairies. The majority of these systems are regulated under the dairy order. Other row crops such as cotton/wheat and carrot/potato rotations result in moderate return flow estimates mostly because of the types of irrigation methods and management employed.

Table 2. Scenario summary for common crop types, regions, soil types and irrigation methods. Summary table also includes assumed irrigation efficiencies, effective rooting depths and resultant return flows and applied water.

Scenario	Region	Crop	Soil	Irrigation Method	Irrigation Efficiency (%)	Rooting Depth (Effective) (ft)	Total Return Flow (in)	Total Applied Water (in)
1	Foothills	Citrus	Medium	Drip/Micro	95%	4	2.3	45.6
2	Foothills	Grape	Medium	Drip/Micro	95%	4	1.9	31.9
3	Kern Fan	Alfalfa	Coarse	Border	85%	6	9.8	61.7
4	Kern Fan	Corn/Wheat	Coarse	Furrow/Border	75%	3	14.8	57.7
5	Kern Fan	Cotton	Coarse	Furrow/Border	80%	3	10.2	40.0
6	Northern	Almonds	Coarse	Drip/Micro (90%) & Flood (10%)	90%	7	5.0	46.2
7	Northern	Grape	Coarse	Drip/Micro (75%) & Flood (25%)	80%	5	7.9	38.1
8	Westside	Almonds	Medium	Drip/Micro	95%	6	2.4	46.6
9	Westside	Pistachio	Medium	Drip/Micro	95%	6	2.7	45.8
10	Westside	Pistachio	Coarse	Drip/Micro	90%	7	5.3	48.3
11	Wheeler Ridge/A-E	Grape	Medium	Drip/Micro	95%	4	2.0	34.1
12	Wheeler Ridge/A-E	Citrus	Medium	Drip/Micro	95%	4	2.9	48.3
13	Wheeler Ridge/A-E	Grape	Coarse	Drip/Micro	90%	5	3.9	36.0
14	Wheeler Ridge/A-E	Carrots/Potato	Coarse	Sprinkler	85%	2	8.2	51.7
15	Clay Rim	Cotton	Fine	Furrow	90%	3	5.2	34.4
16	Clay Rim	Cotton/Wheat	Fine	Furrow/Border	85%	3	8.7	55.2
17	Clay Rim	Alfalfa	Fine	Border	85%	5	9.6	60.3
18	Foothills	Pistachio	Medium	Drip/Micro	95%	6	2.8	42.1
19	Northern	Alfalfa	Medium	Border	85%	6	8.6	60.4
20	Westside	Almonds	Coarse	Drip/Micro	95%	7	2.8	46.6
21	Clay Rim	Pistachio	Fine	Drip/Micro	95%	5	2.6	41.2

Note: Irrigation efficiencies and rooting depths reviewed by Blake Sanden, UCCE Cooperative Extension, Kern County. Other input provided by Boswell and Paramount Farms, etc.

Nitrate Hazard Index (NHI) Approach

Introduction and Purpose

An NHI was developed by UC Davis and other researchers as a qualitative method to assess the potential for nitrate leaching to groundwater based on at least three initial variables (e.g. crop type, soil type and irrigation method). The NHI was developed for the southern San Joaquin Valley and the Salinas Valley.

The advantages of using a NHI approach include:

- Offers the ability to span and create a relative assessment over large areas of land with a spatial resource
- Easily shows change over time as a result in crop or irrigation method changes
- Easily modified, flexible, and understandable
- Based on a field by field assessment, therefore can be aggregated to a larger area
- Results in strategic and justified locations for monitoring and therefore cost savings
- Approved as an acceptable method for quantifying the potential for nitrate leaching by the State Water Resources Control Board

The potential disadvantages of using the NHI approach include:

- A qualitative assessment, however is based on quantitative/proven research and local knowledge
- Requires some grouping of input data (e.g. soil type) at times depending on the size of the area and data resources available
- Requires up-to-date crop mapping (readily available for Kern County on an annual basis, however less frequently available elsewhere)

An excellent discussion of the justification, use, strengths, limitations and results of the NHI for the Southern San Joaquin Valley (including the Kern Sub-Basin) can be found at the following reference below. The reader is particularly encouraged to review section 2.2.3 (pages 12-17) – Leaching Vulnerability Assessment.

http://groundwaternitrate.ucdavis.edu/files/139103.pdf

or at:

Dzurella, K.N., Medellin-Azuara, J., Jensen, V.B., King, A.M., De La Mora, N., Fryjoff-Hung, A., Rosenstock, T.S., Harter, T., Howitt, R., Hollander, A.D., Darby, J., Jessoe, K., Lund, J.R., & Pettygrove, G.S. 2012. Nitrogen Source Reduction to Protect Groundwater Quality. Technical Report 3 in: Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis.

The purpose of this effort was predominantly to develop a preliminary Kern Sub-Basin specific NHI that would demonstrate the changes over approximately 20 years as well as show the flexibility by addition of Nitrogen Use Efficiency (NUE) estimates.

Approach

The approach for the NHI assessment for the Kern Sub-Basin was similar to that performed by researchers at UC Davis (Dzurella, et al., 2012). The approach was modified for the unique attributes of the Kern Sub-Basin area. One of the major differences is that previous researchers used DWR crop mapping from 2006, while 2011 crop mapping from Kern County was used for our analysis. Also, irrigation practices specific to the Kern Sub-Basin were considered for this analysis including representative distribution of current irrigation methods.

An NHI was developed based on DWR crop mapping and associated irrigation practice for 1990 and Kern County crop mapping for 2011. Soil type remained constant for all analyses.

An additional NHI was developed for 2011 results only and attempted to incorporate three very broad NUE estimates of 25%, 50% and 75%. The purpose in conducting this analysis was to show the flexibility and additionality of the NHI approach, however is not intended to represent actual field conditions.

Results and Conclusions

A comparison of 1990 and 2012 NHI results (Figures 15 and 16) specifically for the Kern Sub-Basin indicate significant reduction in nitrate risk to groundwater. It is intuitive that this reduction has developed from the conversion of annual field and row crops (irrigated with less efficient surface methods) to permanent tree and vine crops (predominantly (>90%) irrigated with drip and micro-irrigation systems).

The results of this analysis also allow for field-specific location of areas where best use of monitoring and management practices can have the most impactful result. The "high vulnerability" areas can be shown at the field level, rather than at a regional level and better represent existing conditions. Identification of specific circumstances that warrant more than just a "high" and "low" vulnerability designation are possible using a modified NHI approach.

A second NHI analysis was conducted to show the flexibility and additionality of the NHI, by incorporating three sub basin-wide NUE estimates of 25, 50 and 75 percent (Figures 17, 18, and 19). Although this is neither realistic nor appropriate in this area due to the variation in crop type and management practices, it does provide an excellent demonstration of incorporation of additional variables to further refine the power of the NHI analysis. As would be expected, NHI is reduced with increasing NUE. The key result of this additional variable, however, is that results can be shown annually on a field by field basis.

Although we have not conducted specific analyses for areas beyond the Kern Sub-Basin related to this work, based on the information presented (Pettygrove, 2012), it is clear that the nitrate risk to groundwater is significantly less and, in many areas negligible for the Kern Sub-Basin as compared to other areas to the north.

It should be noted that additional variables can likely be included in a modified NHI calculation, thus strengthening its predictive capabilities. Some of these additional variables may include, but are not limited to:

- Nitrogen use efficiency
- Effective precipitation
- Depth to groundwater
- Variations in stratigraphy and soil type
- Specific best management practices

Overall the NHI approach is a powerful, flexible, and defensible tool that can be used for assessing large landscapes over time and documenting relative nitrate leaching hazards. It is preferable to the approach proposed in the Tentative Order because it specifically considers that contaminant of concern (N), and does not use other contaminants (pesticides) as an unsuitable proxy for N movement, and accounts for agricultural management, which is not a factor in the vulnerability assessment provided in the Tentative Order.

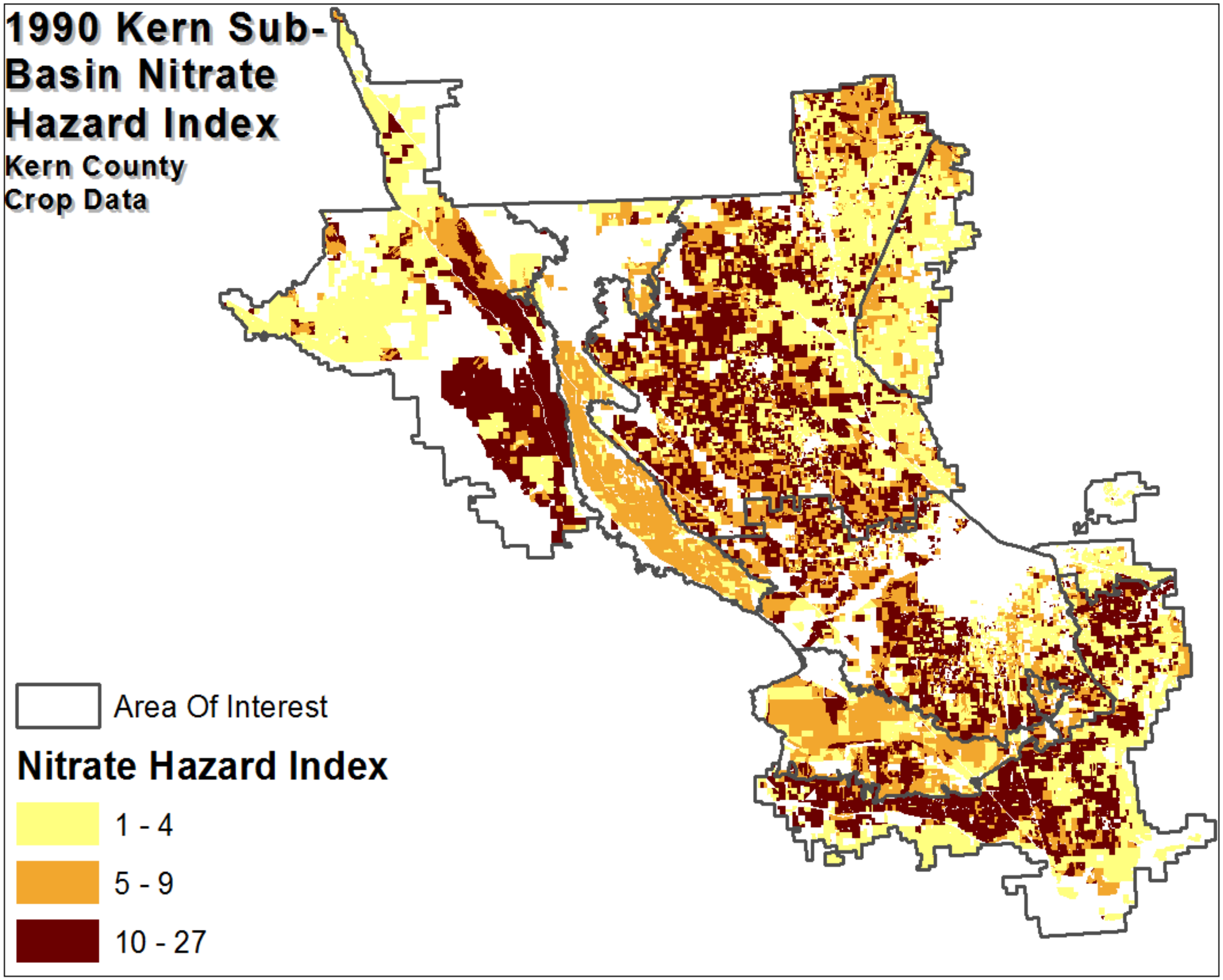


Figure 15. Kern Sub-Basin preliminary Nitrate Hazard Index – 1990

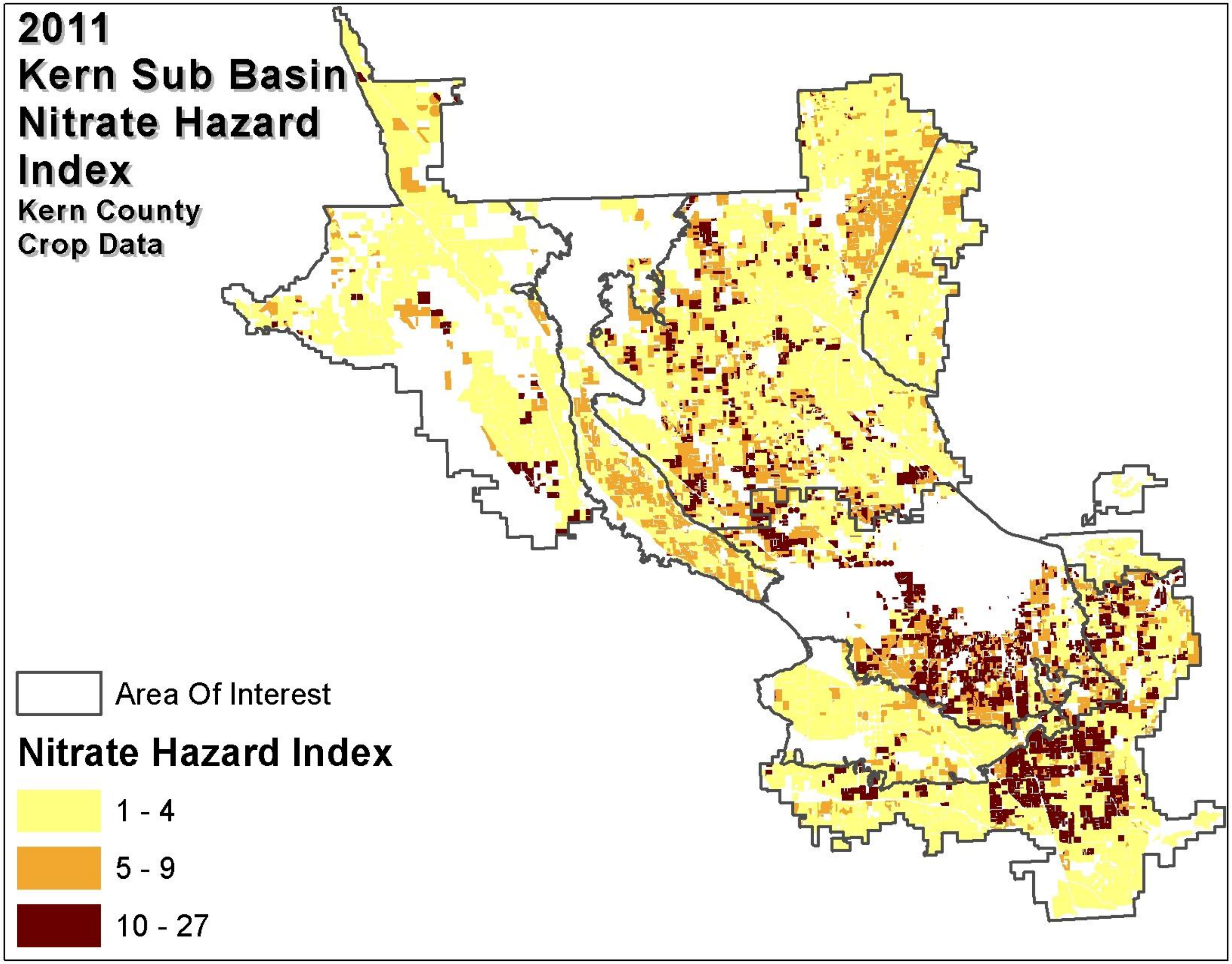


Figure 16. Kern Sub-Basin preliminary Nitrate Hazard Index - 2011

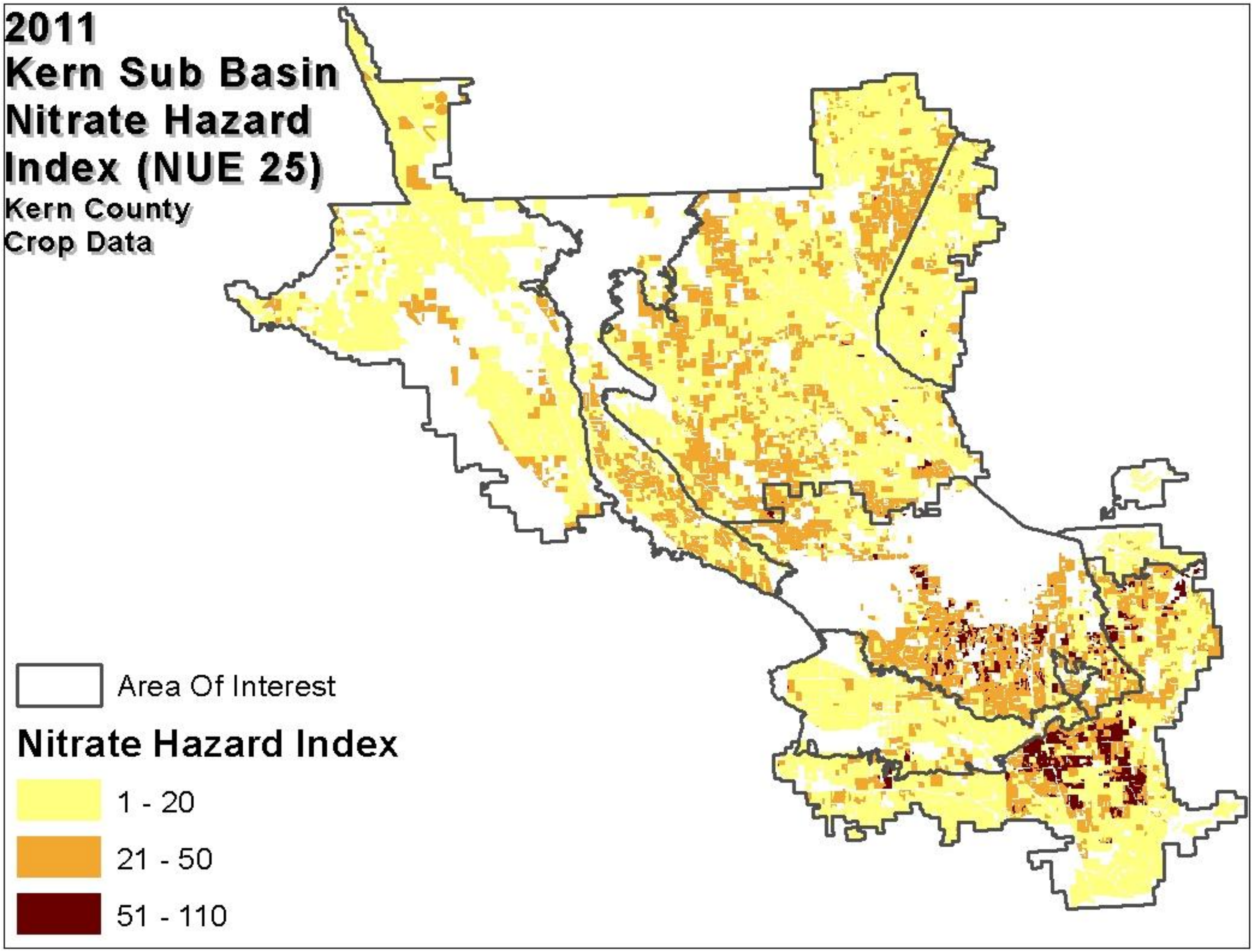


Figure 17. Kern Sub-Basin preliminary Nitrate Hazard Index, including 25% NUE estimate – 2011

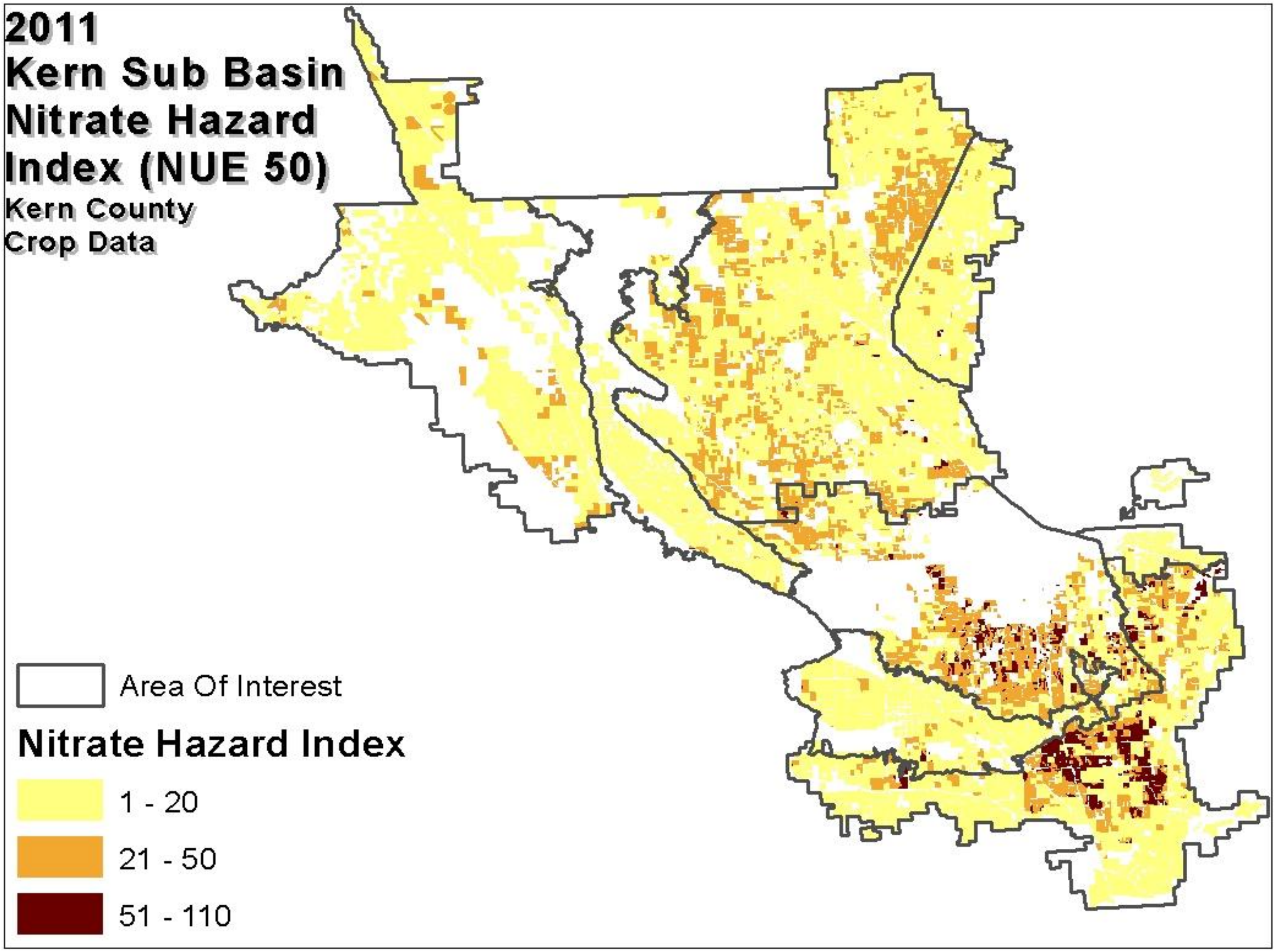


Figure 18. Kern Sub-Basin preliminary Nitrate Hazard Index, including 50% NUE estimate - 2011

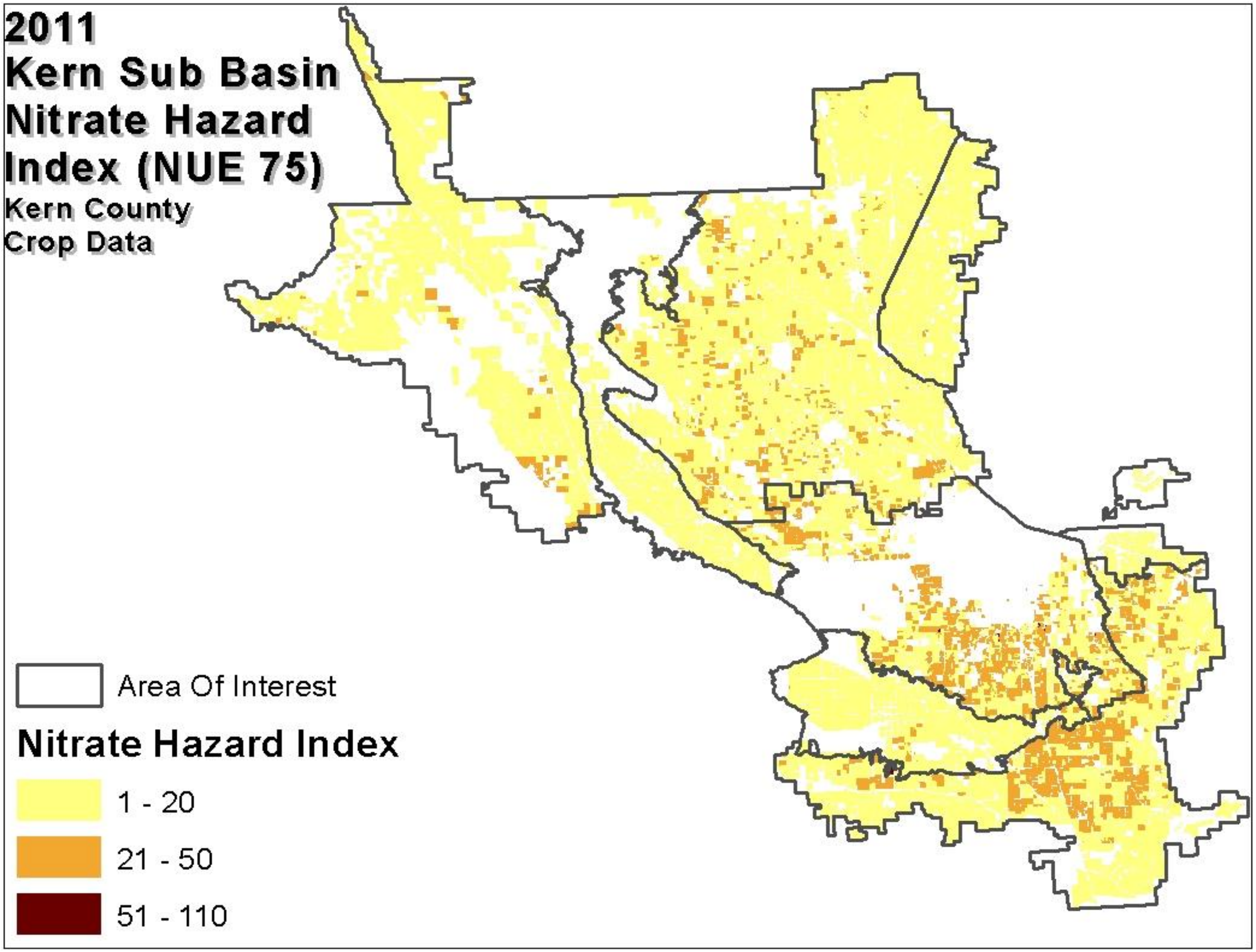


Figure 19. Kern Sub-Basin preliminary Nitrate Hazard Index, including 75% NUE estimate - 2011

References

Al-Jamal, M.S., T.W. Sammis, and S.T. Ball. A case study for adopting the nitrate chloride technique to improve irrigation and nitrogen practices in farmers' fields. Applied Engineering in Agriculture 17(5): 601-610.

Al-Jamal, M.S., T.W. Sammis, and T. Jones. 1997. Nitrogen and chloride concentration in deep soil cores related to fertilization. Agricultural Water Management 34: 1-16.

Allaire-Leung, S.E., L. Wu, J.P. Mitchell, B.L. Sanden. 2001. Nitrate leaching and soil nitrate content as affected by irrigation uniformity in a carrot field.

Arpaia, M.L. and L.J. Lund. 2003. Nitrogen management in citurs under low volume irrigation. Annual Report.

Balasubramanian V, Alves B, Aulakh M, Bekunda M, Cai Z, Drinkwater L, Mugendi D, van Kessel C, Oenema O, (2004) Crop, environmental and management factors affecting nitrogen use efficiency. In: Mosier AR, Syers JK, Freney JR (eds) Agriculture and the nitrogen cycle. The Scientific Committee on Problems of the Environment (SCOPE). Island Press, Covelo, California, USA, pp 19–34.

Bhargava, B.S. Potassium Nutrition of Grapes. http://www.ipipotash.org/udocs/Potassium%20Nutrition%20of%20Grapes.pdf. Accessed November 14, 2012.

Boaretto, R.M., D. Mattos Jr., J.A. Quaggio, H. Cantarella, and P. C.O. Trivelin. 2010. Nitorgen-15 uptake and distribution in two citrus species. 19th World Congress of Soil Science solutions for a changing World. Brisbane, Australia.

Bronson, K.F. 2008. Nitrogen Use Efficiency of Cotton Varies with Irrigation System. Better Crops 92(2008, No. 4).

Bronson, K.F., A Malapati, J.D. Booker, B.R. Scanlon, W.H. Hudnall and A.M. Schubert. 2009. Residual soil nitrate in irrigated Southern High Plains cotton fields and Ogallala groundwater nitrate. Journal of Soil and Water Conservation. 64(2):98-104.

Brown, P. 2011. Development of a Nutrient Budget Approach to Fertilizer Management in Almond. In 19th Annual Fertilizer Research and Education Program Conference Proceedings November 16-17. Tulare, California. Ed. E.A. Lewis. California Department of Food and Agriculture.

Cassman KG, Dobermann A, Walters DT (2002) Agroecosystems, nitrogen use efficiency, and nitrogen management. Ambio 31:132–140.

Chang, A., T. Harter, J. Letey, D. Meyer, R. Meyer, M. Campbell Mathews, F. Mitloehner, S. Pettigrove, P. Robinson, R. Zhang. 2005. Managing Dairy Manure in the Central Valley of California. University of California Division of Agriculture and Natural Resources Committee of Experts on Dairy Manure Management.

Dzurella, K.N., Medellin-Azuara, J., Jensen, V.B., King, A.M., De La Mora, N., Fryjoff-Hung, A., Rosenstock, T.S., Harter, T., Howitt, R., Hollander, A.D., Darby, J., Jessoe, K., Lund, J.R., &

Pettygrove, G.S. 2012. Nitrogen Source Reduction to Protect Groundwater Quality. Technical Report 3 in: Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis.

Embleton, T.W., C. O. Pallares, W.W. Jones, L.L. Summers and M. Matsumara. 1980. Nitrogen fertilizer management of vigorous lemons and nitrate pollution potential of groundwater. University of California Water Resource Center. Contribution 182.

Evaluation of soil and plant nitrogen tests for maize on manured soils of the Atlantic coastal plain. Agron. J. 87:213-222.

Follett (ed.) Nitrogen Management and Ground Water Protection. Elsevier Science.

Fritschi, F.B. B.A. Roberts, D. William Rains, R.L. Travis and R.B. Hutmacher. 2004. Fate of nitrogen-15 applied to irrigated Acala and pima cotton. Agron. J. 96:646–655.

Hanson, E.J. and G.S> Howell. 1995. Nitrogen accumulation and fertilizer use efficiency by grapevines in short-season growing areas. HortScience 30:504-507

Harter, T. Y.S. Onsoy, K. Heeren, M. Denton, G. Weissman, J.W. Hopmans, and W.R. Horwath. 2005. Deep vadose zone hydrology demonstrates fate of nitrate in eastern San Joaquin Valley. California Agriculture 59(2): 124-132.

Harter, T. and J.R. Lund. 2012. Addressing Nitrate in California's Drinking Water With a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of Davis, California.

Hermanson, R., W. Pan, C. Perillo, R. Stevens, C. Stockle. Undated. Nitrogen Use by Crops and the Fate of Nitrogen in the Soil and Vadose Zone. Washington State University and Washington State Department of Ecology Interagency Agreement No. C9600177. Publication No. 00-10-015

Holtz, B. Nitrogen efficiency in almond production. UDDE Field Notes May 2012. University of California Agriculture and Natural Resources.

Hutmacher, R.B., R.L. Travis, D.W. Rains, M.P. Keeley, and R. Delgado. 2005. Residual Soil Nitrogen and Nitrogen Management for Acala Cotton Summary Report. California Department of Food and Agriculture – Fertilizer Research and Education Program. http://www.cdfa.ca.gov/is/docs/00-0604Hutchmacher%2005.PDF. Accessed February 5, 2013.

Hutmacher, R.B., R.L. Travis, D.W. Rains, R.N. Vargas, B.A. Roberts, B.L. Weir, S.D. Wright, D.S. Munk, B.H. Marsh, M.P. Keeley, F.B. Frischi, D.J. Munier, R.L. Nichols, and R. Delgado. 2004. Response of recent acala cotton varieties to variable nitrogen rates in the San Joaquin Valley of California.

J. M. Powell,* W. E. Jokela, and T. H. Misselbrook. 2011. Dairy Slurry Application Method Impacts Ammonia Emission and Nitrate Leaching in No-Till Corn Silage. J. Environ. Qual. 40:383-392.

Jayasundara, S. C. Wagner-Riddle, G. Parkin, P. von Bertoldi, J. Warland, B. Kay and P. Voroney. 2007. Minimizing nitrogen losses from a corn-soybean-winter-wheat rotation with best management practices. Nutr Cycl Agroecosyst 79:141-159.

Jemison, John M. Jr., and Richard H. Fox. 1994. Nitrate leaching from nitrogen-fertilized and manured corn measured with zero-tension pan lysimeters. J. Environ. Qual. 23:337-343.

Krupnik TJ, Six J, Ladha JK, Paine MJ, van Kessel C (2004). An assessment of fertilizer nitrogen recovery by grain crops. In: Mosier AR, Syers JK, Freney JR (eds) Agriculture and the nitrogen cycle. The Scientific Committee on Problems of the Environment (SCOPE). Island Press, Covelo, California, USA, pp 193–207.

Lea-Cox, J.D. and J.P. Syvertsen. 1996. How nitrogen supply affects growth and nitrogen uptake, use efficiency, and loss from citrus seedlings. J. Amer. Soc. Hort. Sci. 121(1): 105-114.

Martínez-Alcántara, B., A. Quiñones, F. Legaz, E. Primo-Millo. 2012. Nitrogen-use efficiency of young citrus trees as influenced by the timing of fertilizer application. Journal of Plant Nutrition and Soil Science. 175:282-292.

Meyer, R.D. 1992. Potential nitrate movement below the root zone in drop irrigated almonds. FREP Contract #92-0631.

Meyer, R.D. 2008. Fertilizer Application Management. Pistachio Short Course presentation.

Morgan, K.T. and E.A. Hanlon. 2006. Improving citrus nitrogen uptake efficiency: understanding citrus nitrogen requirements. University of Florida Extension Publication SL-240.

Navarro J.C., J.C. Silvertooth, A. Galadina. 1997. Fertilizer nitrogen recovery in irrigated upland cotton. In Proc. Beltwide Cotton Conf., New Orleans, LA, 6–10 Jan. 1997. Natl. Cotton Counc., Memphis, pp 581–583.

Nitrate Groundwater Pollution Hazard Index Information. 2012. University of California. Regents of the University of California, Division of Agriculture and Natural Resources. http://ucanr.edu/sites/wrc/Programs/Water_Quality/Nitrate_Groundwater_Pollution_Hazard_Index/.

Peacock, B., P. Christensen, D. Hirschfelt. Undated. Best Management Practices for Nitrogen Fertilization of Grapevines. University of California Tulare County Cooperative Extension, Tulare County. Publication NG4-96.

Peacock, W.L., L.P. Christensen, and F.E. Broadbent. 1989. Uptake, storage and utilization of soil-applied nitrogen by Thompson Seedless as affected by time of application. Am J. Enol. Vitic. 40:16-20.

Rains, W. and R.L. Travis. Undated. Nitrogen budget in California cropping systems. FREP Contract #97-0365 M97-09.

Rotz, C.A. 2004. Management to reduce nitrogen …

Saman, Z., T. Sammis, R. Skaggs, N. Alkhatin and J. Deras. 2005. Measuring on-farm irrigation efficiency with chloride tracing under deficit irrigation. Journal of Irrigation and Drainage Engineering 131(6): 555-559.

Saint-Fort, R., J.S. Schepers, and R.F Spaulding. 1991. Potentially mineralizable nitrogen and nitrate leaching under different land-use conditions in western Nebraska. J. Environ. Sci. Health. A26(3), 335-345.

Sanden, B. 2012. Using soil chloride concentrations to identify the bottom of the root zone and estimate effective leaching fraction and nitrate leaching below the root zone: An example in Kern County almonds. Unpublished.

Sanden, B., B. Hockett and R. Enzweiler. 2003. Soil moisture sensors and grower “sense” Abilities: 3 years of irrigation scheduling demonstrations in Kern County. The Irrigation Association 2003 Conference Proceedings.

Scheppers, J.S., and R.H. Fox. 1989. Estimation of N Budgets for Crops. p. 221-246. In: R.F. Silvertooth, J.C., K.F. Bronson, E. R. Norton, and R. Mikkelson. 2011. Nitrogen Utilization by Western U.S. Cotton. Better Crops 95(2011, No. 2): 21-23.

Silvertooth, J.C., E.R. Navarro, E.R. Norton, and A. Galadina. 2001. Soil and plant recovery of labeled fertilizer nitrogen in irrigated cotton. Arizona Cotton Report. http://ag.arizona.edu/pubs/crops/az1224/. Accessed November 14, 2012.

Silvertooth, J.C., A. Galadina and E.R. Norton. 2006. Residual soil nitrogen evaluations in irrigated desert soils, 2005. Arizona Cotton Report (P-145) July 2006.

Sims, J. Thomas, Bruce L. Vasilas, Karen L. Gartley, Bill Milliken, and V. Green. 1995.

Syvertsen, J.P. 1996. Nitrogen uptake efficiency and leaching losses from lysimeter-grown citrus trees fertilizer at three nitrogen rates. J. Amer. Soc. Hort. Sci. 121(1): 57-62.

Viers, J.H., Liptzin, D., Rosenstock, T.S., Jensen, V.B., Hollander, A.D., McNally, A., King, A.M., Kourakos, G., Lopez, E.M., De LaMora, N., Fryjoff-Hung, A., Dzurella, K.N., Canada, H.E., Laybourne, S., McKenney, C., Darby, J., Quinn, J.F. & Harter, T. (2012) Nitrogen Sources and Loading to Groundwater. Technical Report 2 in: Addressing Nitrate in California’s Drinking Water with a

Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis.

Weinbaum. S.A. and D.A. Goldhamer. 1991. Nitrogen fertilizer management to reduce groundwater degradation.

Williams, L.E. Growth of “Thompson Seedless” grapevines: II. Nitrogen distribution. J. Amer. Soc. Hort. Sci. 112:330-333.

Wu, L., Letey, J., French, C., Wood, Y. & Birkle, D. (2005) Nitrate leaching hazard index developed for irrigated agriculture. Journal of soil and water conservation, 60, 90–95.

Zasoski, R.J. 1994. Nitrogen efficiency in drip irrigated almonds.

Appendix A. General Concepts of Nitrogen Recovery and Losses

Introduction

No biological system is 100% efficient. A general rule of thumb is that N fertilizer uptake efficiency is 50 percent, on average, for agricultural crops (Meyer, 2008). However, typical fertilizer N uptake efficiencies of major agronomic crops range from less than 30 to greater than 70% because of several factors. First, it is not possible for a plant to deplete the entire inorganic N from the soil solution. As the nitrate and ammonium concentrations decrease in solution, the rate of N uptake also decreases, in a relationship similar to substrate-enzyme reactions (Jackson et al., 1986).

Minimal N concentrations in the soil are required to drive the N influx into crop roots. In addition, some N losses (volatilization or leaching) from the root zone are inevitable during the season. As a result, not all of the N supplied will be available for plant uptake. Finally, and perhaps most importantly that to achieve maximum or near maximum yields, N must be supplied at high levels. According to Mitscherlich's Law, as N supply increases, there is a decrease in the incremental yield increase per unit of N input. As a result, N use efficiency invariably decreases at high levels of N input that are required to achieve maximum yield. On the other hand, if minimal N is supplied so that the soil N is depleted to near zero to minimize nitrate leaching potential, there is an insufficient concentration of soil N to drive maximal rates of N uptake, and crop yield will be limited. For this reason, the presence of residual soil N at the end of a growing season is inevitable in intensively managed cropping systems that are achieving near maximum or maximum economic yields (Hermanson, et al., (undated)).

Nitrogen Uptake and N Fertilizer Recovery

In general, the amount of N accumulated by a crop is affected by:

- the amount and location of N supplied by the soil or added as fertilizer
- the genetic potential of the species or cultivar to absorb N, which is influenced by genetic factors such as tolerance to biotic and abiotic stresses, rooting pattern and physiological N uptake efficiency
- the growth or yield potential under a set of environmental conditions and soil properties
- the ability to retain N in the root zone during the period of crop N uptake.

Nitrogen fertilizer recovery estimates for different fertilizer management and cropping systems are summarized in Table 1 and show varied and wide differences depending on crop type and timing of application.

Table 1. General guidelines for estimating N fertilizer recovery fraction when using N rates for maximum or near maximum yield [1] (Bock and Hergert, 1991).

Relative Efficiency of N-Application Timing	Perennial Grasses	Upland Cereal Grains	Shallow-rooted Crops	Flooded Crops
Low [2]	0.55	0.45	0.35	0.25
Medium [3]	0.70	0.60	0.50	0.40
High [4]	0.80	0.70	0.60	0.50

[1] N fertilizer recovery fraction values assume medium to high nitrate loss potential as determined by soil type and moisture regime and no or negligible NH3 volatilization losses.
[2] One N application (without nitrification inhibitor) well in advance of the growing season. When nitrate loss potential is low due to soil type or moisture regime, use nitrogen use efficiency values for medium to high efficiency of N application timing.
[3] One N application near beginning of growing season.
[4] Multiple N applications with first application near beginning of growing season; use of nitrification inhibitor may substitute for splitting N applications.

NITROGEN LOSSES

It should be clearly noted that N losses are extremely variable and are influence by a myriad of factors, some of which can be controlled or managed and some of which cannot. Estimating N use efficiencies (NUE) requires an understanding of field by field variables that impact N losses. Therefore, utilizing NUE across large landscapes to ultimately determine nitrate available for plant uptake or leaching is marginal at best. Rather, these approaches are more accurate at the field-scale level where a more detailed understanding of soil type, crop type, management practices, climatic conditions, soil chemistry, etc. can be determined.

The amount of N lost from an agricultural soil-plant system is also affected by many factors, all specific to different types of loss. These losses include volatilization, denitrification, and leaching.

Volatilization

Volatilization can occur whenever free ammonia is present near the surface of the soil. The ammonia concentrations in the soil solution will increase by applying ammonia-based fertilizers or decomposable organic materials to neutral or alkaline soils. The amounts of ammonia volatilized are small when N materials are incorporated into the soil, and ammonia losses are also low (≤15% of applied N) when ammonia-based fertilizers are applied in the surface of acidic or neutral soils.

Ammonia volatilization is a complex process involving chemical and biological reactions within the soil, and physical transport of N out of the soil. The method of N application, N source, soil pH, soil cation exchange capacity (CEC), and weather conditions influence ammonia emissions from applied N. Conditions favoring volatilization are surface applications, N sources containing urea, soil pH above 7, low CEC soils, and weather conditions favoring drying. Precise estimates of ammonia emissions are only possible with direct local measurements. Depending on application conditions, general ranges would be 2 to 50% emissions for soil pH > 7 and 0 to 25% emissions for soil pH < 7. If the N source is mixed into an acid soil, the emissions are usually greatly reduced (0 to 4% lost) (Meisinger and Randall, 1991).

Ammonia volatilization is a major pathway of N loss from livestock slurries following their application to land. Approximations of ammonia emissions from volatilized dairy manure are listed in Table 2 and shows the extreme variability as associated with ammonia volatilization under manure applied conditions. Research conducted on synthetic fertilizers show similar results.

Table 2. Approximate ammonia emissions of land-applied manure. These values are rough estimates of the percent of applied N lost; actual values depend on weather conditions after application, type of manure, ammonia content, etc. (Meisinger and Randall, 1991).

Manure Application Method	Type of Manure	Short-term Fate		Long-term Fate	
		N (%)			
		Lost	Retained	Lost	Retained
Broadcast, no incorporation	Solid	15-30	70-85	25-45	55-75
	Liquid	10-25	75-90	20-40	60-80
Broadcast, immediate incorporation	Solid	1-5	95-99	1-5	95-98
	Liquid	1-5	95-99	1-5	95-98
Knifed	Liquid	0-2	98-100	0-2	98-100
Sprinkler irrigated	Liquid	15-35	65-85	20-40	60-80

Denitrification

Compared to volatilization, denitrification emissions in agricultural systems are generally lower, however can be significant in some high water table/reduced soil environments. Emissions of N_2O were found to be lower than 5 to 7 % of the applied N, even at high application rates of 680 kg N/ha/year (Ryden and Lund, 1980). Similarly, Mosier et al. (1986) reported that, on well drained clay-loam soil sown with corn in 1982, 2.5% of the 200 kg N/ha applied as $(NH_4)2SO_4$ was lost as N_2O or N_2. The following year, only a loss of 1% could be measured from the same soil sown with barley. Denitrification estimates for soils with different organic matter contents and drainage classes are provided in Table 3. Clearly, poorly drained soils with high water tables and substantial organic matter can experience significant losses due to denitrification.

Again, it is imperative to understand each unique soil/crop/management system in order to somewhat reasonably estimate potential losses of N due to denitrification. The Kern Sub-Basin has a variety of soil types, management practices, and conditions that result in varied losses due to denitrification.

Table 3. Approximate denitrification estimates for various soils. (Meisinger and Randall, 1991).

Soil Organic Matter Content (%)	Soil Drainage Classification				
	Excessively well-drained	Well drained	Moderately well-drained	Somewhat poorly-drained	Poorly drained
	Inorganic Fertilizer N Denitrified (%)				
<2	2-5	3-9	4-14	6-20	10-30
2-5	3-9	4-16	6-20	10-25	15-45
>5	4-12	6-20	10-25	15-35	25-55

Note: Adjust as follows: for no-tillage use one class wetter drainage; for manure N double all values; for tile-drained soils use one class better drainage; for paddy culture use values under poorly drained; for irrigation or humid climates use value at upper end of range; for arid or semi-arid non-irrigated sites use values at lower end of range; for soils with compacted very slowly permeable layer below plow depth, but above 4-ft depth, use one class wetter drainage.

Leaching

The amount of nitrogen lost with percolating water through the root zone depends on the nitrate concentration in the soil profile. This nitrate concentration is strongly influenced by N application rates, methods and management. Cropping systems are a major factor in regulating nitrate movement below the root zone and toward the water table. Rooting depth, N placement, water requirement, climatic conditions, irrigation efficiency, water-use rate, N-uptake rate, and time of water and N uptake are all factors involved in nitrate leaching that can be affected by choice of cropping system. For nitrate leaching to occur, appreciable concentrations of nitrates must be present in the root zone at the time that water is percolating through that root zone. It is known from experiments with mineral N fertilizers that different cropping systems can influence the rate of leaching of N. Generally, the leaching of N is lower on grassland than on tillage land and is lower for plants with a longer vegetation period than those with a shorter vegetation period. This would also be consistent with the Kern Sub-Basin and the predominant population of permanent crops.

Altman et al. (1995) reported NO_3-N losses from crops amounting to 24 to 55% of the N applied at economic optimum rates (typically providing for near maximum crop yields). In Pennsylvania, the apparent recovery of N fertilizer (ammonium nitrate) applied at the economic optimum N rate in 42 experiments averaged 55% (Fix and Piekielek, 1983). Thus, even when using optimum fertilization rates, a potential exists for fertilizer N to accumulate in the soil with subsequent risk of loss through leaching. This risk is reduced in the Kern Sub-Basin due to the predominance of permanent crops, excessively low effective rainfall, and highly efficient irrigation and N uses.

Perhaps the greatest uncertainty when measuring or predicting deep water percolation and associated nitrate leaching in soil deals with the heterogeneous pore distribution in the root zone and below where microbial N cycling can greatly alter N availability for leaching. Large pores created by shrinking and swelling of clays, decomposition of roots, and faunal activity can accelerate water movement (two to five times higher for soils without obvious macropores, and as much as twenty times for soils with cracks). This increased water movement will have different effects on nitrate leaching depending on N concentration of those areas of the soil "bypassed" by infiltrating water, the rate of water application, the N concentration of infiltrating water, and other factors. The net result, however, is generally one of increased N amounts being transported beyond the reach of crop roots. Aschmann et al. (1992) detected flushes of nitrate and other ions and attributed them to preferential flow through the profile. The methods of highly efficient irrigation in the Kern Sub-Basin (e.g. drip/micro) coupled with deep-rooted permanent crops reduce this risk significantly.

Randall and Iragavarapu (1995) also showed that the amount of N leaching is highly related to the amount of percolating water. They conducted a study on a poorly drained clay loam in Minnesota with continuous corn and N fertilization rates of 200 kg N/ha for several years (fertilizer N was applied as one dose in the spring before planting). They found that annual losses of NO_3-N in the tile water ranged from 1.4 to 139 kg/ha. In dry years, losses generally were equivalent to less than 3% of the fertilizer N applied, whereas in the wet years, losses ranged from 25 to 70% of that applied. Pang et al (1997), in an irrigation quantity and uniformity study, concluded that N leaching was very low when the N application was close to crop N uptake and slightly higher when the uniformity coefficient of the irrigation was 90%. When N application exceeded N uptake, N leaching increased dramatically for all uniformity levels.

Hart et al (1993), working with labeled-N in winter wheat, indicated that most of the labeled-N was presumably mineralized during the fall and winter when the losses are high and crop demand is low. They concluded that leaching of NO_3-N from cereals comes predominantly from mineralization of organic N, not from residual unused N. Olson (1982), after working in the fate of N applied in the fall using labeled-N and agronomic rates in winter wheat, found that from all the leaching produced during the winter time, only about 10% of it came from the fertilizer nitrogen.

Gaines and Gaines (1994) indicated that soil texture affects NO_3-N leaching. In coarser soils, NO_3-N will leach faster than from finer ones. The addition of peat in sandy soils helps in reducing the velocity of N leaching. Tindall et al (1995), in a laboratory analysis, indicated that leaching of NO_3-N was significant in both clay and sandy soils. They concluded that in clay soils leaching occurred less rapidly than in sandy soils.

Crop production, irrigation practices and environmental conditions in the Kern Sub-Basin offer very unique attributes that will result in a relatively low nitrate leaching potential. For example much of the irrigated ground in the Kern Sub-Basin is continuing to rapidly transition from annual, relatively shallow rooted crops generally irrigated with lower efficiency irrigation systems to permanent, deep rooted, highly efficient irrigated systems.

One of the most significant contributors to leaching of nitrate is concentrated and significant rainfall, especially that which is considered as “effective rainfall.” Effective rainfall is defined as the amount of rain that is stored in the soil profile and available for leaching. The average annual rainfall in Bakersfield, Fresno, Merced and Sacramento is 6.5, 11.1, 13.1, and 18.7 inches respectively (National Climate Data Center). Saying that, the actual effective precipitation is likely 1-3 inches in Bakersfield, 5-8 inches in Fresno, 6-9 inches in Merced, and as much as 10+ inches in Sacramento. This is due to the fact that most of the rainfall occurs in the winter. The main difference is that 1-3 inches of effective rainfall over a number of months may not result in any leaching below the root zone in moderate to deep rooted crops, whereas this is not the case in other areas of the state. With deep rooted crops, this limited effective rainfall available to leach nitrate is usually stored within the root zone.

Joel E. Kimmelshue, Ph.D., CPSS

Principal Soil and Agricultural Scientist, Partner - NewFields Agricultural & Environmental Resources, LLC

Education

Ph.D., Soil Science (Water Resources concentration), North Carolina State Univ., Raleigh, 1996
M.S., Soil Science (Ag Engineering concentration), North Carolina State Univ., Raleigh, 1992
B.S., Soil Science (Crop Sci. concentration), California Polytechnic State Univ., San Luis Obispo, 1990

Professional Registrations and Organizations

Certified Professional Soil Scientist (CPSS - #18204) – American Registry of Certified Professionals in Agronomy, Crops and Soils; American Society of Agronomy; Soil Science Society of America

Distinguishing Qualifications

Expert/Specialist in the following areas:

- Soil/water/plant relations in arid climates
- Soil and water salinity management for agriculture
- Water quality for irrigated agriculture
- Regulatory support and negotiation for agriculture
- Policy, regulatory, and environmental influences on agricultural production systems
- Irrigation and drainage management
- Land use assessments
- Expert witness testimony
- Production agricultural systems
- Water resources
- Soil nutrient interactions and environmental issues in soils
- Soil and water conservation
- Soil and land use evaluations for the implementation of irrigation systems and crop production
- Agricultural research
- Agricultural land application and reuse systems for various liquid and solid byproducts

Relevant Experience

Dr. Kimmelshue is a Principal Soil and Agricultural Scientist for NewFields Agricultural and Environmental Resources, LLC. Dr. Kimmelshue is also a founding Partner in the firm. He has experience in agricultural and water resources consulting in the western United States (especially California), and agricultural research and crop production throughout the United States. This experience stretches to various locations in Europe and the Middle East. Dr. Kimmelshue has performed technical leadership and/or managed more than 100 projects and tasks of nearly $9 million dollars over the past 16 years. These projects are directly related to the distinguishing qualifications listed above and listed in more detail as selected representative projects below.

Dr. Kimmelshue's consulting experience includes practical and applied solutions for development of water/soil management systems and agricultural systems, specifically with irrigated agriculture. This technical expertise also includes expert witness testimony, regulatory support and negotiation, water resources science and planning, land reclamation, soil/plant nutrient dynamics, irrigation and drainage in arid and humid climates, soil classification, crop production, land application of municipal and agricultural wastes, vegetative and nonvegetative erosion control, and revegetation/reclamation efforts.

Predominantly, the objective scientific work that Dr. Kimmelshue performs is driven by ever-changing policy, legislative and environmental pressures on production agricultural systems. Dr. Kimmelshue thoroughly understands these drivers and applies sound and objective scientific results to help his clients address these challenges.

Select Representative Projects – Domestic Work

(Complete work experience includes efforts in the states of: California, Arizona, Colorado, Florida, Georgia, Idaho, Iowa, Louisiana, Massachusetts, Montana, Nevada, New Mexico, North Carolina, Oregon, Texas, Utah, Washington, and Wisconsin.)

Representative projects include:

- **Technical Lead – San Joaquin River Restoration Program, Seepage Management Plan, Expert Review Panel Member; United States Bureau of Reclamation; Sacramento, CA.** Dr. Kimmelshue was retained as a salinity, agricultural production, and irrigation and drainage expert to review a completed current version of the Seepage Management Plan for seepage impacts to agriculture including acceptable water table depths, salinity management, yield decline, remotely sensed solutions and irrigation and drainage management considerations. This work will result in completion of a comprehensive management document offering a review of thresholds, solutions and mitigation opportunities as a result of future increased flows in the San Joaquin River.
- **Technical Lead and Project Manager – Kern River Watershed Coalition Authority, Sub Basin Review of Agricultural Irrigation and Drainage Practices and Crop Impacts; Bakersfield, CA.** Dr. Kimmelshue was retained by the KRWCA as an expert in providing sound technical agronomic information related to the unique irrigation and crop production practices of the Kern Sub Basin area within the Southern San Joaquin Valley Water Quality Coalition. This work involved understanding and interpreting changes in cropping patterns, irrigation methods, salinity management, fertilization practices and overall water and nitrogen use efficiency. A portion of this work included intensive ground truthing for development of remotely sensed crop mapping products. Those ground truthing data included permanent crop irrigation method documentation for use in irrigation method change over time.
- **Project Manager and Technical Lead–Blending of Saline Mine Water with Central Arizona Project (CAP) Water for Irrigation to Cotton, Alflafa, and Sod; Rio Tinto Mining Company – Resolution Copper; Superior and Queen Creek, Arizona.** Dr. Kimmelshue is leading an effort to create an acceptable blended water quality for irrigation to alfalfa, cotton and sod on approximately 5,500 acres of land within the New Magma Irrigation and Drainage District (NMID). This project involves direct working efforts with the USBR, the state of Arizona Lands Department, NMID, the University of Arizona Soil, Water and Environmental Science Department, and the Resolution Copper Company. Many of these multi-stakeholder meetings were for the purpose of obtaining permitting documents and satisfying the discharge requirements. The work involves real-time monitoring of treated mine water, CAP water, and the blended result. This monitoring network comprises in-canal Total Dissolved Solids (TDS), temperature, and pH probes. A web-based portal will be used for instantaneous water quality assessment and tracking. Also, a comprehensive soil, water, and tissue sampling program will take place at least quarterly during the 3 to 4 year project.

Crop growth stages and tracking will also be conducted. The dewatering of this mine is necessary to make copper ore available from the largest copper mine in North America.

- **Project Manager and Technical Lead–Santa Clara River Watershed Total Maximum Daily Load (TMDL) Collaborative Process; Agricultural Irrigation Thresholds for Chloride and Salinity; Los Angeles County Sanitation Districts; Fillmore, California.** This project included the development of a detailed literature review and evaluation for determination of the potential threshold of irrigation water quality constituents of concern, specifically chloride, on sensitive crops as a basis of a TMDL process in working with the California Regional Water Quality Control Board. This collaborative process included work with a multitude of stakeholders including the California Avocado Commission, the California Strawberry Commission, Nursery Crop Growers, Ventura County Farm Bureau, and Los Angeles County Sanitation Districts. A multitude of crops were evaluated for their individual tolerances to specific constituents of concern. Only the most susceptible crops were further evaluated and included avocados, strawberries, and nursery stock. This work involved detailed assessment of water quality, irrigation practices, cultural practices and drainage management for the overall determination of acceptable irrigation water quality. The work also included comprehensive public notification efforts with stakeholder groups, public officials, researchers, and farm managers. The ultimate outcome of the work has been highly influential in establishing a chloride TMDL for irrigation of sensitive species in the Santa Clara River Basin.

- **Expert Witness and Technical Lead–Prepared Testimony for United States District Court – Eastern District of California; Judge Oliver W. Wanger; Tehama Colusa Canal Authority Water Deficit Evaluation; Willows and Fresno California.** Dr. Kimmelshue was retained to prepare a detailed evaluation of the influence of regulated deficit irrigation on a variety of crops including almonds, grapes, walnuts, rice, olives, alfalfa, tomatoes and a variety of other permanent and annual field and row crops. The preparation of this testimony was conducted to determine the influence of a deficit of irrigation water at predetermined periods of the growth cycles of the crops mentioned above – predominantly focusing on perennial crops such as almonds. The results of this work indicate the extreme detrimental influence of insufficient irrigation during key growth stages of the crop.

- **Technical Lead–Soil Salinity Evaluation; Glenn Colusa Irrigation District (GCID); Willows, California.** This soil salinity evaluation took place over approximately 200,000 acres of within GCID and some neighboring Districts. Dr. Kimmelshue managed and worked with GCID staff to sample the entire District and adjacent areas for soil salinity within the root zone. Sampling and analysis results were compared with historical measurements by the U. S. Bureau of Reclamation (USBR). The trend of salinization was analyzed for its relationship to long-term irrigation management, including a regulatory drought during which irrigation was curtailed throughout the District.

- **Expert Witness and Technical Lead–Prepared Testimony for Santa Clara County Superior Court; Judge Jack Komar; Crop Water Demand and Estimation of Return Flows in Irrigated and Nonirrigated Areas; Southern California Water Company; Santa Maria, California.** This project involved expert witness testimony, both in deposition and in trial settings, based on an 8-month effort to assess crop water use for an historical 58-year period over a 164,000-acre basin. The work focused on pumped water and return flows to groundwater under irrigated and nonirrigated areas. Crop and native vegetation evapotranspiration and soil storage modeling was conducted. Water was assessed to ensure adequate quality for sensitive crop production. The expert witness testimony included 2 days of deposition and 2 additional days of trial testimony, including cross-examination. The work was conducted as a component of a groundwater basin assessment focusing on the potential for overdraft. This was a multi-stakeholder case, which included agricultural, urban and local, state, and federal agencies.

- **Expert Witness and Technical Lead–Perparing Testimony for Los Angeles County Superior Court; Judge Jack Komar; Crop Water Demand and Estimation of Return Flows in Irrigated and Nonirrigated Areas; Antelope Valley Groundwater Agreement Association; Lancaster, California.** This work centered around the quantification of a water right adjudication of the Antelope Valley. Dr. Kimmelshue represented the agricultural interests in the Valley and conducted a detailed and comprehensive assessment of crop water use, irrigation methods and efficiencies, return flows, and other parameters to ultimately assess a component of the safe yield of the groundwater basin based on agricultural pumping. This work was prepared for expert witness testimony in early 2011. Modeling was conducted to assess not only a variety of crop types in irrigated agricultural, but also irrigated urban areas.

- **Project Manager and Technical Lead–Cold Water Rice Yield Loss Determination; Western Canal Water District, Richvale Irrigation District, Biggs West Gridley Irrigation District; Cold Water Influences on Rice Yield; Nelson, Richvale, and Gridley, California.** This project centered on the development and implementation of Settlement Agreement technical protocols between the three Districts (approximately 100,000 acres) and the California Department of Water Resources. The implementation of this Agreement will result in payment by the State of California to the growers within the Districts for loss of rice yield due to cold water diversion from the State Water Project at Oroville Dam and the Thermalito afterbay. The determination of yield loss is being conducted using aerial, satellite and other remote sensing techniques. This approach is being correlated to field measured yield losses utilizing grower owned and operated, combine-equipped GPS yield monitors. Also, in-canal temperature measurements were taken at 125 locations throughout the Districts for a period of up to 90 days. A temperature interpolation map and equation has been developed and is a third method of estimating yield loss determination. These three methods are being correlated against each other for an ultimate yield loss estimate. This work involves consistent contact and interaction with Districts' managers and staff, representatives from the California Department of Water Resources in Sacramento and Red Bluff, cooperating growers, and sub-consultants.

- **Technical Lead; Water Resources Plan–Oakdale Irrigation District; Oakdale, California.** This effort involved detailed assessment of historic land use and projections for future trends based on agricultural market conditions and urban and environmental pressures. This project also involved the development of a comprehensive water resources planning model. Main inputs to this dynamic model were crop water use estimates, water storage and conveyance, deep percolation, losses, recycled water use, and overall long-term water management options for both agricultural and urban uses.

- **Project Manager and Technical Lead–Historic and Present Crop Evaluation and Water Use Estimate; Brownstein, Hyatt, Farber, Schreck – Water Law Firm – representing a Confidential Client; Bakersfield, California.** This project involved the historic and present quantification of water use at a confidential site near Bakersfield. Historic remote sensing imagery was acquired to determine the irrigated area changes over time as well as the cropping pattern shifts from the early 1950s to present day. Water use estimates were determined for the current cropping patterns as well as diverted water quantities. A comprehensive site evaluation was performed with the client and area grower/owner to determine soil type, water conveyance, irrigation methods and management, storage, crop types, etc. This work was used to facilitate a potential substantial land purchase and water rights quantification.

- **Project Manager and Technical Lead–Irrigation Water Reuse – Water Demand Estimates and Water Quality Suitability; City of Hollister and San Benito County Water District; Hollister, California.** This project involved the quantification of water needs assessment from both a quantity and quality perspective for irrigation with treated wastewater. Dr. Kimmelshue led multiple public education sessions related to the water quality and worked closely with both the City and Water District to ensure acceptance by the farming community. Water quality and quantity estimates were determined and were coupled with appropriate crop types and practices. A key portion of this work involved an update of the Recycled Water Master Plan for approval by the Regional Water Quality Control Board and other entities.

- **Project Manager and Technical Lead–Coalbed Methane Produced Water Discharge and Irrigation Suitability; Petroglyph Operating Company; La Veta, Colorado.** Dr. Kimmelshue evaluated the suitability of highly concentrated sodium-rich water from a coalbed methane operation for discharge and irrigation to corn and alfalfa near Walsenburg, Colorado. This work involved evaluating soil and water amendments to compensate for the high sodium concentrations. This challenging project involved public presentations at local community forums as well as ongoing collaboration with Colorado State University and the Colorado Cooperative Extension Service.

- **Project Manager and Technical Lead–Pilot Study and Full-scale Reuse Program; ChevronTexaco; Richmond, California.** This water quality effort included agricultural reuse of approximately 11 million gallons of processing rinse water from a former nitrogen fertilizer manufacturing facility. The processing rinse water was registered with the State of California Department of Food and Agriculture as an agricultural mineral and labeled as Nitro One. Nitro One contains approximately 4 percent total nitrogen. A pilot study was conducted on a cooperating farmer's land that evaluated the effects of different application rates, injection protocols, and handling techniques on corn production. A public relations campaign was conducted to educate the area farmers about the benefits of using Nitro One and the management considerations of the product.

- **Technical Lead–Nutrient Management for the City of Los Angeles Biosolids Land Application Farm; City of Los Angeles Bureau of Sanitation; Bakersfield, California**. Over the past 8 years, Dr. Kimmelshue has been the lead technical consultant for the City of Los Angeles biosolids land application program at Green Acres Farms. This project involved a multitude of nutrient management programs and land application recommendations including irrigation, crop and overall farm management (including a Comprehensive Farm Management Plan) for the 5,000-acre site. The farm receives and beneficially reuses Class A biosolids from multiple municipal treatment plants in the Los Angeles Basin. Recent work involved the refinement of soil and plant tissue monitoring plans, a phased soil amendment schedule, crop fair market value assessment, and customized biosolids database and agronomic loading rate calculation tool Cybersolids™ for use at Green Acres Farm.

- **Technical Lead and Task Manager–Blackfeet Indian Reservation Water Right Adjudication; Bureau of Indian Affairs/Department of Justice; Browning, Montana.** Technical expert since 1997 leading efforts related to the establishment of a water rights claim for the Blackfeet Indian Tribe. These efforts have and continue to include determination of practicably irrigable acres, detailed land classification for the determination of arable and irrigable lands, present and historic irrigation delineations, water demand estimates of both agricultural and urban uses, drainage evaluations for the purpose of avoiding salinization of lands, and overall task management for nearly $1.7M of labor, subconsultants, and expenses.

- **Technical Lead–Feasibility Study to Determine the Chemical and Hydraulic Effects of Irrigating 420,000 Gallons per Day of Saline Wastewater to an 80-acre Orchard and 75 Acres of Landscaping; IBM; San Jose, California.** This evaluation included a detailed cost estimate of modifying the existing irrigation system and management plan to accept the reuse irrigation water. It also included a comprehensive water quality evaluation that reviewed different blending ratios to ensure adequate water quality according to plant species receiving this irrigation water.

- **Technical Lead and Manager–Clark County Water Reclamation District Biosolids Management Study: Market Assessment; Las Vegas, Nevada.** This effort included a diverse evaluation of potential end-use for Exceptional Quality (EQ) biosolids (in pelletized and bulk form) in the Las Vegas area for the Clark County Water Reclamation District. A key end-use included land application to alfalfa in an arid environment. The end result included recommendations for loading, crop rotations, soil sampling and analysis, tissue sampling and analysis, and potential economic return.

- **Technical Lead–Land Application of Former Fertilizer Processing Solids; ChevronTexaco; Fort Madison, Iowa.** This $1.2 million project included the land application of fertilizer pond wastewater (1.5 million gallons) and solids (16,000 cubic yards) to approximately 2,200 acres of suitable farmland in Lee County, Iowa. Roles and responsibilities included management of site suitability analysis, pilot testing with Iowa State University, request for subcontractor proposal development, contract negotiations, and regulatory requirements.

- **Project Manager and Technical Lead–Detailed Nitrogen Balance Model as a Component to a Required Plan of Study (POS); Anheuser-Busch; Jacksonville, Florida.** This POS evaluated the nitrogen dynamics resulting from multiple-year application of brewery processing waters to more than 300 acres of sod grass through center-pivot irrigation systems. Products included the development of a detailed nitrogen balance historic and predictive model for improvement of site irrigation management. An assessment report and findings were presented to the Florida Department of Environmental Protection and approved for permit extension.

- **Technical Lead–Detailed Engineering Report and Wastewater Discharge Permit Application for the Washington State Department of Ecology; ALCOA and Northwest Alloys, Inc.; Chewelah, Washington.** This report and permit were necessary for continued land application of approximately 2.0 million gallons annually of saline rinse waters to alfalfa and grass hay crops. This project involved protection of shallow groundwater that is already high in total dissolved solids (TDS). Also oversaw the monitoring and analysis of soil, crop, and groundwater testing within the land application field.

- **Technical Lead–Central Utah Water Resources and Land Classification Project; Central Utah Water Conservancy District; Roosevelt, Utah.** Successfully mapped nearly 10,000 acres of lands slated for supplemental irrigation and drainage improvements. Responsibilities included quality control for soil sampling and data interpretation. Co-authored a report to the USBR for final project approval and certification by the United States Congress.

- **Technical Lead–Detailed Site Investigation of Infiltration Rates and Soil Characteristics; Victor Valley Wastewater Reclamation Authority; Victorville, California.** Lead consultant for site investigation for the Victor Valley Water Authority for development of rapid infiltration basins. This work involved the delineation of various soil mapping units, repeated infiltration testing, soil laboratory data interpretation, overall data analysis, and report recommendation development. Infiltration testing work was performed at the edges of the Mojave Desert to evaluate infiltration rates and provide soil profile descriptions for a variety of soils for Victor Valley Wastewater Reclamation Authority. Testing included evaluation of over 300 acres of relatively coarse-textured desert landscape overlain by finer-textured eolian (wind-blown) deposits at various depths. A network of soil profile descriptions and mobile cone-penetrometer testing was performed to locate reasonable areas for siting of infiltration basins for recharge of treated wastewater. Basins were sited according to previously determined distances from the Mojave River to allow adequate treatment capabilities through the soil matrix. The rapid infiltration ponds were constructed successfully, are currently operational, and are satisfying the design rate estimates for infiltration of treated wastewater.

- **Technical Lead and Project Manager–Investigation of Sites for Infiltration Basins; Pajaro Valley Water Management Agency; Watsonville, California.** This project involved the evaluation of the infiltration rates through testing of a variety of soils for irrigation water infiltration, storage, and reuse. This infiltration testing was conducted to provide groundwater recharge of surface water supplies to a predominantly agricultural area that was experiencing groundwater overdraft and potential seawater intrusion. Two locations were selected for testing of native materials for siting the basins. The first location was in the dune lands of the valley directly adjacent to the Pacific Ocean. The second location was sited inland, close to the Pajaro River in fine-textured soils derived from alluvial sources. This second location was to be modified from an existing stormwater capture basin. Results of this investigation led to the construction and operation of the dune-land infiltration basin network and provided some protection from seawater intrusion into the valley. This basin is operated seasonally and aids in the overall water management plan of the Pajaro Valley.

- **Project Manager–Design and Construction of a Constructed Wetlands System for Lake County Sanitation District; Lakeport, California.** Role was to provide design and construction management services during an $110,000 development of a constructed wetland system. The project was designed to improve and enhance wildlife habitat, beneficially reuse secondary treated wastewater, provide for public access and education, and secondarily to improve water quality.

- **Technical Lead–Detailed Engineering Report and Wastewater Discharge Permit Application for the Washington State Department of Ecology; ALCOA and Northwest Alloys, Inc.; Chewelah, Washington.** This report and permit were necessary for continued land application of approximately 2.0 million gallons annually of saline shallow groundwater that is high in total dissolved solids. Also oversaw the monitoring and analysis of soil, crop, and groundwater testing within the land application field.

- **Project Manager and Technical Lead–Caltrans Statewide Vegetative Erosion Control Review; Sacramento, California.** This $390,000 project involved all aspects of project management from proposal development; presentation and interview for project; development of scope of work and budget; implementation of unique project evaluation tools; management of 11-person team, statewide field efforts; subcontractor selection and contracting; scientific publication development; and development and presentation of final report.

- **Project Manager and Technical Lead–Caltrans Nonvegetative Alternative Soil Stabilizers; Bishop, California.** This $300,000 project resulted in the focus of nonvegetative erosion control technologies for soil stabilization. The project management roles of this follow-on work effort involved proposal development; presentation and interview for project; development of scope of work and budget; evaluation of multiple nonvegetative/vegetative erosion control technologies; management of eight-person team; subcontractor selection and management; and report development.

- **Technical Lead–State of California Erosion Control and Cover Establishment Guidelines; California Integrated Waste Management Board; Sacramento, California.** The end product was a practical, and easy-to-use specification to revegetate disposal areas. The specification was tailored to separate the state into individual climatic regions for better species selections and survivability. This specification is being utilized throughout the state for revegetation of illegal dumps sites after clean up.

- **Technical Lead–Selection and Incorporation of Plant Species in a Remediation Effort; Beale Air Force Base; Sacramento, California.** This project involved using a variety of plant and tree species within a slurry wall design for containment and natural degradation of a shallow contamination plume. This work also involved the rerouting of a seasonal stream and revegetation and irrigation of the stream channel.

- **Technical Lead–Riverbend Landfill Leachate Management Study; McMinville, Oregon.** Developed and implemented a client-useable water balance so that the landfill could accurately monitor land application progress and nutrient loadings. Performed detailed water balance modeling and co-authored the initial Leachate Management Plan and three subsequent monitoring reports. These detailed reports were approved by the Oregon Department of Environmental Quality.

Select Representative Projects – International Work

(Complete work experience includes efforts in the countries of: Turkey, Malaysia, Germany, Egypt Israel, Jordan, and The West Bank) Representative projects listed here include:

- **Project Manager and Technical Lead–Development of a Reuse Feasibility Assessment for Irrigation of Conventionally Treated Wastewater; Adana, Turkey**. This project was stimulated by the need to conserve on-base water supplies at the Incirlik Air Base. The feasibility study evaluated the needs associated with the conversion of some on-base irrigation water sources from potable water to treated wastewater. This $100,000 project limited the reliance on off-base water supplies through irrigation with treated wastewater and other conservation practices associated with landscape and crop irrigation. The use efficiency was maximized in this project because storage was limited. A nutrient and hydraulic management plan was constructed for this work to ensure that no over-application of treated wastewater takes place.

- **Project Manager and Technical Lead–Development of Evaluation Strategy for Agricultural Reuse at 19 Wastewater Treatment Plant Sites throughout the Country of Jordan; Amman, Jordan.** These efforts included a technical strategy development for agricultural reuse for the currently operating 19 wastewater treatment plants in Jordan. This involved an evaluation of influencing factors such as soils, climate, crop production in the area, market conditions, cultural acceptance, wastewater quality, and crop recommendations. The technical report was used to preliminarily prioritize agricultural reuse development for specific areas.

- **Technical Lead–Development of a Feasibility Assessment for Agricultural Reuse of Treated Wastewater for the Hebron Wastewater Treatment Plant Improvements Project; Hebron, West Bank.** This project involved initial development and site location options for reuse of treated wastewater from the anticipated wastewater treatment plant serving Hebron and surrounding communities. Four main sites were evaluated according to land suitability; climatic regimes; proximity to markets; available land area; wadi discharge, potential storage areas and sizing; and impacts to the surrounding environment. Preliminary hydraulic and nutrient balance modeling was conducted for each site and for projected increases in treated wastewater production. This included development of water and nutrient balances for agricultural reuse with local cropping patterns.

- **Technical Lead–Development of a Master Planning Document for the Hebron Wastewater Treatment Plant Improvements Project; Hebron, West Bank.** This project involved a detailed hydraulic and nutrient loading modeling effort for the agricultural reuse component initially proposed in a previous Feasibility Assessment effort. This work was a component of an overall wastewater master planning effort and was driven by environmental and economic concerns of the region.

- **Technical Lead–Development of a Feasibility Study for the Mafraq Wastewater Treatment Plant Improvements Project; Mafraq, Jordan.** This project involved development of water and nutrient balances for beneficial agricultural reuse of treated wastewater based on various scenarios of different cropping patterns, storage sizing, and wadi discharge for forecasted wastewater flows to 2025. Managing climatic influences and the seasonality of application were optimized to maximize the land base available for application.

Previous Experience

Before co-founding NewFields Agricultural and Environmental Resources, LLC, Dr. Kimmelshue spent over 11 years with CH2MHILL. During that time, Dr. Kimmelshue was the firm-wide leader for

Agricultural Services Technology, which represented nearly 70 people throughout the firm. Dr. Kimmelshue was also the Business Development Lead for all water resources related projects for a 7-state southwestern region. Prior to that, Dr. Kimmelshue worked as a research associate at North Carolina State University and managed portions of an irrigated agricultural farm in northern California, producing a variety of tree, field, and row crops.

Professional Responsibilities and Accomplishments

State Committee Member – California Department of Food and Agriculture – Specialty Crop Block Grant Advisory Committee – A 3-year appointment for review and selection of proposals for up to $16M in United States Department of Agriculture funding annually. Sacramento, CA

Fellow – California Agricultural Leadership Program – Class 37 – a 2-year, intensive leadership development program designed for the advancement of current and future leaders in California agriculture. Sacramento, CA

National Committee Member – American Society of Agronomy Career Placement and Professional Development, Minneapolis, MN

Participant – California Water Education Foundation Tours – Sacramento Valley and Central Valley Tours.

Board Chair and Member – Advisory Board for California Polytechnic State University Earth and Soil Sciences Department, San Luis Obispo, CA

Board Member – Advisory Board for California State University Geosciences Department, Chico, CA

Board Member – Shasta Land Trust, Redding, CA

Selected Publications

Kimmelshue, J.E. 2010. A Case Study of Reuse and Conservation of Water during Resource Management: Resolution Copper Mining. Chapter in: Sustainable Land Development and Restoration – Decision Consequence Analysis. Brown, Hall, Snook and Garvin. Elsevier, Inc.

Heilmann, M., B. Inman, J. Kimmelshue, B. Schmid, J. Dickey, R. Coles, and R. Harasick. 2006. Classification of the Owens Dry Lake Playa Surface Using Satellite Imagery and Unique Surface Characterization Methods. 2006. World Congress of Soil Science: Frontiers in Soil Science, Philadelphia, PA, July 2006.

Kimmelshue, J.E. and G. Eldridge. 2006. Agricultural Reuse – A Component of Total Water Management. National Water Resources Association. Park City, UT, July 2006.

Kimmelshue, J.E., K. Freas, and S. Sulaiman. 2006. VOYAGE – A Total Water Management Modeling Tool. AsiaWater 2006. Kuala Lumpur, Malaysia. March 2006.

Griffes, D., D. Meerbach, J. Kimmelshue and P Rude. 2003. Reuse of Treated Wastewater and its Impact on the Environment: Research Priorities. Proceedings of: The First Conference for Scientific Research at Jordan Universities. Amman, Jordan.

Griffes, D., D. Meerbach, J. Kimmelshue, and P. Rude. 2003. Reuse of Treated Wastewater and its Impact on the Environment: Research Priorities. The First Conference for Scientific Research at Jordan Universities. Amman, Jordan.

Kimmelshue, J.E. and D. Kruse. 2003. Feasibility and Water Savings of Treated Wastewater Reuse for Irrigation of Golf Course and Landscaped Areas at Incirlik Air Base. 5th Biennial European Command Joint Environmental Conference. Sonthofen, Germany.

Sloan, A.J., M.L. Scharff, M. Hart, L. Karren. J.E. Kimmelshue, and B. Hallock. 2002. Development of the Highway Erosion Assessment Tool (HEAT) for evaluation of roadside slopes in California. Proceedings of the International Erosion Control Association Conference, Orlando, FL, February 25-March 1, 2002.

Kimmelshue, J.E., M. Dellinger, R. Langis, and J. Bays. 2000. Basin 2000/Lyons Creek wildlife habitat and treatment wetlands design and construction. WEFTEC 2000 Annual Meetings, Oct 16-19, 2000. Anaheim, CA.

Kimmelshue, J.E., J. Maier, and C. Peck. 2001. Land Application of 25 Years of Phosphorus Fertilizer Residues. WEFTEC 2001 Technical Proceedings.

Kimmelshue, J.E., R. Langis, M. Dellinger and J. Bays. 2000. *Wildlife Habitat and Treatment Wetlands Design and Construction.* Treatment Wetlands for Water Quality Improvement - Quebec 2000 Conference Proceedings (Selected Papers). CH2M HILL, Waterloo.

Kimmelshue, J.E., M. Dellinger, R. Langis, and J. Bays. 2000. Basin 2000/Lyons Creek wildlife habitat and treatment wetlands design and construction. WEFTEC 2000 Technical Proceedings.

Kimmelshue, J.E., R.O. Evans, and J.W. Gilliam. 1996. Extraction and instrumentation of round soil monoliths for monitoring evapotranspiration and solute movement. Evapotranspiration and Irrigation Scheduling in Proceedings of International Conference of American Society of Agricultural Engineers.

Kimmelshue, J.E., J.W. Gilliam, and R.O. Evans. 1996. The influence of drainage management and nitrogen additions on nitrate leaching. Soil Science Society of North Carolina Proceedings.

Kimmelshue, J.E., J.W. Gilliam, and R.O. Evans. 1996. Agronomy Abstracts. Influence controlled drainage on nitrate leaching. American Society of Agronomy 88th Annual Meetings. Nov. 2, 1996. Indianapolis, IN.

Kimmelshue, J.E. 1996. *TheIinfluence of Drainage Management and Nitrogen Fertility Practices on Nitrate Leaching.* Ph.D. dissertation. North Carolina State University. Raleigh, NC.

Kimmelshue, J.E., J.W. Gilliam, and R.J. Volk. 1995. Water management effects on mineralization of soil organic matter and corn residue. *Soil Science Society of America Journal*. 59:1156-1162.

Kimmelshue, J.E., R.O. Evans, and J.W. Gilliam. 1995. Extraction and use of large intact soil cores and a field site in drainage management studies. Soil Science Society of North Carolina Proceedings. 38:83-87.

Kimmelshue, J.E. and J.W. Gilliam. 1993. Controlling the mineralization of organic nitrogen in lower coastal plain soils. Soil Science Society of North Carolina Proceedings. 36:29-34.

Kimmelshue, J.E. and J.W. Gilliam. 1992. Agronomy Abstracts. Nitrogen mineralization of 15N labeled corn residue as influenced by water management. American Society of Agronomy 84th Annual Meetings. Nov. 5, 1992. Minneapolis, MN.

Kimmelshue, J.E. 1992. *Nitrogen Mineralization of 15N Labeled Corn Residue as Influenced by Water Management.* M.S. Thesis. North Carolina State University. Raleigh, NC.

Kimmelshue, J.E. 1990. *Sulfur Additions to an Alkaline Soil in the Northern Sacramento Valley of California and Influence on Almond Production*. Unpublished bachelor's thesis. California Polytechnic State University. San Luis Obispo, CA.

Stephanie K. Tillman, M.S., CPSS, CPAg

Project Soil and Agricultural Scientist - NewFields Agricultural & Environmental Resources, LLC

Education

M.S., Soil Science, University of Saskatchewan, 2001

B.S., Agriculture (Environmental Science), University of Saskatchewan, 1998

B. Music Performance – Brandon University, 1993

Professional Registrations

Certified Professional Soil Scientist (CPSS) – American Registry of Certified Professionals in Agronomy, Crops and Soils

Certified Professional Agronomist (CPAg) – American Registry of Certified Professionals in Agronomy, Crops and Soils

Distinguishing Qualifications

Expert/Specialist in the following areas:

- Implementing and monitoring regulatory compliance programs for land application of industrial wastewater
- Evaluating soil and plant systems and water quality for beneficial agricultural reuse
- Developing grower marketing programs
- Characterizing soil profiles
- Mapping rangeland and developing rangeland management plans
- Modeling agricultural water and nutrient use
- Researching salinity-related problems in agriculture
- Reclaiming sodic/saline soils
- Evaluating industrial co-products for beneficial agricultural use

Relevant Experience

Ms. Tillman has worked in the consulting and agri-business industries for 12 years. She has worked with clients to understand and comply with regulations related to beneficial agricultural use and land treatment of industrial wastewater. Water quality issues also figure prominently in project work that involves estimating water use in various plant and soil systems. These systems often include salinity issues that must be managed for the benefit of clients, crops, and soils. Ms. Tillman has extensive experience working with growers on various projects such as rangeland management plans, product development, and irrigation projects. Ms. Tillman has worked on projects throughout California and in other Western States.

Representative Project Experience

- **Soil and Agricultural Scientist – Modeling Carbon Flux of Almond Pruning Practices; Almond Board of California; Modesto, CA.** Conducted literature review of carbon and nitrogen dynamics of almond management practices. Conducted survey of university extension agents, industry experts, and growers and compiled information for greenhouse gas model. Collaborated with remote sensing and GIS specialists to conduct almond crop mapping in California.

- **Soil and Agricultural Scientist – Reclaiming Sodic Soil; Petroglyph Energy; Walsenburg, CO.** Collaborated to develop soil reclamation treatment and monitoring program for dairy farm. Soil had become sodic from irrigation with coal bed methane discharge. Worked with landowner, client, and state industry commission to determine and coordinate field operations.
- **Soil and Agricultural Scientist – Water and Soil Quality Monitoring and Crop Water Use Estimating; Resolution Copper Mining; Superior, AZ.** Assisted in determining and developing monitoring protocol for irrigation district using blended, treated mine discharge water. Developed estimates for water quantity and quality appropriate for applicable crops.
- **Soil and Agricultural Scientist – Researching and Coordinating Rice Yield Monitoring; Western Canal Water District, Oroville, CA.** Developed protocol for monitoring rice yield with GPS-equipped harvesters. Coordinated communication between water districts, landowners, and technical experts for data analysis. Assisted with various technical aspects of applying remote sensing technology to yield determination on large scale.
- **Soil and Agricultural Scientist – Determining Carbon Credits; Barksdale Airforce Base, Barksdale, Louisiana.** Assisted with technical aspects of using remote sensing and management information for modeling greenhouse gas flux from large area of land. Researched economic and technical mechanisms used in the carbon trading industry.
- **Project Manager–Waste Discharge Requirements Permitting; Wilbur Packing Company; Yuba City, California.** Managed monitoring program to ensure regulatory compliance. Colusa Industrial Properties owns and operates a fruit packing facility and several orchards. Project management responsibilities included scope, budget, and schedule development and tracking; client service, project team management, and coordinating technical document submittals to the Regional Water Quality Control Board on behalf of the client.
- **Project Manager–Land Treatment System Monitoring; Colusa Industrial Properties; Colusa, California.** Managed a monitoring program to ensure regulatory compliance. Colusa Industrial Properties owns and operates a land treatment system for disposal of industrial wastewater. Project management responsibilities included scope, budget, and schedule development and tracking; field soil sampling; writing technical and annual summary reports; tracking hydraulic and nutrient loading on the site; and coordinating project staff and document submittals to the Regional Water Quality Control Board on behalf of the client.
- **Task Manager/Soil Scientist/Agricultural Specialist–Upper Santa Clara River Chloride TMDL Collaborative Process; County Sanitation Districts of Los Angeles County**. Conducted extensive literature review and evaluation on chloride and salt tolerance of salt sensitive crops. Developed scoring system to rank literature on quality, applicability, and scope relevance to study area. Developed extended study alternatives including sand tank studies, field studies, and outdoor containers for avocado, strawberry, and nursery crops.
- **Assistant Project Manager–Rangeland and Riparian Managements Plans; Deer Creek Watershed Conservancy; Cottonwood, California**. Conducted all mapping (GPS), landowner interviews, stocking rate assessments, and developed management practice implementation plans and monitoring plans for 20,000 acres on five ranches in Deer Creek Watershed. Mapping and planning included management units, fences, invasive weeds, water developments, and cultural and historical resources.
- **Soil Scientist–Facility Runoff Control Plans; Colorado Department of Transportation (CDOT).** Conducted site visits and assisted in writing Facility Runoff Control Plans for CDOT maintenance yards in and around Denver. Assisted in developing Best Management Practices to reduce erosion and pollutants in stormwater discharges.
- **Soil Scientist–Cottonwood Creek Watershed Management Strategy and Plan; Cottonwood Creek Watershed Group; California.** Conducted public meetings on strategic resource areas

including groundwater and surface water quality, erosion and flooding, aquatic habitat, rangeland and timber, and terrestrial and riparian habitat. Worked collaboratively with Technical Review Team and stakeholders to develop strategic areas including fuel reduction and vegetation management, inventory and mapping, outreach and education, management plan development, and monitoring and modeling.

- **Soil Scientist–Santa Maria Basin Return Flow Modeling Under Agricultural Lands, Santa Barbara County, California.** Modified existing water balance in order to model return flow under irrigated crops, non-irrigated agricultural lands, and native vegetation. Researched and developed key model inputs such as rooting zones and consumptive water use for native vegetation and irrigated and non-irrigated crops.
- **Task Manager–Soil Sampling and Analysis; Owens Lake Dust Mitigation Program; Los Angeles Department of Water and Power (LADWP).** Coordinating soil sampling and analysis in conjunction with court-ordered dust mitigation program. Owens Dry Lake is the nation's largest single source of dust emissions. LADWP must mitigate the emissions with dust control measures that include shallow flooding and establishing managed vegetation. Compliance must be accomplished under extremely saline conditions. Tasks included developing sampling plans, performing soil sampling and interpreting data for soil reclamation, and developing soil profile descriptions.
- **Regulatory Compliance–Jacksonville Brewery Land Application Site; Anheuser-Busch; Jacksonville, Florida.** Responsible for assisting Anheuser-Busch with regulatory compliance activities associated with land application of process water. This site is regulated by the Florida Department of Environmental Protection (DEP) for nitrate contamination in groundwater. Involvement included developing a nitrogen balance tool by summarizing and manipulating historical and present-day data to identify alternatives for compliance with DEP regulations.
- **Soil Scientist/Agricultural Specialist–Agricultural Reuse Pilot Study and Marketing Program; Chevron-Richmond; Richmond, California.** Chevron Environmental Management Company requires a means to dispose of its industrial process water. Responsibilities included designing and conducting a pilot field study to evaluate agricultural reuse and developing a marketing program with local state agency staff and academic community experts for growers to use Chevron’s industrial process water as fertilizer.
- **Soil Scientist–Stormwater Monitoring, Multiple Statewide Projects, California Department of Transportation.** Contributor to various Caltrans erosion control and stormwater management projects, including the Caltrans Statewide Vegetative Erosion Control Review and Caltrans Non-Vegetative Alternative Soil Stabilizers project. Tasks included stormwater sampling, non-vegetative erosion control methods study plan documentation, and assisting in the design of stormwater collection methods.

Previous Experience

Prior to her employment at NewFields, Ms. Tillman worked as a soil and agricultural scientist at CH2M HILL for 6 years. Preceding her work in consulting, Ms. Tillman worked in the agri-sales, development and research industry across three Canadian provinces for Simplot Canada and Rhone-Poulenc. International experience includes volunteering at a project in Mali, West Africa, which encouraged agricultural and economic diversification by teaching local farmers about cotton production.