Mapping Spatial Distribution of Almonds Using Remote Sensing – Enhancement of Existing Methods and Products for Applications

Project No.: **12-STEWCROP4-Kimmelshue**

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Objectives:

Crop mapping in extensively broad agricultural areas can be accomplished using remote sensing more accurately and efficiently than traditional land use survey methods. Satellite and aerial imagery can be used not only to quantify and locate specific crops, but in many cases to determine attributes of that crop, such as age, density, and yield. While the initial effort to create a statewide spatial database of almonds is considerable, the effort to update that database yearly is minimal because a much more simple change analysis is sufficient to update perennial crop maps. Therefore, the potential to improve spatial and temporal accuracy of crop maps from current data sources is significant.

This methodology is proprietary to Land IQ and results provided in this Annual Report should not be reused without written permission from Land IQ.

The original objective of this project was to provide the Almond Board of California with an almond distribution map that would guide efforts to influence regulatory policy and other Almond Board of California efforts, such as production and marketing improvements. Between the time of funding request and actual funding the capability to map almonds statewide was mastered by Land IQ. Therefore, the original objectives of this research request were altered to then modify these products and determine applications based on the crop mapping results for the Almond Board of California.

Specifically, these and other objectives included:

- Determining the minimum level of accuracy that is required to make the crop map useful.
- The relative effort of achieving this minimum level of accuracy, and the effort associated with increasing increments of accuracy.
- Optimizing accuracy and cost, or the point of diminishing returns, through various combinations of remote sensing imagery, ground truthing, and analysis.
- Leveraging other sources of geospatial crop data to minimize mapping effort in general.
- Determining the yearly level of effort required to update almond crop maps using change analysis.

- Using the final product for real-world application (case studies) that are currently facing the Almond Board of California.

Interpretive Summary:

Land IQ has developed advanced remote sensing methods to map crops throughout the entire Central Valley of California. This methodology has been developed over more than a decade. It uses a range of advanced software and statistical approaches, and implements a hierarchical object-based process. Current results are 97% accurate in almonds and similar precision is achieved in other permanent and annual crops. This methodology is also proprietary to Land IQ and results provided in this Annual Report should not be reused without written permission from Land IQ.

The distribution of crops in the Central Valley has been dynamic for decades and is expected to continue to be so. Accurate and timely crop acreage estimates are valuable for a variety of reasons and purposes (i.e. yield estimates, market forecasts, transportation planning, environmental considerations, etc.). It is especially valuable if these estimates are developed spatially. For the purposes of this brief summary, an irrigated area in the Central Valley is given as an example.

Furthermore, applications and examples based on this crop mapping technology are provided. They include a proximity analysis to sensitive habitats, age determination of almonds by field and use of overall crop mapping in development of regulatory solutions such as the California Irrigated Land Regulatory program.

Materials and Methods:

Efforts were directed at a pre-mapped pilot area within the Central Valley of California, using criteria such as significant almond acreage, varied contextual examples such as landscape features, and availability of appropriate imagery resources. These efforts included investigation of archived spatial resources and application of algorithms, statistical approaches and temporal analyses.

In general, the steps involved in the crop mapping protocols developed by Land IQ include the following:

- Image Acquisition
- Field Delineations
- Initial Ground Truthing
- In-House Remote Sensing
- Accuracy Assessments/QA-QC
- Final Ground Truthing
- Final Product Delivery

The image resources that are used for crop mapping are diverse and possess spectral, textural and temporal variation to result the necessary highly accurate results of >97% for almonds.

Field delineations are developed so that a “field” boundary encompasses a homogenous crop type (**Figure 1**). This definition of a field may or may not be synonymous with a grower’s definition of a field or APN parcel boundaries.

The Land IQ crop mapping approach has been developed and proven methods developed over last 10 years. The technology has been implemented on large projects in San Joaquin, Sacramento, and Imperial Valleys. The method centers on a hierarchical object based approach and allows for photo-interpretive elements, multi-temporal & multi-resolution analysis, input of hundreds of predictor variables, and contains proprietary statistical tools including data mining techniques. The approach leverages our spatial & spectral crop library which is constantly updated to account for the ever-changing agricultural landscape of California – especially in the Central Valley. The overall product results in accurate crop maps, statistics, and crop change available for the entire Central Valley.

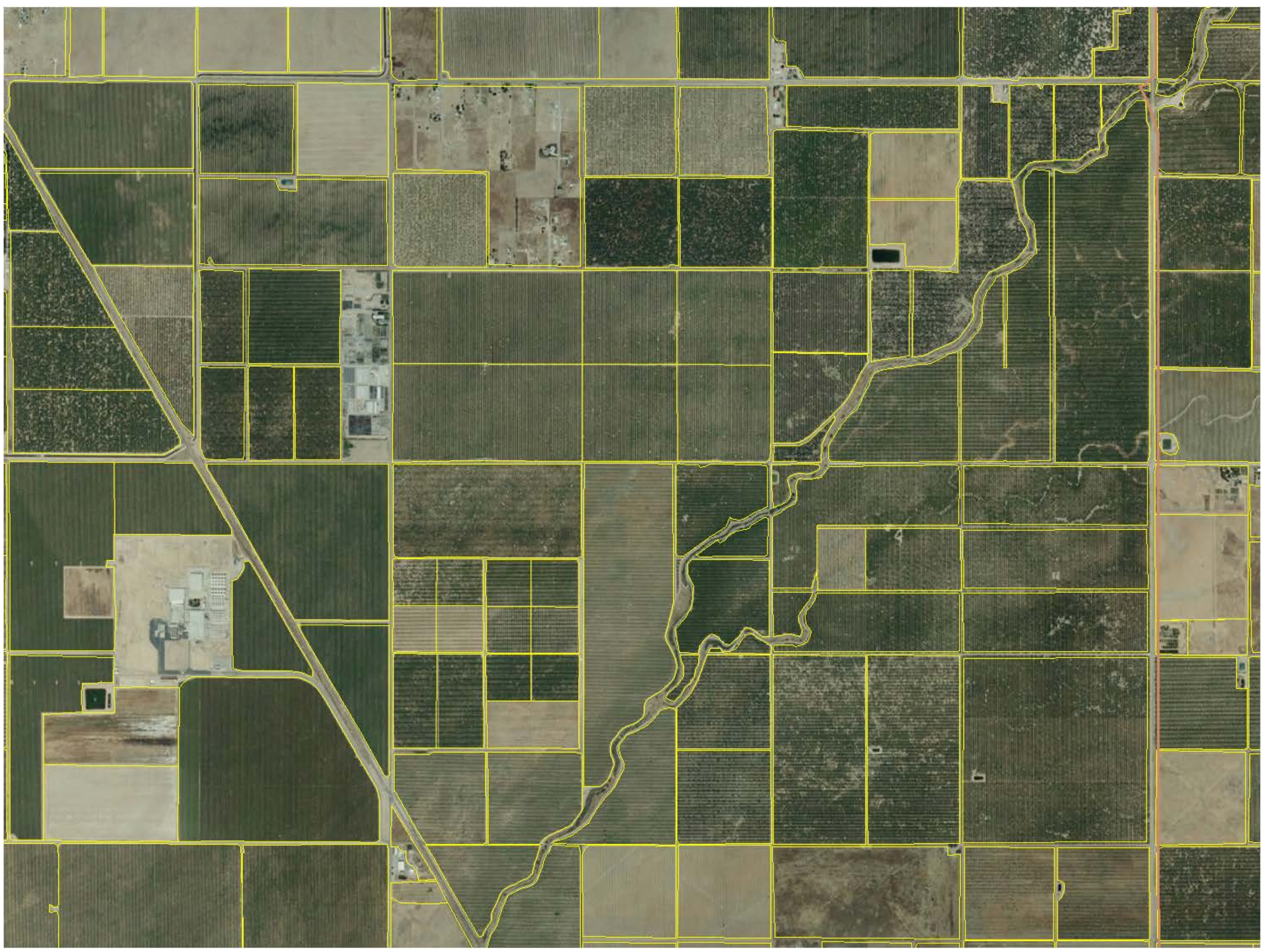

Figure 1. An example of field delineations showing homogeneous crop type within boundaries.

The field boundaries are then taken to the field and used as locators during ground-truthing efforts. During the growing season of 2012, approximately 4,500 miles of ground-truthing was collected across the Central Valley (**Figure 2**).

The ground-truthing information is then taken back to our remote sensing analysts for use with our proprietary methodologies for determination of crop type. Accuracy assessments and extensive QA/QC efforts are then conducted to determine the low probability predicted fields. Finally, another ground-truthing effort is conducted to verify those low probability fields and further inform the process for continual improved accuracy.

The final product with a pre-determined legend is then developed. For the purposes of the Almond Board of California, Land IQ segregated out the previously mapped almond acreages in an area of the Central Valley for purposes of development of practical and real-world applications.

It is expected that the results of this work will demonstrate clearly that remotely sensed geospatial crop data is far more accurate, timely and useful than other available resources.

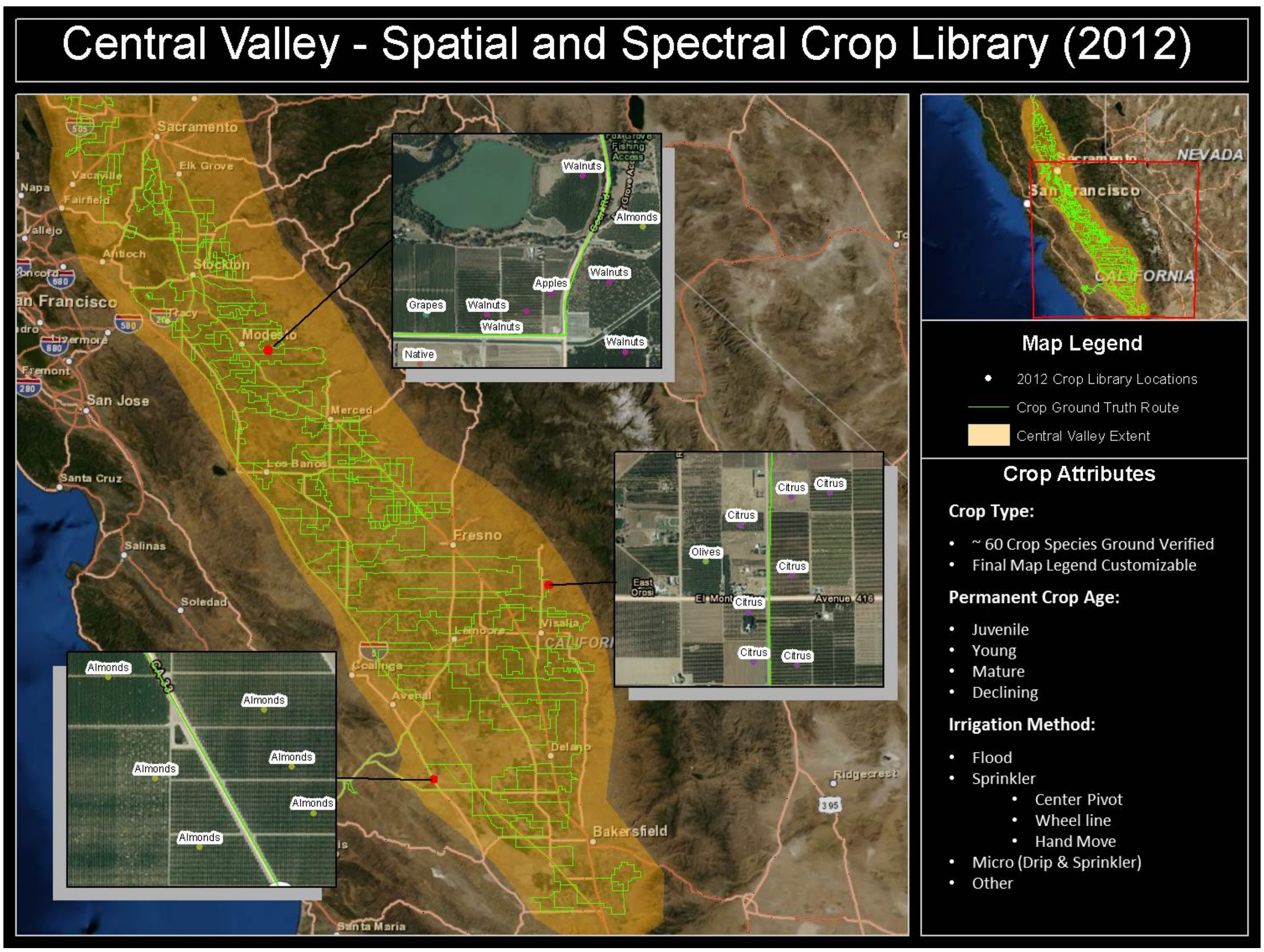

Figure 2. The 2012, 4,500-mile route map driven for collection of ground-truthed data.

Results and Discussion:

The California Department of Water Resources (DWR) conducts crop mapping for all irrigated lands in the Central Valley and a product for an area in the Central Valley in 2001 is provided (**Figure 3**). These spatial maps, although accurate, are produced only once every 6-10 years and are usually published at least 1 or 2 years after the actual survey year. The National Agricultural Statistics Service (NASS) produces a remotely sensed spatial product; however it is approximately 75 percent accurate in California. Land IQ has implemented a proven methodology to produce a timely and highly accurate spatial crop mapping product for almonds and a whole host of other crops. An example of this product for the same Central Valley area in 2011 (**Figure 4**) shows significant change in crop distribution as compared to DWR mapping ten years prior (**Figure 3**).

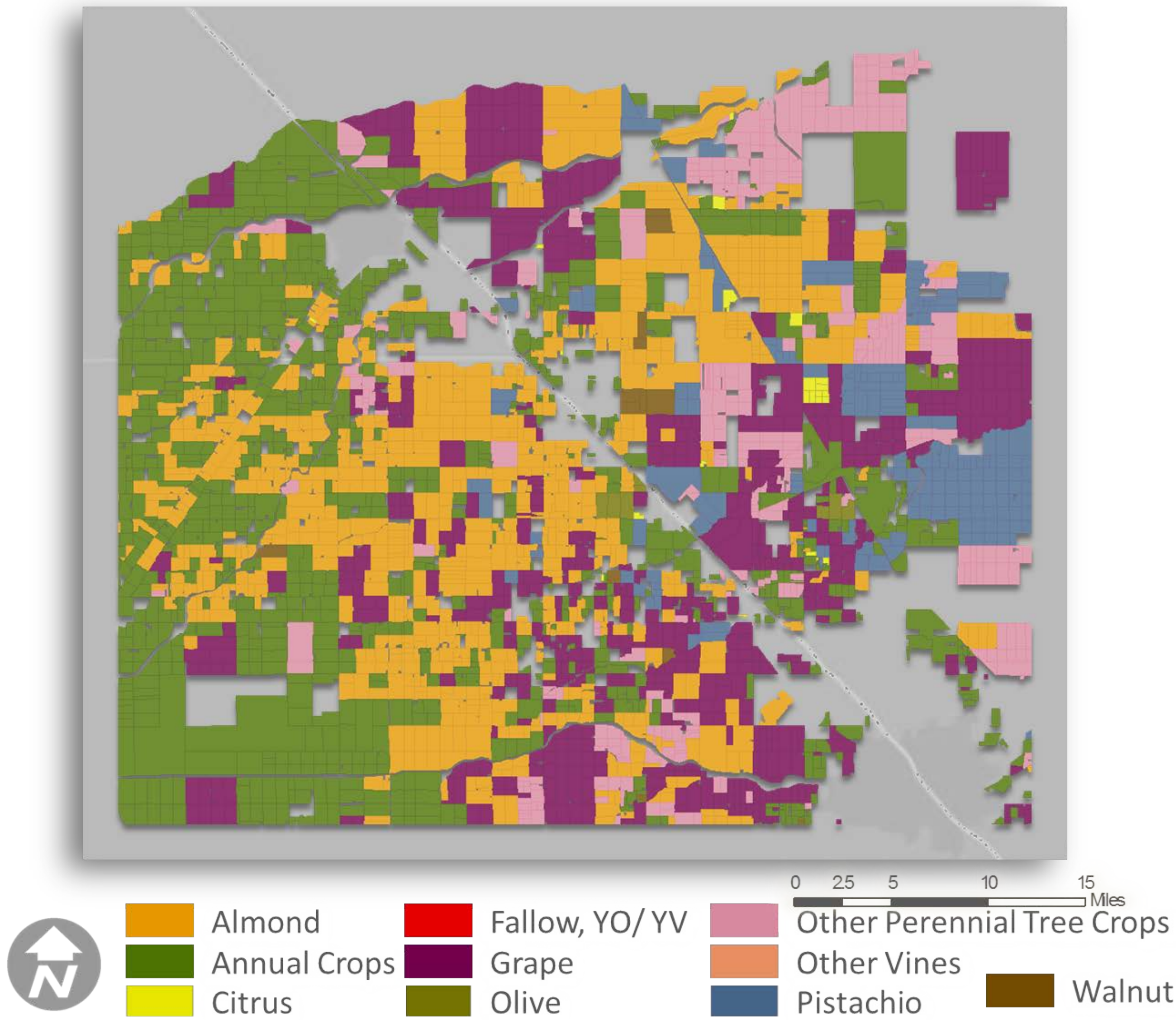

Figure 3. 2001 DWR crop mapping in a select area of the Central Valley.

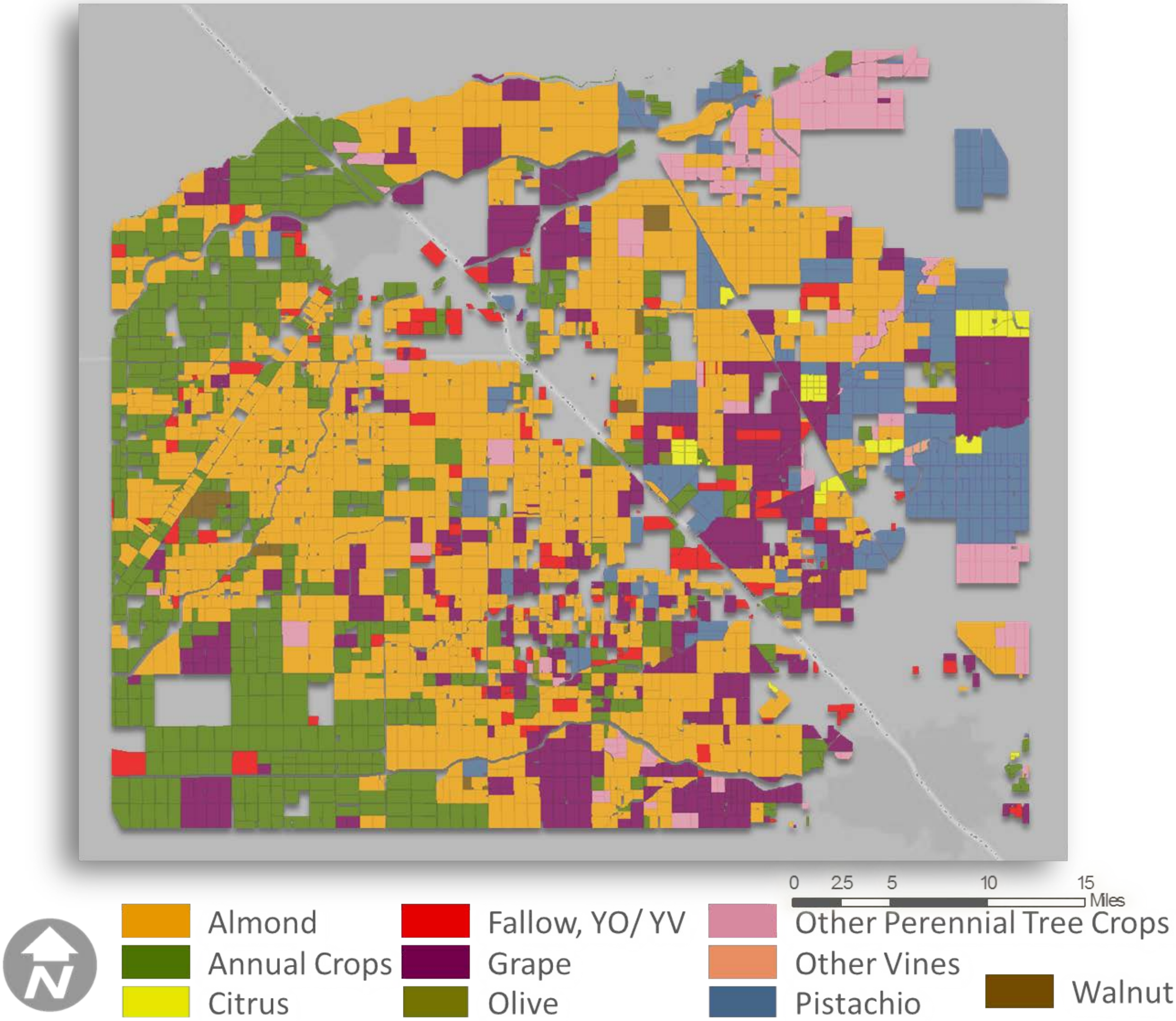

Figure 4. 2011 Land IQ crop mapping in a select area of the Central Valley.

Almonds are a major component of the crop mix throughout the Central Valley approaching nearly 900,000 acres. An example of the significant distribution of almonds can be found in a select part of the Central Valley (**Figure 5**). A comparison with 2001 DWR spatial mapping (**Figure 6**) again shows significant change in just ten years. A comparison of the Land IQ almond acreage estimates and various published sources show significant differences in 2011 (**Figure 6**). Comparing the two almond distribution maps shows a significant increase in acreage over this 10-year period. At a previous meeting with the Almond Board of California Acreage Committee, it was indicated that the committee's belief is that almond acreage in the state is under-reported. At this time Land IQ is estimating higher almond acreages in the state than what is being report by other sources and this corresponds to the industry understanding.

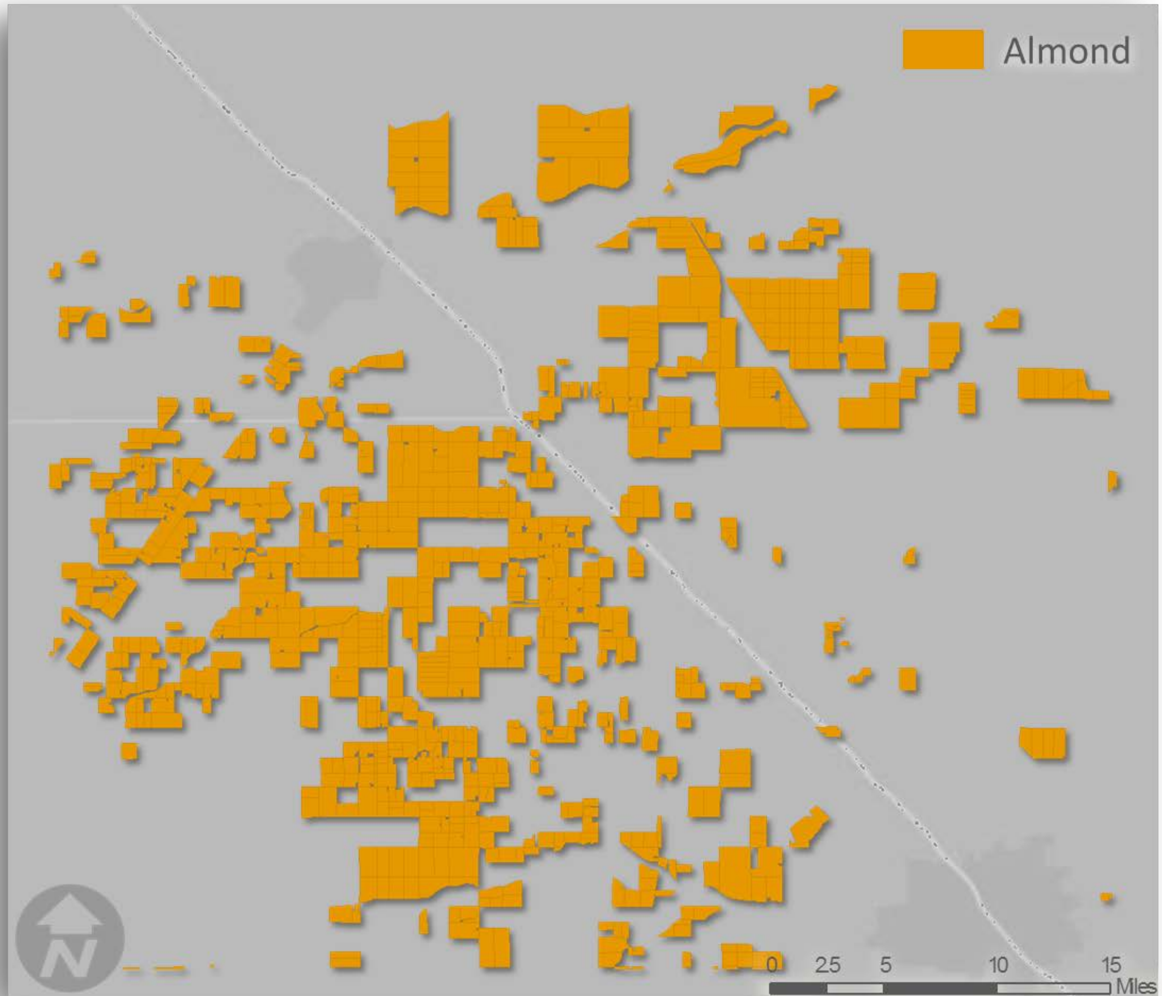

Figure 5. 2001 DWR almond mapping in a select area of the Central Valley.

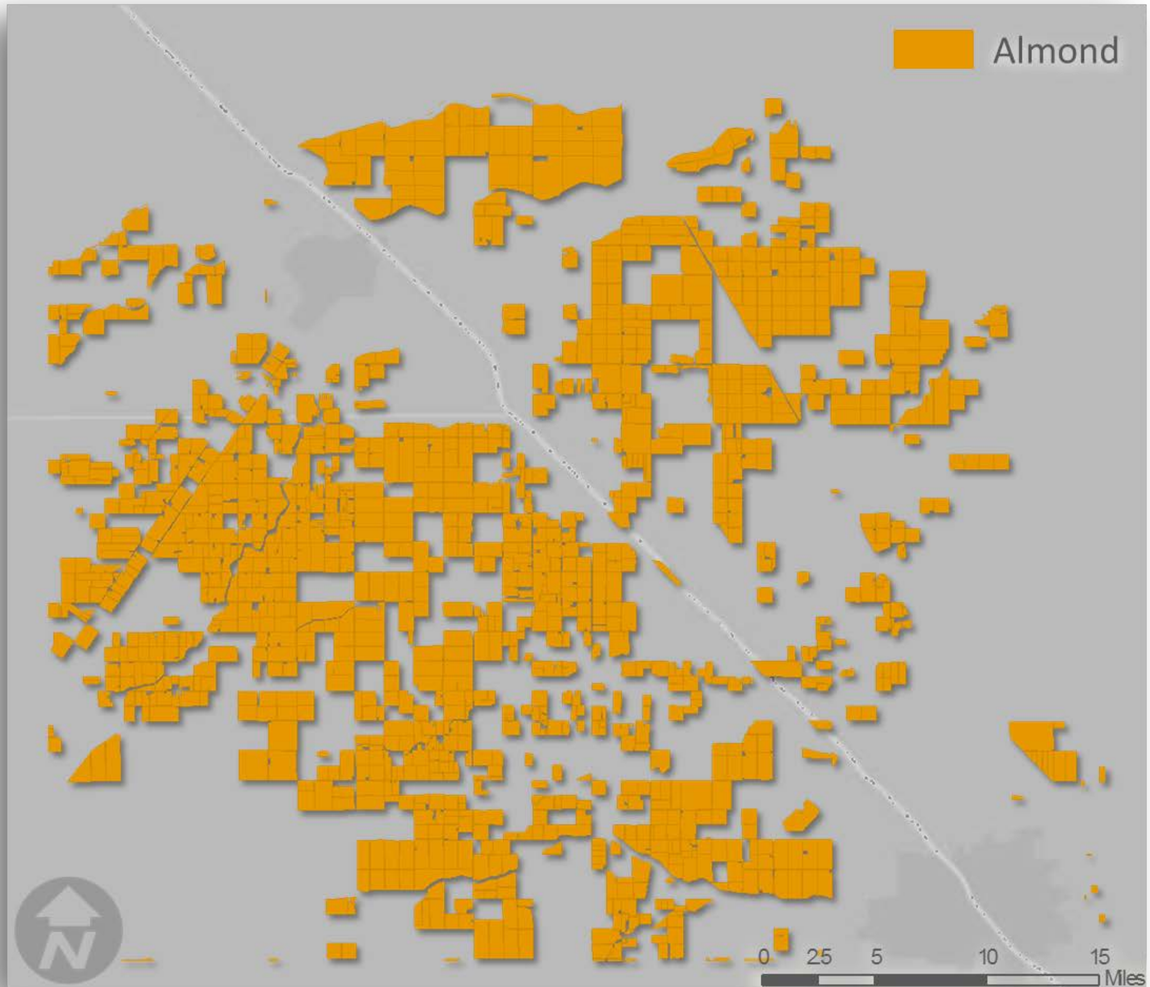

Figure 6. 2011 Land IQ almond mapping in a select area of the Central Valley.

Applications

Almond Age Determination:

Beyond crop mapping, determination of planting date is one of many additional benefits of producing a timely and spatially accurate annual almond mapping product. With our mapping approaches and new remote sensing developments, Land IQ has the capability to identify the actual planting year of each orchard with a current accuracy of approximately 80-90 percent (**Figure 7**). Data availability allows for this analysis to take place as far back as 1984. Acreages of new plantings can be determined annually as well as the total number of new orchards. Newly planted orchards are simply classified as “young orchard” until the 3rd or 4th leaf, at which time they can be accurately classified as almonds as compared to other tree species.

Figure 7. Almond age determination

Proximity Analysis:

One of the applications that Land IQ developed for the Almond Board of California was a proximity analysis with a simple GIS overlay and proximity radius applications. With ever increasing environmental pressures on agriculture it is every more important to know the spatial distribution of almonds and other crops, rather than just the tabular, non-spatial, often county-wide values. An example of this is comparison of almond acres in an area of the Central Valley in comparison to US Fish and Wildlife Service (USFWS) sensitive species habitats (**Figure 8**). These species habitats included a comprehensive variety of sensitive plants and animals:

- Fresno Kangaroo Rat
- Conservancy Fairy Shrimp
- Vernal Pool Fairy Shrimp
- Vernal Pool Tadpole Shrimp
- California Tiger Salamander

- Colusa grass
- Fleshy Owls Clover
- San Joaquin Orcutt Grass
- Hairy Orcutt Grass
- Greenes Tuctoria

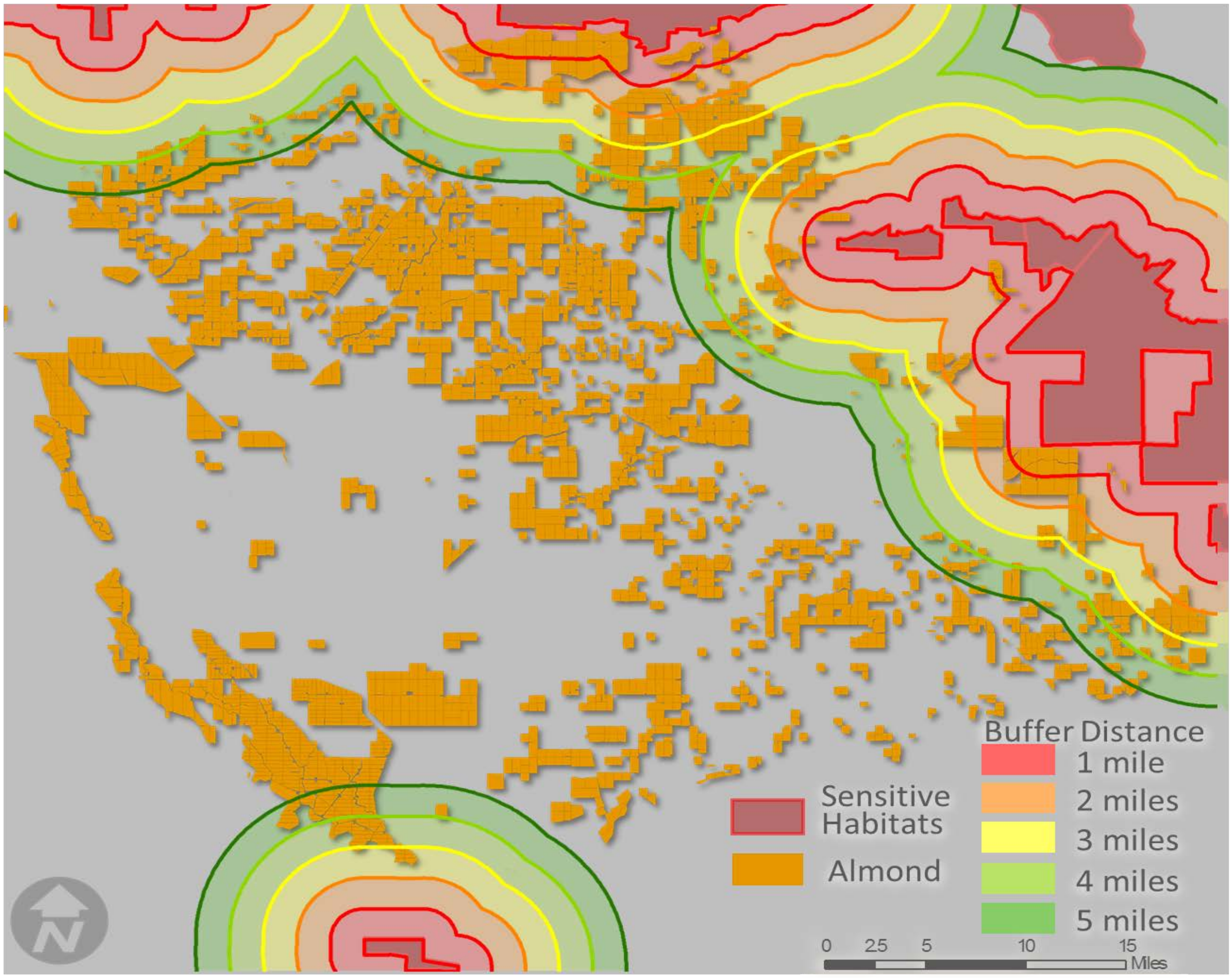

Figure 8. Results of a proximity analysis in a portion of the Central Valley. The analysis shows the spatial relationship of almond orchards in 2011 to US Fish and Wildlife Service designated sensitive species.

Regulatory Analysis:

Another example of the value of having an accurate and timely crop map can be realized when evaluating large landscapes for regulatory requirements. Currently the Irrigated Land Regulatory Program is issuing regulatory orders to agricultural producers for the purpose of determining potential contributions of nitrate from fertilizers to groundwater.

To assist in determined the relative risk of different crop types (i.e. a crop map is required) and consideration of soil type and irrigation method, a modified nitrate hazard index (NHI) was developed for the Kern sub basin; an area of over 1.0 million acres.

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)

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). Crop mapping from 2011 crop mapping from Kern County was used for the analysis. Irrigation practices specific to the Kern Sub-Basin were considered for this analysis including representative distribution of current irrigation methods. The SURRGO spatial soils database was also used.

A comparison of 1990 and 2011 NHI results (**Figures 9 and 10**) 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 and this is significantly based on having an accurate and timely crop mapping product.

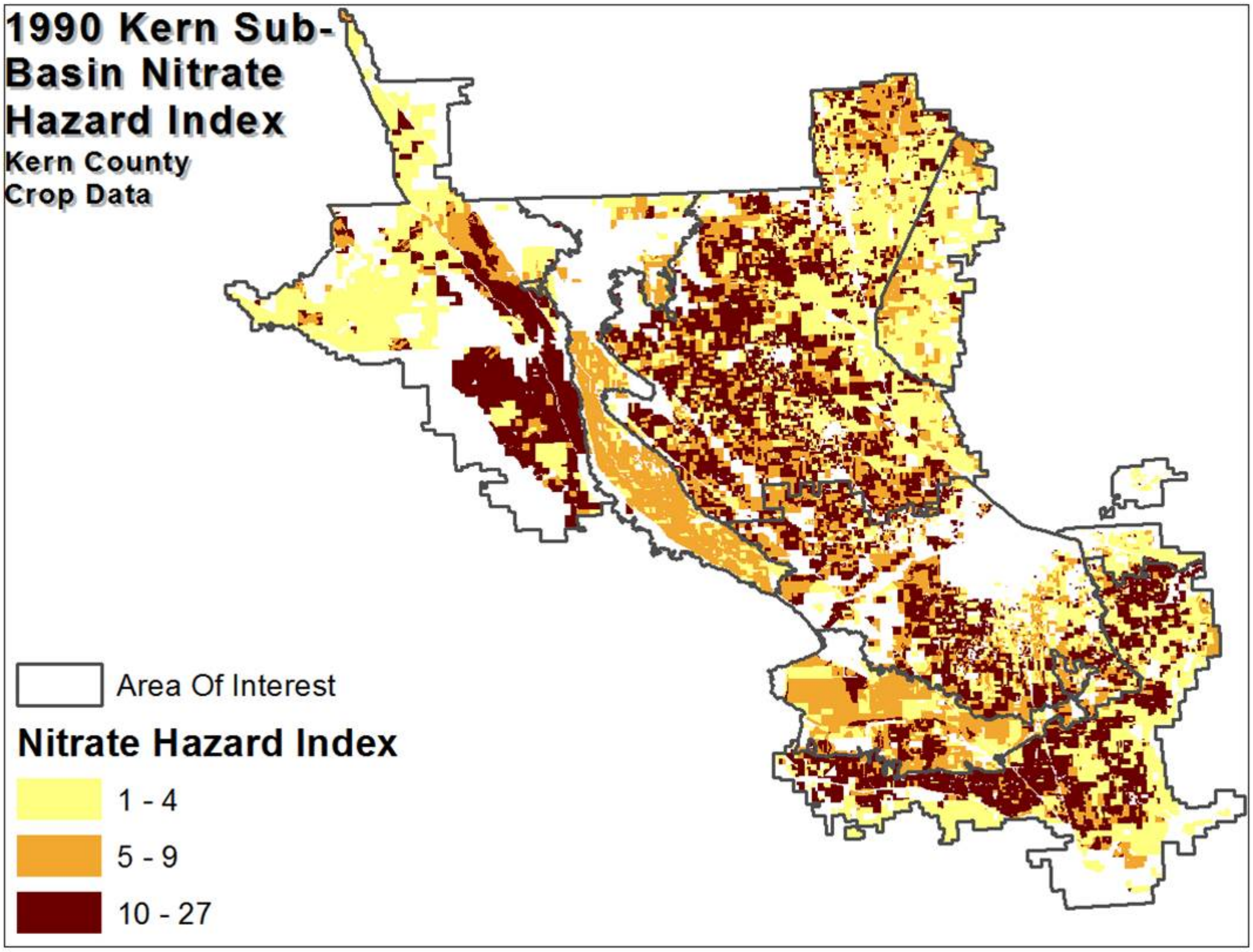

Figure 9. 1990 Kern sub-basin nitrate hazard index.

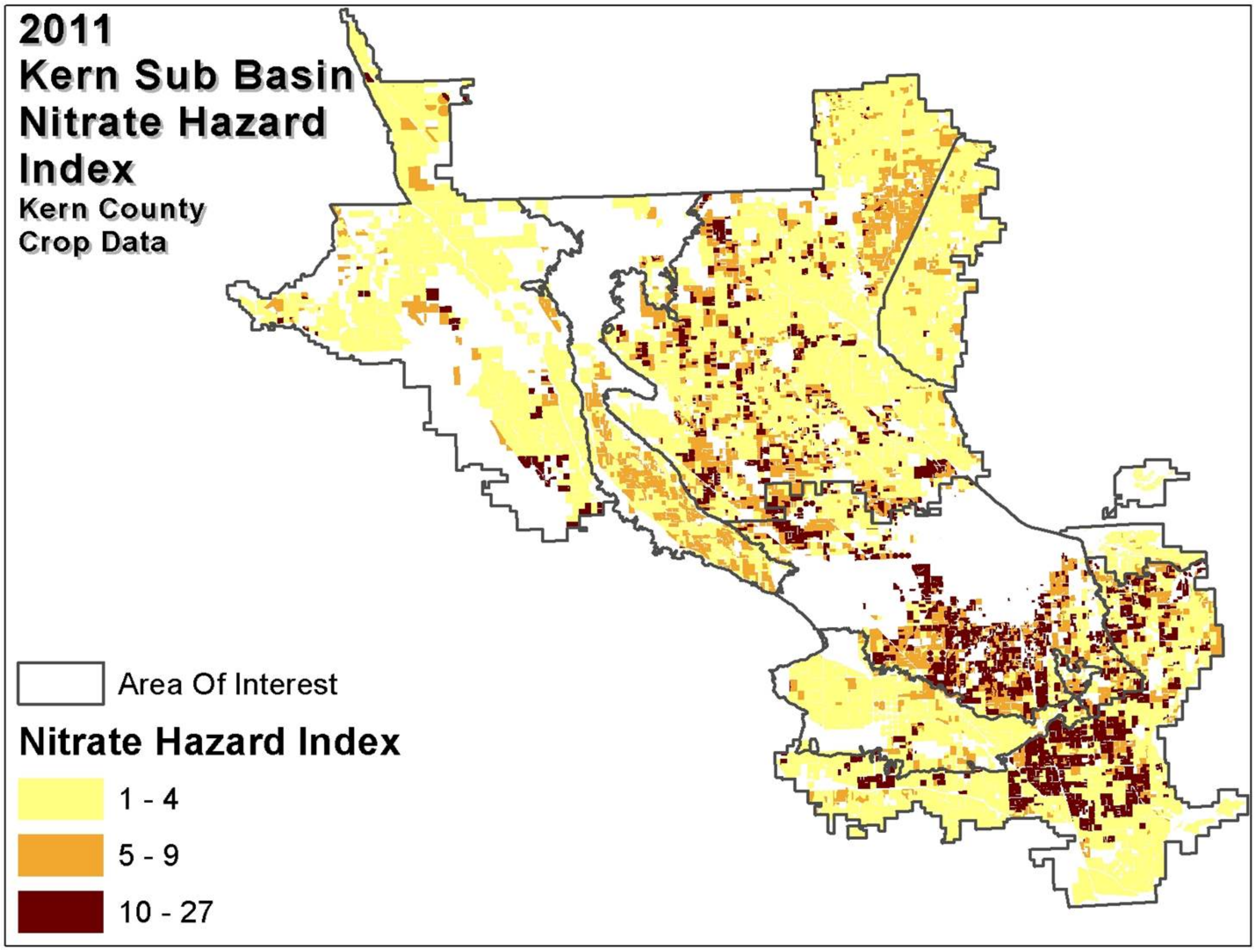

Figure 10. 2011 Kern sub-basin nitrate hazard index.

Research Effort Recent Publications:

None

References Cited:

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.