Development of a Statewide Spatial Database for Walnuts, Almonds, and Pistachios

Project No.: **14-STEWCROP4-Kimmelshue**

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Objectives:

1. The primary objective of this project is to produce a statewide spatial database of almond crops with accuracies approximating 95% using remote sensing, statistical, and temporal analysis methods. This database will provide timely, consistent, and comprehensive information on the location, extent, and acreage of almond crops throughout the state for a baseline year of 2014. The methods utilized to produce this baseline database lay the groundwork for relatively easy updating of the database in subsequent years.
2. The secondary objective is to determine the age of each almond orchard (from 1984 forward) with 80-90% (+/- 1 year) accuracy. This will be accomplished using remote sensing temporal analysis techniques.

Interpretive Summary:

Accurate and current information on constantly changing acreage and location of nut crops is critical for environmental applications. Growers and commodity groups need to understand the impacts of land use, crop location, crop acreage, tree age and best management practices on environmental attributes such as water quality, air quality, disease, and/or pest vectors. Conversely, environmental factors, such as climate change and sensitive habitats, increasingly influence how much and where these crops are grown.

In response to this need for information, this project was undertaken to develop an accurate spatial database of almond crops for the 2014 growing season throughout the Central Valley. The project is nearing completion. Initial results indicate that accuracies exceeding 95% have been achieved in a timely and cost-effective manner using a

specially developed remote sensing crop mapping methodology in combination with rigorous, annual ground truth data.

As the same methodology is being utilized to map the almond crop across the whole Central Valley, the result is a consistent and comprehensive numerical and spatial (mapped acreage) database of the almond crop for 2014 – something that has not been achieved by previous efforts that relied on grower surveys or decadal staggered mapping of individual counties.

Significantly, this project paves the way for cost-effective updates of the inventory over time using focused remote sensing change analysis methods. Recommendations are that funding be appropriated to update the database on an interval preferred by the interested representatives of the cropping systems mapped (almonds, walnuts, and pistachios). Updates will identify changes (removal and new plantings) in the almond crop and ultimately will allow for the subsequent identification the nut types that were previously classified as Young Orchards class. The methodology used to classify the tree crops can identify that a field has an orchard planted in it, but cannot identify the actual tree species until the 3rd or 4th leaf depending on the species. In lieu of this specific classification, these newly planted orchards are classified simply as Young Orchard and subsequent years mapping will classify them into appropriate species. Now that the base-layer is complete, various applications can be considered. None of these applications could be accomplished unless an accurate, timely, field by field base layer existed. Some, but not nearly all applications could include:

- Proximity Analyses – where are almonds in close proximity to other tree crops, urban areas, environmentally sensitive areas, processing facilities, etc.?
- Irrigation Management – Where are almonds irrigated and with what water sources? How reliable are those sources?
- Market Intelligence – The ability to track large and small plantings within the state or region and how those variables affect market supply/demand.
- Biomass Estimations and Management – As a result of the age analysis and known biomass/carbon accumulation in trees, estimates of sequestered carbon and further management can be known.
- Regulatory Management – The ability to track and monitor nutrient (e.g. N) management on an orchard by orchard basis. The ability to overlay other impactful spatial data layers to determine environmental risk management.
- Historic Analyses – What crops preceded almonds? When did specific areas experience growth in almond plantings?

Materials and Methods:

Data used in the mapping project included: 1) field (management unit) delineations, 2) extensive ground truth data collection in the field, and 3) multiple image sources. Detailed management unit (field) boundary delineations formed the basic units of the analysis. Individual field boundaries (not parcels, but rather homogeneous crop types) of all permanent crops were generated so that each field could be analyzed independently and assigned to a crop class. Statewide, this amounted to hundreds of

thousands of individual field boundaries **(Figure 1)**. The fields exclude roads, buildings, ponds, and other non-cropped areas **(Figure 2)**, thus resulting in accurate acreages of actual cropped/irrigated lands.

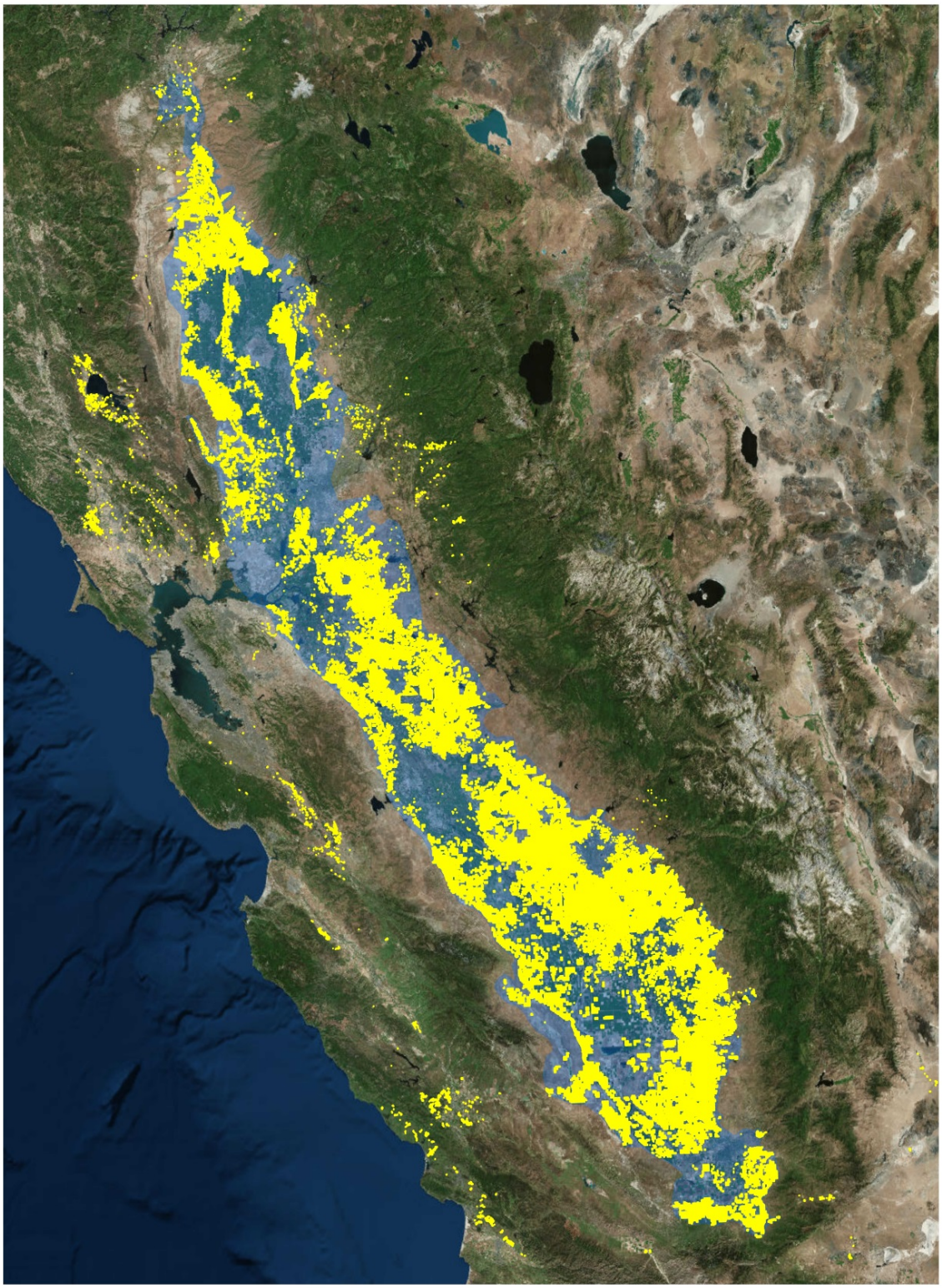

Figure 1. Statewide field boundary extent of all permanent crops.

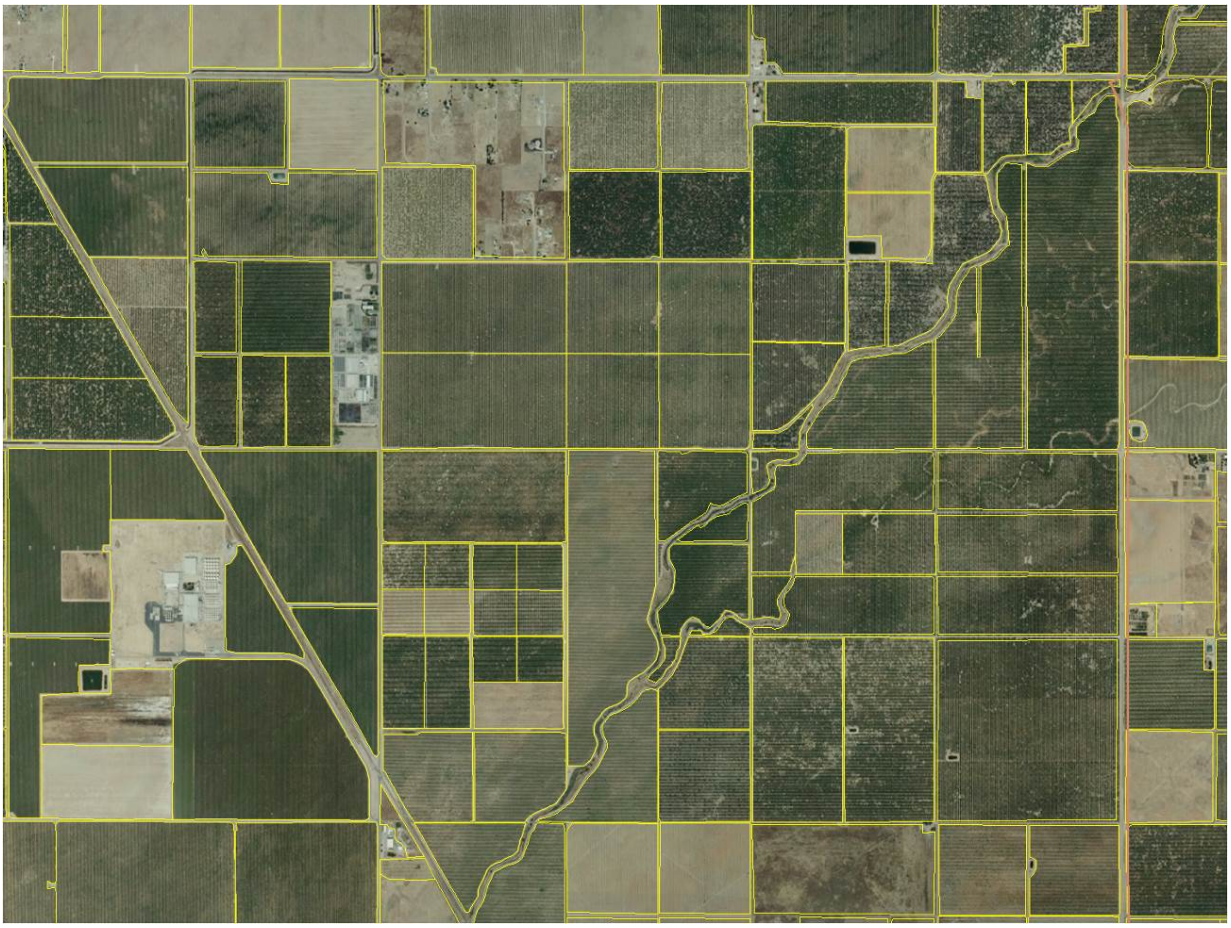

Figure 2. Example of field boundary delineations

Ground truth data was collected in the field for use in the mapping analysis and to determine the accuracy of the resulting map. GPS devices were used to tag or mark the crop type of individual fields. Primary field data was collected during the 2014 growing season throughout the Central Valley. Numerous ground truth points were collected over approximately 4,000 miles (**Figure 3**). Additional ground truth data was collected during the 2015 growing season to augment the 2014 field data, targeting areas where 2014 data was not collected. Similarly, ground truth data from 2012 was also used for this purpose. The 2012 and 2015 field data was carefully checked against high resolution imagery from 2014 to make sure that no change had occurred in the perennial nut and vine crops between the date of the imagery used for mapping (2014) and the 2015 date of field data collection. Any 2015 field sites that did not appear to accurately represent the crop type present in 2014 were omitted from use in the mapping analysis. Similarly, field data collected in 2012 was verified against the 2014 imagery and used as additional ground truth where needed to fill gaps. The ground truth data was divided randomly into training and validation data sets. The validation sites were set aside to assess the accuracy of the resulting map.

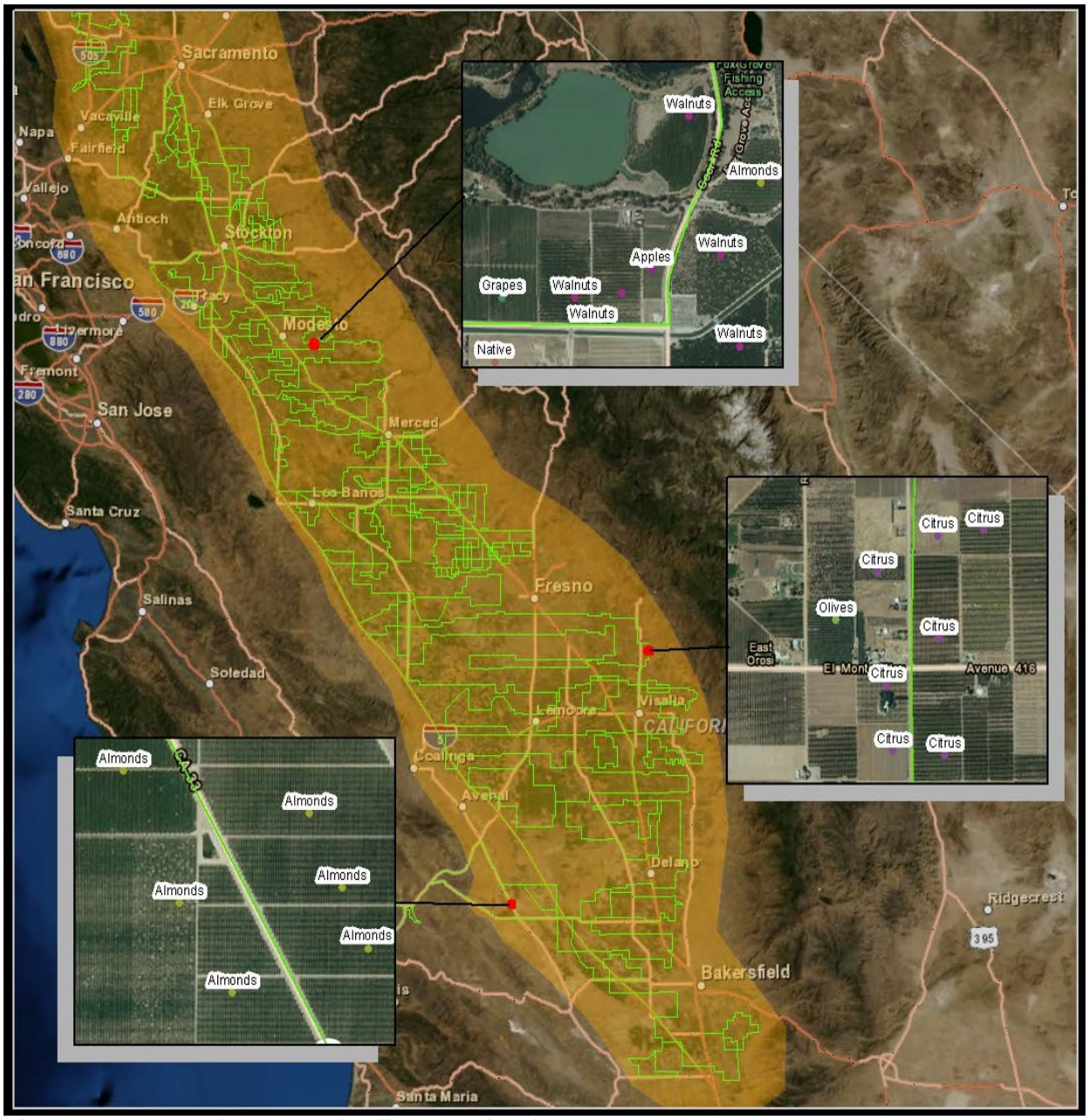

Figure 3. An example of Central Valley ground truth extent.

The remotely sensed crop mapping methodology utilized for this project involved analysis of multiple image sources that encompass a range of spectral characteristics, spatial resolutions, and temporal representation of specific phenological characteristics of the crops of interest. These methods were derived from and guided by Land IQ and cooperating partners' (e.g. ABC, CPRB, CWB) understanding of agricultural systems, landscape processes, production systems, and crop phenology.

Multiple sources and dates of imagery were assembled to serve as input, along with the training samples, to the remote sensing classification process. As a result of this process, each field was assigned a crop class label. As a quality check, fields with low

classification probabilities were reviewed. When an error was identified, based on expert photo-interpretation, the class label was corrected.

For the age analysis, an automated process has been developed and was implemented to evaluate imagery from multiple years to determine when each field was initially planted (as far back as 1984). Orchards planted prior to 1984 are grouped into one category of age, because no annual, appropriately timed, and reliable images exist prior to 1984. By subtracting the planting date from the 2014 baseline map date, an estimated age (+/- 1 year) will be assigned to each field.

Results and Discussion:

To date, classification of almonds, pistachios, and walnuts are complete for the entire state of California. Currently QA/QC efforts are being completed as well as finalization of the age analysis. An accuracy assessment has been completed for the southern and central thirds of the state using the validation ground truth sites. The overall accuracy was calculated at 96% for almonds, 97% for pistachios, and 95% for walnuts. This accuracy is calculated on a field basis (or field count), independent of field size. When field acreage was considered (i.e. larger acreages generally have higher accuracies) accuracies increase (on an acreage basis) by an approximate additional 1%. This is comparable to and in some cases exceeds the accuracies obtained during pilot efforts that were performed prior to this project. An example map of some of the mapping areas shows the final project spatial results (**Figure 4**).

The total acreages of almonds, walnuts, and pistachios were not available at the time of this publication, however will be available by the end of October, 2016. Young orchards were classified separately in this category. Usually orchard type can be determined remotely at the 3rd or 4th leaf, but not sooner. Ground truthing efforts on young orchards not only classified them as young orchards, but the type of tree is also recorded in the field. To estimate which non-bearing acreages are which tree type, the regional percentages of tree species recorded during ground truthing are applied to the remaining remotely sensed young orchard category.

The initial classification of the northern one-third of the Central Valley has been completed and is currently being reviewed. Accuracy assessment has not been completed. Once final QA/QC of the northern one-third of the Central Valley is complete, an overall statewide mapping accuracy will be completed. It is expected that these accuracies will be similar to those already completed.

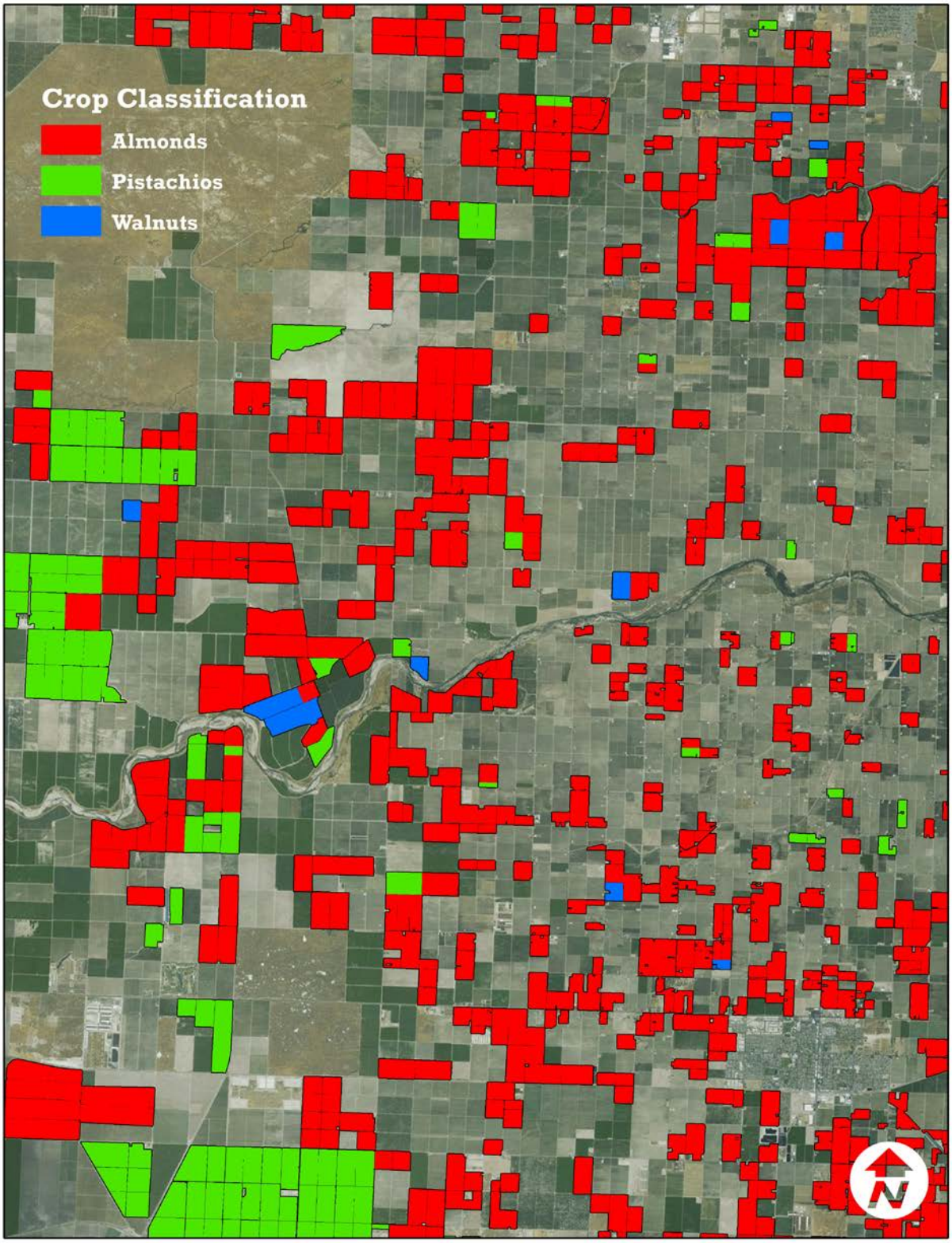

Figure 4. An example of three tree crops (almonds, walnuts, and pistachios) mapped in a select area of the state.

As mentioned in the Materials and Methods section, an age analysis currently is being implemented to determine the approximate age of the orchard in each field. An example area of orchard age is shown (**Figure 5**). We anticipate this will also be completed by the end of October.

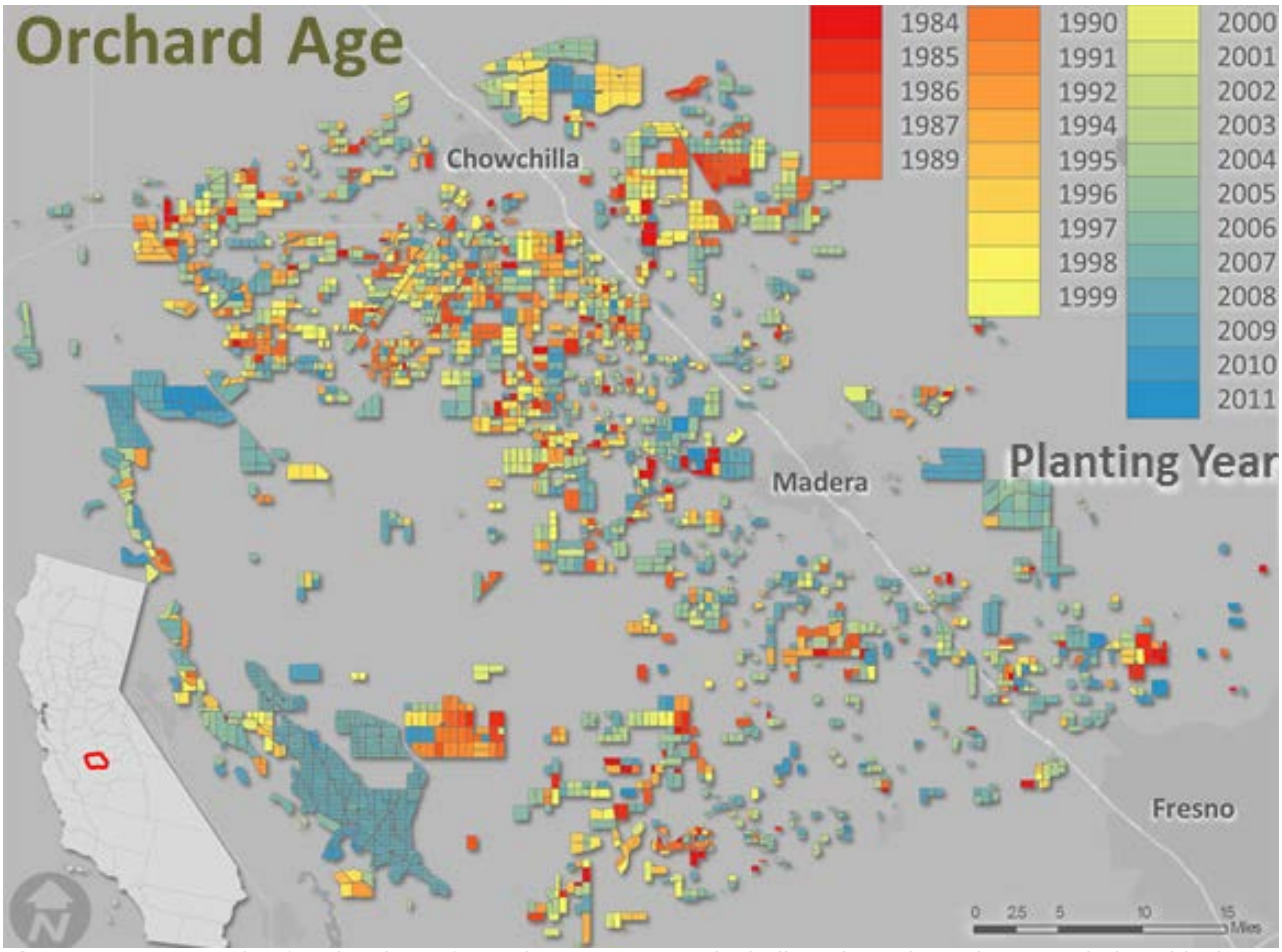

Figure 5. An example of orchard age for various tree crops, including almonds, walnuts, and pistachios) mapped in a select area of the state.

Research Effort Recent Publications:

No recent publications have been developed for this work. A summary presentation has been provided on separate occasions to the following entities and conferences: Almond Board of California Annual Conference – 2014, California Department of Water Resources, United States Conference on Irrigation and Drainage, Delta Water Master, etc.