ANNUAL REPORT COMPREHENSIVE RESEARCH ON RICE
January 1, 2019 - December 31, 2019

PROJECT TITLE:
Identifying opportunities for improving water use efficiency in California rice systems.

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OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

Background

In previous proposals for this project, I have provided a full background on water-use in California rice systems. This included pathways of water loss and potential management practices to reduce water use in rice systems. In brief, the objectives of this project were to quantify water use in rice systems and identify options for conserving water in CA rice systems. This has been completed and some of the outputs include (1) a model that is able to predict various stages of crop development, (2) quantifying salinity in rice systems and (3) understanding the hydrology of rice systems - in particular rates of seepage and percolation and how these might relate to the underground water table. These projects have all been completed and while the overall objective did not change from what was initially conceived, over time the project took on new areas of research related to water use and conservation. Progress on all of these areas can be seen in the 2018 Rice Research Board RM-11 Report.

Going forward, we are proposing to examine land-use change in the Sacramento Valley – particularly focusing on rice acreage. Land use is changing which is likely linked to water. Some rice area is being converted to permanent crops, some being rotated with other annual crops and other land is being fallowed. From 2000 to 2013 rice area averaged 543,000 acres (Figure 1). In the five years that have followed, rice acreage has been 500,000 acres or lower in four of those years. What has driven this change has been water. In some years (2014 and 2015) it has been drought, in other years it has been late rains (2017). However, other water issues have also driven this change, including water sales in drought and other years, which have left significant rice acreage fallow. Some land has been converted to other crops including orchard crops but also annual crops.

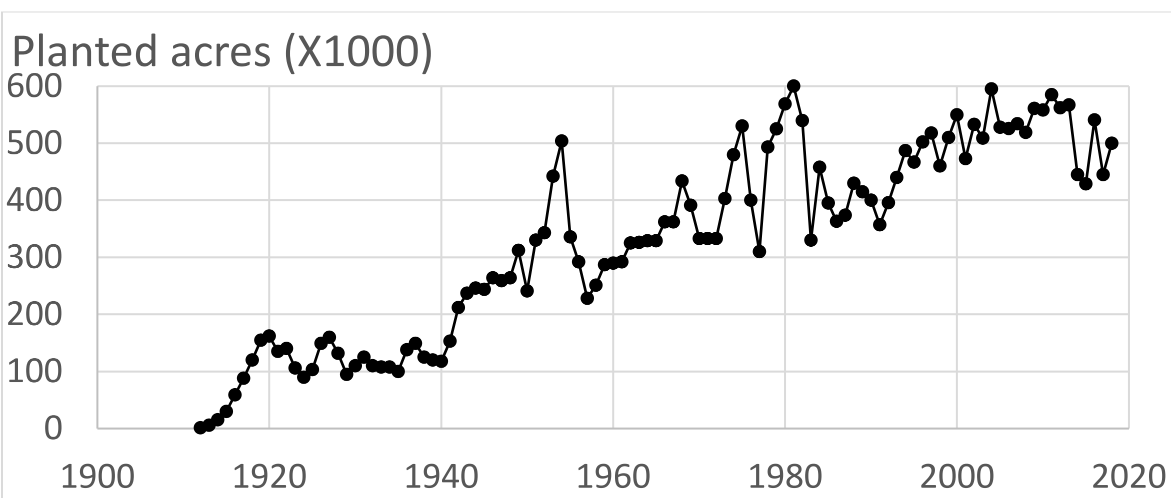

Figure 1. Planted acres from 1912 to 2018 in California (Source: USDA).

Understanding this change is important for the industry moving forward. Are these changes more permanent (i.e. rice land converted to orchard crops), are they short term responses to drought or water limiting conditions, or economic changes to more profitable crops? Additionally, if change is being made, what has been successful and what not? Where is the change being made? What counties, irrigation districts or soil types are most affected? In terms of land being fallowed or used for other annual crops, it would be good to know if this is a strategy that farmers can employ as it may lead to promising ways to control herbicide resistant weeds or weedy rice. We would like to know what annual crops farmers can grow economically on rice soils that would help with these weed control issues. A number of weed researchers (Albert Fisher, Kassim Al-Khatib, and Whitney Brim-DeForest) have all suggested that crop rotation would be a useful practice to control some of our main weed problems.

With this in mind, the broad objective of this project is to quantify land-use change in the Sacramento Valley, focusing on changes in rice area. In specific we want to know:

1. When there has been major shifts in land use
2. What caused those changes
3. What was the change? fallow, annual crop, orchard
4. Where did those changes occur (focusing on soil type and irrigation districts)

From this information and based on what has caused recent changes, we can look forward to see what may cause further changes. As the project moves forward, we will also be looking for areas (soil types) where there has been successful annual crops grown in rotation with rice. We plan to talk with growers about what does and does not work, in an effort to develop more robust practices to manage herbicide resistant weeds and weedy rice.

2019 OBJECTIVES

1. The primary objective of 2019 will be to collect all LandSat satellite data from 2000 to present from the Central Valley of California. The spatial resolution of the Landsat data is 30 meters for spectral bands 1 to 5 and 7, and 120 meters for band 6. The temporal resolution is 16 days. Landsat data is available via USGS. Image classification techniques will allow us to identify all rice acreage in California in each year.
    a. For rice field classification within the Landsat data, we will need to develop criteria to clearly identify rice acreage in each year. This could involve identification of flooded fields during May using near-infrared and middle infrared (740-2,500 nm) wavelength spectral bands, which are best for identifying water. Rice fields will be separated from open water bodies based on other elements of image interpretation including location, size, shape, and situation/site.
2. Identify other crops in the region focusing on annual field crops, orchards and fallow land.
    a. Supervised machine learning techniques will be used to identify rice and other crops in the region. A spectral fingerprint will be determined for each land cover type using validated training data. The trained algorithm can then be applied to

larger land areas to identify all the other land areas that match the training site's spectral fingerprint.

3. Land-use change detection.
    a. By identifying land cover types from year 2000 to present, it will be possible to identify and measure patterns of land-use change in California over time and space. In particular, changes in rice growing acreage, annual field crops, orchards, and fallow acreage will be examined.

SUMMARY OF 2019 RESEARCH (major accomplishments), BY OBJECTIVE:

Objective 1: Collect all LandSat satellite data from 2000 to present from the Central Valley of California.

Rather than downloading and collecting Landsat satellite data, we did this analysis in Google Earth Engine (GEE), a cloud-based computing platform that allows us to analyze and interpret Landsat satellite imagery very efficiently via the cloud. Furthermore, we focused our 2019 efforts on analyzing the USDA Cropland Data Layer (CDL) dataset, which consists of annual crop maps for 2008 to 2018 for the entire US (LandSat data is not available for 2000-2008 for rice in the Sacramento Valley). The CDL data set has a pixel resolution of $30m^2$ (323 ft^2) and the satellite flies over every 16 days.

Objective 2: Identify other crops in the region focusing on annual field crops, orchards and fallow land.

By working with CDL, we were able to determine the major crops in California's Central Valley and this preliminary analysis drives our future questioning. Importantly, we detected problems and sources of error with the CDL data set that limits their accuracy and is motivating us to build our own improved crop classification algorithms. Problems with CDL include low detection accuracy for fallow and some orchard crops, and low accuracy for field boundaries where two different crops exist in the same $30m^2$ pixel.

By assessing the CDL data set and conducting preliminary analysis of land-use change patterns in the Sacramento Valley, we developed a road map for building an improved crop-map data set and generated questions for further analysis. In 2020, we will improve upon the CDL data set by adding a field boundary layer, built by LandIQ, which will give us greater within field-crop detection accuracy and better acreage estimates. We will also incorporate each crop's annual and perennial spectral fingerprint into our classification algorithms which will help us distinguish fallow fields from newly planted orchards. We will build maps from the year 2000 to present and validate our maps using the 2014 and 2019 LandIQ crop maps. Finally, we will incorporate farmer input into our validation process to further increase accuracy. Once we have built high accuracy maps for 2000 to present, we will re-apply our data set to the analysis pipeline that we have already started with the CDL data set.

This phase of the project is currently underway and is now a primary objective for 2020. Using the CDL data set, we conducted preliminary analysis of change patterns between four of the major crops in the Sacramento Valley: Rice, Walnut, Almond, and Fallow. By assessing the methods by which the CDL was built and discovering errors in the CDL, we became aware of the methods we will use to build our own machine learning algorithm to make crop maps, as explained in objective 1. Furthermore, by doing preliminary analysis with CDL, we learned that our maps should include the following six classes which seem to be the major players in land-use change dynamics in the Sacramento valley: rice, walnut, almond, alfalfa, annual crops, and fallow. The crop detection algorithms for rice and walnut are largely built by other researchers at UC Davis, and we have access to these maps. The algorithms for the remaining crops will be built by our research team in 2020. Compiling all of these classification algorithms into one classification program for the Sacramento Valley is now an objective for 2020. This will be conducted in Google Earth Engine. The field boundary layer from LandIQ will also be applied, after the algorithms are built, to improve acreage estimates. Validation and ground truthing processes are ongoing to refine and improve our classification.

Objective 3: Land-use change detection.

Land change detection using the CDL data set has showed us some of the major land change patterns in California's rice growing region. We examined land-use transitions by water district in the Sacramento valley using CDL. Once we have completed our own crop maps for 2008 to 2018, we will re-apply the maps to this analysis. *It must be noted that the analyses reported on below are very preliminary, and as mentioned above, may be inaccurate as we need to improve the maps. It is presented as providing the type of analysis we can do.*

Time Series Analysis

By examining change over time in the eleven-year CDL data set, we are able to examine rice planting intensity and rotation patterns in the Sacramento Valley. 222,607 acres were planted to rice every year from 2008 to 2018. 548,423 acres were planted in rice at least half of the years from '08 to '18 (Figure 2). Some of these fields that were in rice more than half of the time may have been rotated annually with other crops, fallowed for five years, or may have been switched to perennial orchard in the last five years. The rice fields planted to rice 100% of the years from '08 to '18 are predominately in the north western part of the Sacramento Valley (Figure 2). This region of the valley also has very high clay content (~60% by weight), which may explain why the fields are always planted in rice as 60% clay content may make the fields unsuitable for most other crops. By examining the planting intensity of rice, as seen in Figure 3, we can begin to determine the regions where rice fields are always planted to rice, or where rice fields are preferentially abandoned for other crops. Figure 3 shows rice planting intensity as a percentage of the eleven year data set that the fields were planted in rice. Fields planted to rice less than 40% of the eleven years tend to be in the southern part of the Sacramento Valley, on the shores of the Sacramento

River. This region is also home to sunflower, peach, or alfalfa, and has increasing almond acreage. These ‘40% or less’ rice fields, planted to rice less than five of the years from ’08 to ’18, may be biannually rotated with other crops, fallowed frequently, rotated with alfalfa which typically has a residence time of 4 years, or were changed permanently to another crop, perhaps an orchard, at least seven years ago. In the coming year of this study we will overlay soil maps and other environmental data that will give us insight into the drivers behind these change patterns.

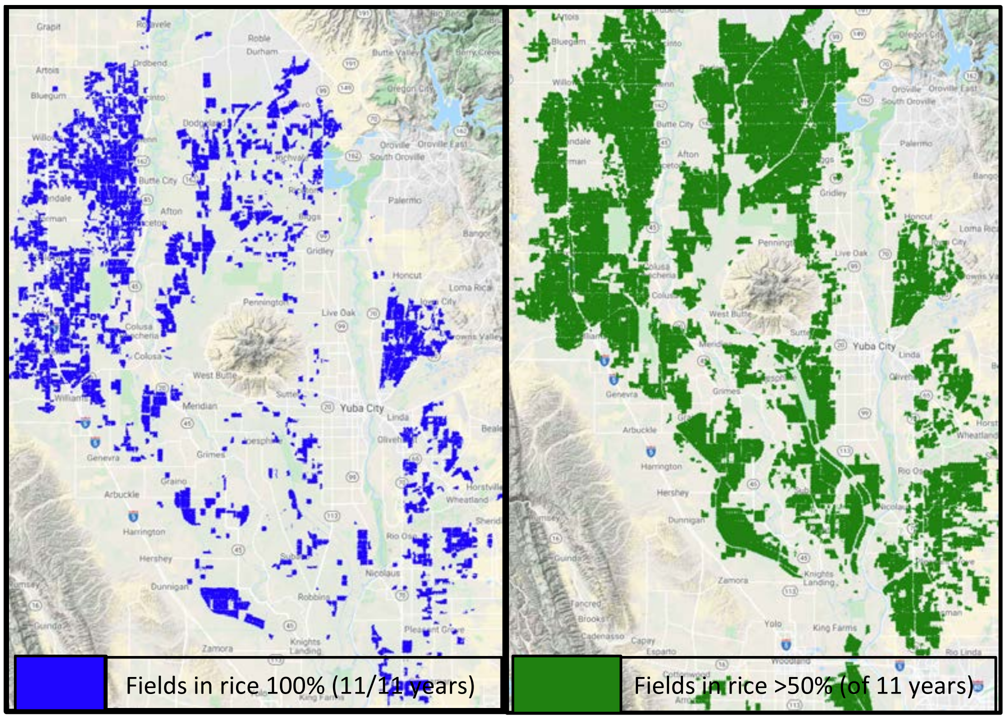

Figure 2. *222,607 acres were in rice every year from 2008 to 2018 (left) and 548,423 acres were in rice at least 6 of the 11 years (right). Data source: USDA CDL*

Change Detection

California produces approximately 1.8Mt of rice annually, 20% of total US rice production. From year 2000 to 2013, CA rice area averaged 543,000 acres per year. Since 2013, rice acreage has decreased and is now less than 500,000 acres. Analyzing the USDA CDL (2008 to 2018) for change detection, we learn that there were 6,449 acres that were rice in ’08 but were in walnut in ’18. There were 2,332 acres that were rice in ’08 but were in almond in ’18. There were 64,375 acres in rice in ’08 that were fallow in ’18.

By using the CDL data set to look within irrigation districts, we can begin to examine the patterns and drivers of land-use changes between 2008 and 2018. For this preliminary analysis, we selected the fifteen major water districts (WD) in the Sacramento Valley rice growing area and looked within them at changes between rice, almond, walnut, and fallow acreage. Total rice acreage within the aggregated districts is 326,629 acres in 2008 and 314,765 acres in 2018, a 3.6% decrease. Fallow acreage between ’08 and ’18 increased from 66,492 to 114,850, a 73% increase (Figure 4). Within these 15 major water districts, most of the rice acreage seems to stay in rice, except in the upper right three WDs where 20-40% of the acreage has been converted to fallow (Figure 5).

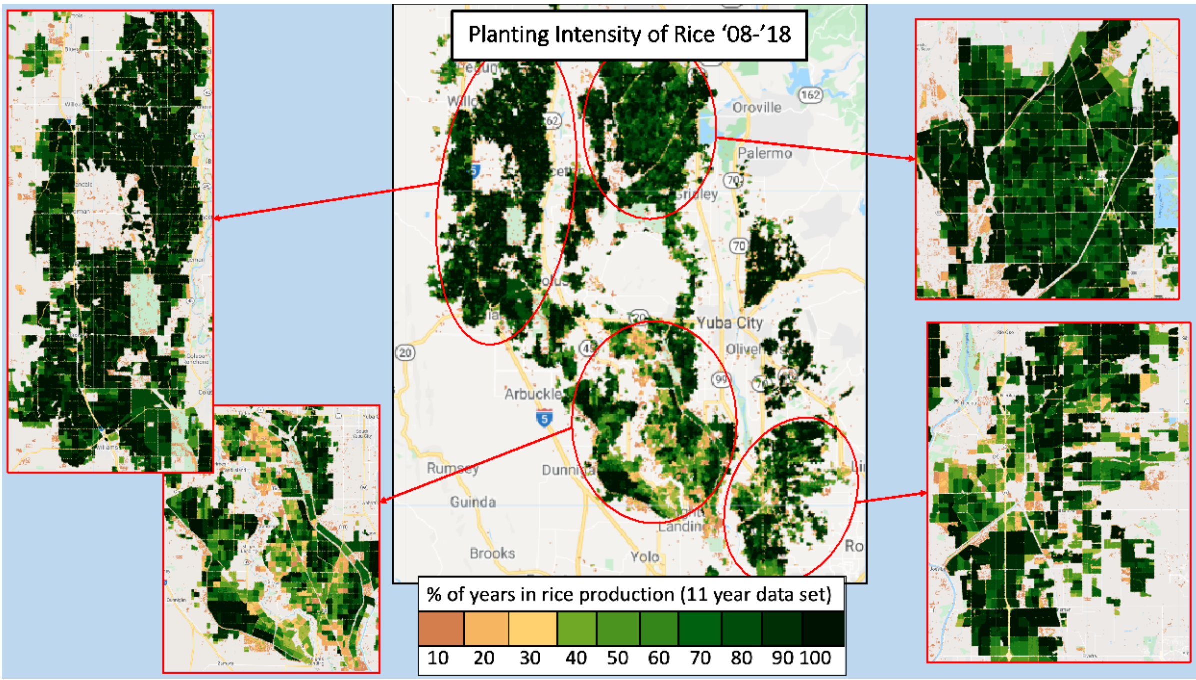

Figure 3*. Planting intensity of rice for 2008 to 2018. Data source: USDA CDL.*

It should be noted, again, that this is only a comparison between the two years '08 and '18. Furthermore, the CDL accuracy for fallow is only 65%, as fallow fields are managed to have only bare soil which is relatively difficult to detect and may be easily misclassified as a newly planted orchard as they have similar spectral signatures (orchards don't have full canopy cover for 3-5 years and thus, from the view of a satellite, look like a fallow field). This is one reason we aim to incorporate farmer input and crop's perennial spectral patterns into our crop classification algorithms. This will increase our accuracy relative to CDL's and improve the separability of fallow field and newly planted orchard classes.

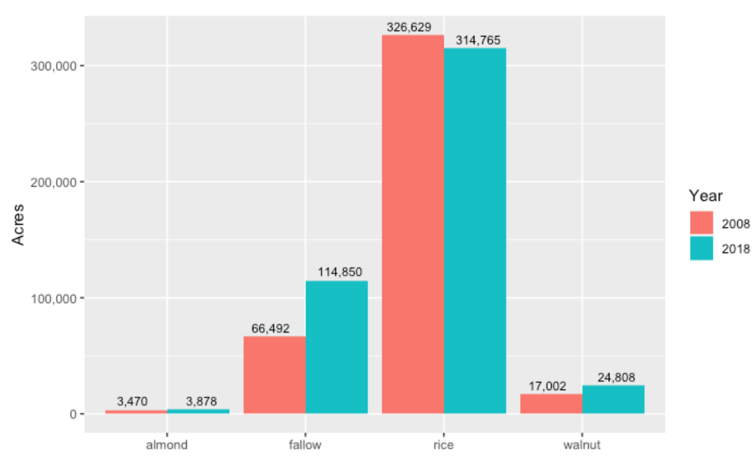

Figure 4. *Crop estimates within the fifteen major water districts (WD) of the Sacramento Valley.*

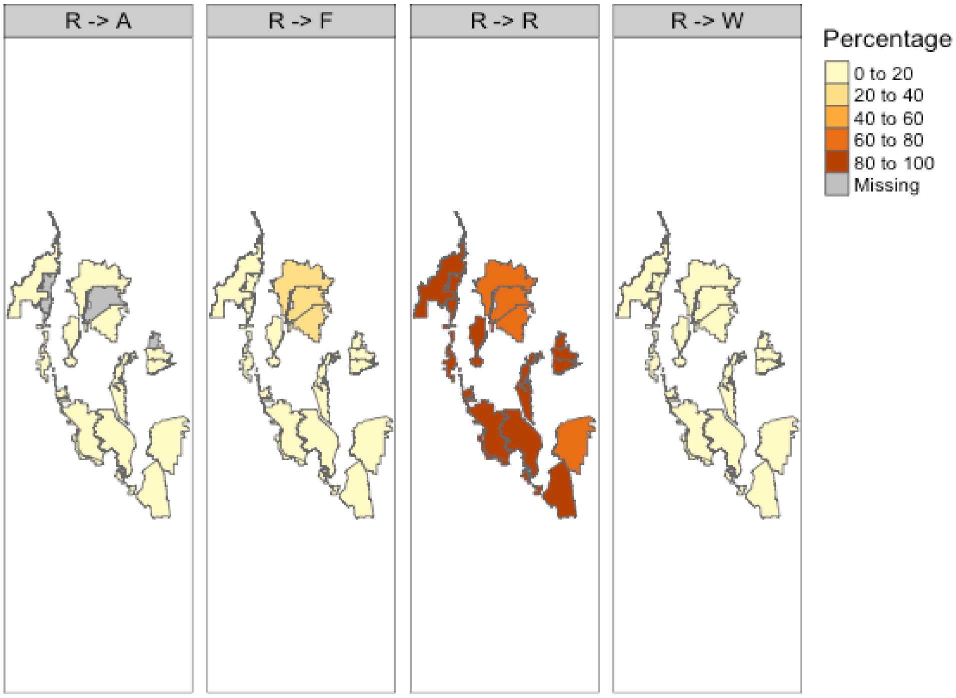

Figure 5. *Change from Rice to Almond, Fallow, Rice, and Walnut (Left to Right, respectively) within the fifteen major water districts of the Sacramento Valley between 2008 and 2018. 80 to 100% of rice acreage in '08 was also rice in 18', except in the upper right three WDs where rice was preferentially changed to fallow which may be due to water sales.*

PUBLICATIONS OR REPORTS:
No reports or publications during this period as data are highly preliminary.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Objective 1: Collect all LandSat satellite data from 2000 to present from the Central Valley of California.

We focused our analysis on analyzing the USDA Cropland Data Layer (CDL) dataset, which consists of annual crop maps for 2008 to 2018 for the entire US (LandSat data is not available for 2000-2008 for rice in the Sacramento Valley). The CDL data set has a pixel resolution of $30m^2$ (323 ft^2) and the satellite flies over every 16 days. We determined the major crops in California's Central Valley. Unfortunately, the CDL has a low detection accuracy for fallow and some orchard crops, and low accuracy for field boundaries where two different crops exist in the same $30m^2$ pixel. This is important for this study; therefore, in 2020, we will improve upon the CDL data set by adding a field boundary layer, built by LandIQ, which will give us greater within field-crop detection accuracy and better acreage estimates.

Using this data set however, did help us generate and test some key questions related to this study. Furthermore, we were able to develop procedures to determine different crops in each year and analyze patterns in land use change including continuous rice, crop rotations, conversion of rice land to orchards and using rice land as fallow. Early tests confirm largely what we might suspect. That is, (1) rotation with annual crops is most common in the southern part of the Sacramento Valley, (2) rice fallow fields are most common in Butte county and (3) “permanent” rice fields (rice every year) is most common in Colusa and Glenn counties. However, given the inaccuracies of the CDL we are uncomfortable in reporting the precise numbers. We feel it is necessary to develop our own data set and have the ability to analyze the data back to 2000.