EXPLORING THE INTERSECTION OF
AGRICULTURAL LAND & WATER RESOURCES
IN THE SAN JOAQUIN VALLEY OF CALIFORNIA
Demonstrating the Utility of Data Basin as a Decision Making Tool

Preliminary Summary Report
June 2017

American Farmland Trust and
Conservation Biology Institute

Introduction

Both land and water resources are critical to San Joaquin Valley agriculture. Water has received more attention because its supply appears to be more limited. But land is no less essential for agricultural production. In fact, it is the intersection of land and water resources – how their characteristics combine in any given area – that determines the agricultural potential of that area.

As part of the San Joaquin Valley Greenprint project, American Farmland Trust (AFT) sought to explore the intersection of land and water resources in the region as they affect agricultural production, both today and in the future. Our inquiry focused on several key questions:

- Where is the quality of agricultural land higher or lower?
- Where are irrigation water resources more or less abundant and reliable?
- How and where does the combination of land quality and water reliability appear to make agriculture more or less resilient?
- How and where will urban growth, regulatory proposals – SGMA and the WRCB Delta plan – and climate change likely to affect agricultural land and water resources?

In trying to shed light on these questions, we also sought to demonstrate the capacity of Data Basin as an analytic planning tool for local governments, state agencies and private business and organizations. Thus, the results of our analysis, the data and the methodology we used will be posted on the San Joaquin Valley Gateway web portal that can be used by anyone for planning or further analytic purposes.

This report is a summary of our preliminary findings, issued to satisfy the requirements of the grant we received from the Greenprint project. These findings may change as we complete our analysis. But they are likely to be fairly close to what will eventually be included in our final report.

Basic Approach

The scope of our study was limited to the floor of the San Joaquin Valley – comprising roughly 6 million acres – where irrigated agriculture predominates and, hence, both land and water resources are essential to food production. To answer the questions we posed, AFT partnered with the Conservation Biology Institute (CBI), which invented the Data Basin geographic information system platform and used it to compile and analyze relevant quantitative, spatial data, some of it generated by the Greenprint project itself. The data were organized using a logic model that defined their relationship and relative weight. The logic model had components related to the qualities of the land, to the abundance and variability of water supplies, and to the degree of urban development risk. The details are discussed below.

In the process of assembling data and constructing a logic model, we held a series of workshops throughout the Valley and a number of on-line webinars to engage stakeholders. We asked for their perspectives on the questions we were investigating and sought their advice on what kind of factors (represented by the data) were most relevant and how much weight they should carry. The public engagement process was not as robust as we had hoped, probably because our outreach budget was limited and key stakehodlers tend to be very busy. But we nonetheless gained valuable insights through these meetings. And, going forward, we hope to further engage a wide range of Valley stakeholders using the results of our final report.

Land Resources

Land is the foundation of agriculture. Indeed, the word agriculture derives from the Latin word for field, i.e., land. And though it is axiomatic that not all land is the same, the very real, practical differences are often overlooked when decsions affecting agricultural land are made.

Methodology for Assessing Land Quality

Our first inquiry was into the intrinsic quality or resource value of the land in the Valley. The focus was on characteristics that are inherent in the land itself and, as such, are impossible, difficult and/or costly to improve or overcome by human intervention. Our assumption was that, all other things being equal, land with more favorable intrinsic characteristics is likely to be more productive, versatile, sustainable and profitable to farm.

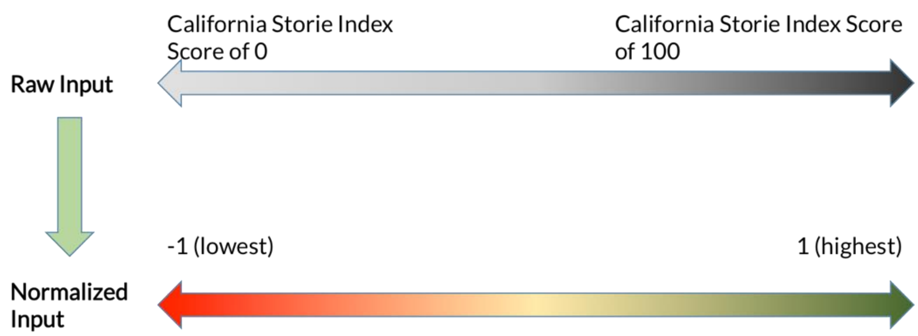
The criteria we used to define the relative quality of agricultural land included both positive and negative attributes reflecting the intrinsic characteristics of the land. The data representing positive attributes included:[1]

[1] The sources of all data will be documented in the final report, though for brevity we have omitted them in this summary.

- California Storie Index (a formal measure of soil productivity for agricultural uses)
- Farmland Mapping & Monitoring Program (FMMP) categories (reflecting soil productivity and active irrigation)
- Aquifer recharge potential (a direct link between land and the availability of water)
- Microclimate (particularly for high value citrus production)

These data were processed for the entire floor of the San Joaquin Valley on a 270 square meter grid, so that each data point represents about 18 acres of land. For all these and other data sets, the range of the data from highest to lowest were converted (normalized) to a scale of one to negative one. (Figure 1) This allowed us to average the normalized scores for the data sets to produce a final score representing the positive attributes or "land asset value" for each grid cell. In so doing, all of the data sets were given equal weight, so that the highest score a parcel could receive on the land asset scale was one and the lowest negative one.

Figure 1 - Example of the Normalization Process



We took the same approach in combining data sets representing negative attributes of the land, including:

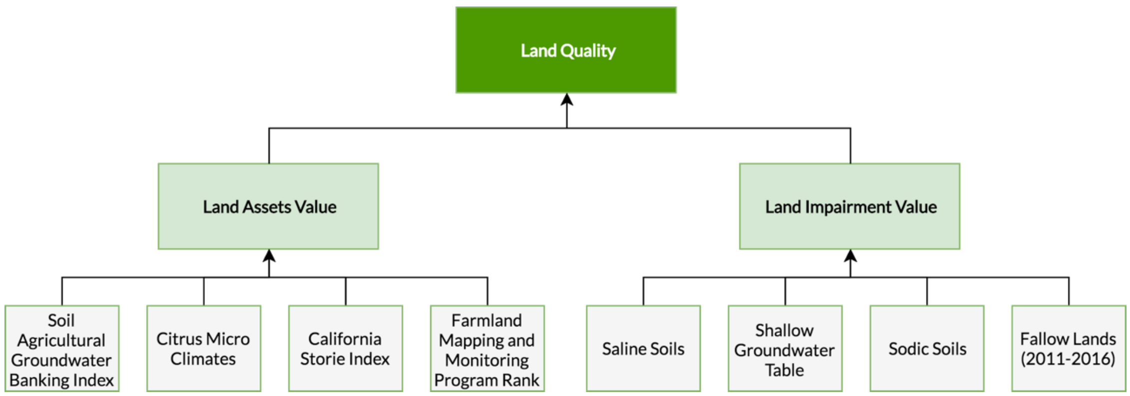
- Soil salinity and sodicity (limiting productivity as well as what can be grown on the land)
- Shallow water tables (also a limitation on production)
- Pattern of recent fallowing (reflecting economic decisions based on land limitations)

This produced a "land impairment value" for each parcel of land, ranging from negative one (most impaired) to one. This was added to the land asset value to obtain an overall land quality score. (Figure 2) [2] The land quality scores throughout the Valley were then divided into high, medium and low ranges using a mathematical protocol called the Jenks

[2] Maps representing each individual data layer will eventually be accessible on the San Joaquin Valley Gateway web portal. https://sjvp.databasin.org/articles/50e144bc34aa40bc959989effd80f1a8 This will enable readers to unpack the data to see how each individual attribute contributed to overall land quality scores.

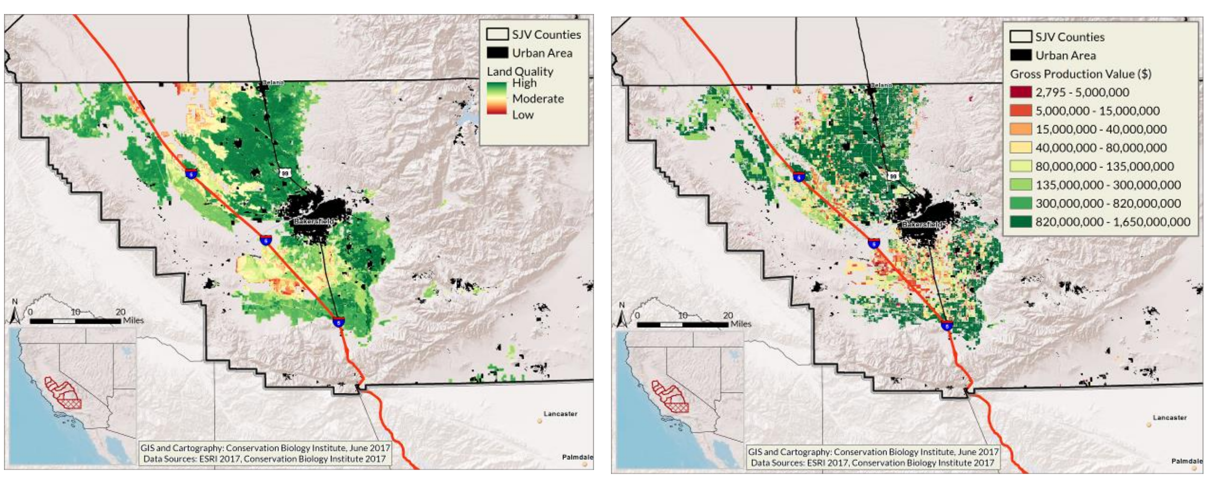
method, which identifies natural breaks in the data. This approach eliminates any bias that would have influenced the breakdown had we used the alternative method of simply selecting break points, e.g., defining the top 25 percent of the data points as "high," etc.

Figure 2 – Land Quality Logic Model



To test the accuracy of our land quality model, we compared our results with the cropping patterns in selected parts of the Valley. Our assumption was that, if the land identified by our model as of highest quality closely mirrored where the highest value crops are grown, it would have successfully captured the intrinsic characteristics of the land that make it most valuable for agriculture. This is, in fact, what it appears to do.[3] (Figure 3)

Figure 3 – Coincidence of High Value Agricultural Land (left) and Highest Value Crops (right) in Kern County

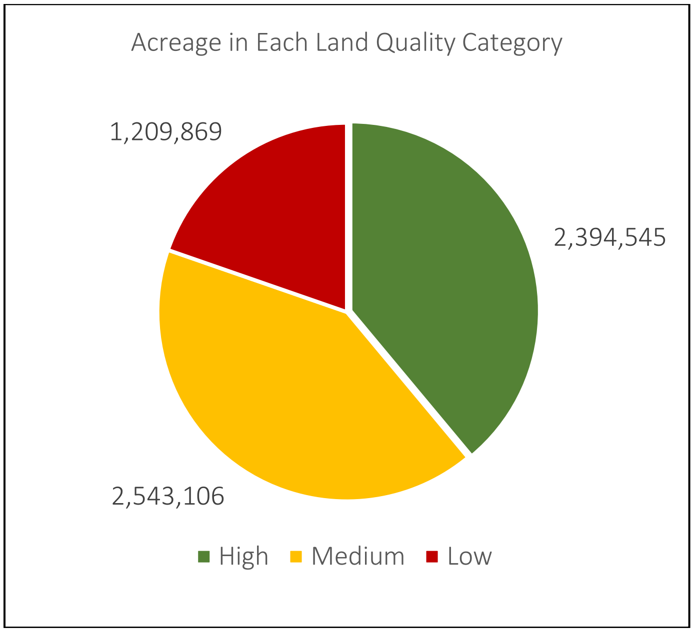


[3] Stakeholders noted, however, that some "lower" value land may contribute more to agriculture than the quality of the land itself would suggest. Examples are land producing low-value forage crops that support the Valley's high value dairy industry or annual crops that support more farm worker jobs per acre than higher-value permanent crops.

Major Findings About Agricultural Land Quality

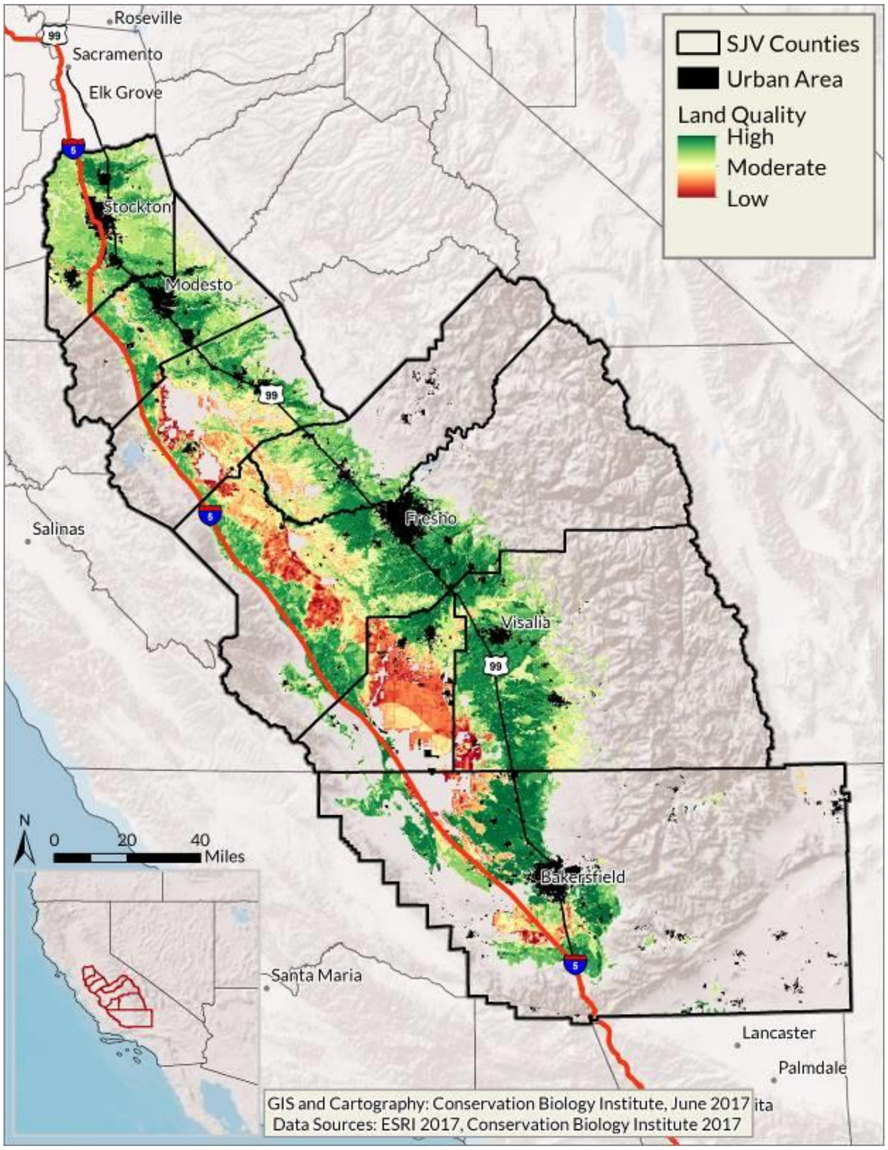
Based on its intrinsic characteristics – again, things that are impossible, difficult or costly to change or overcome – a relatively small fraction (39%) of the agricultural land in the San Joaquin Valley qualifies as high quality. (Figure 4)

Figure 4 – Profile of Agricultural Land Quality in the San Joaquin Valley



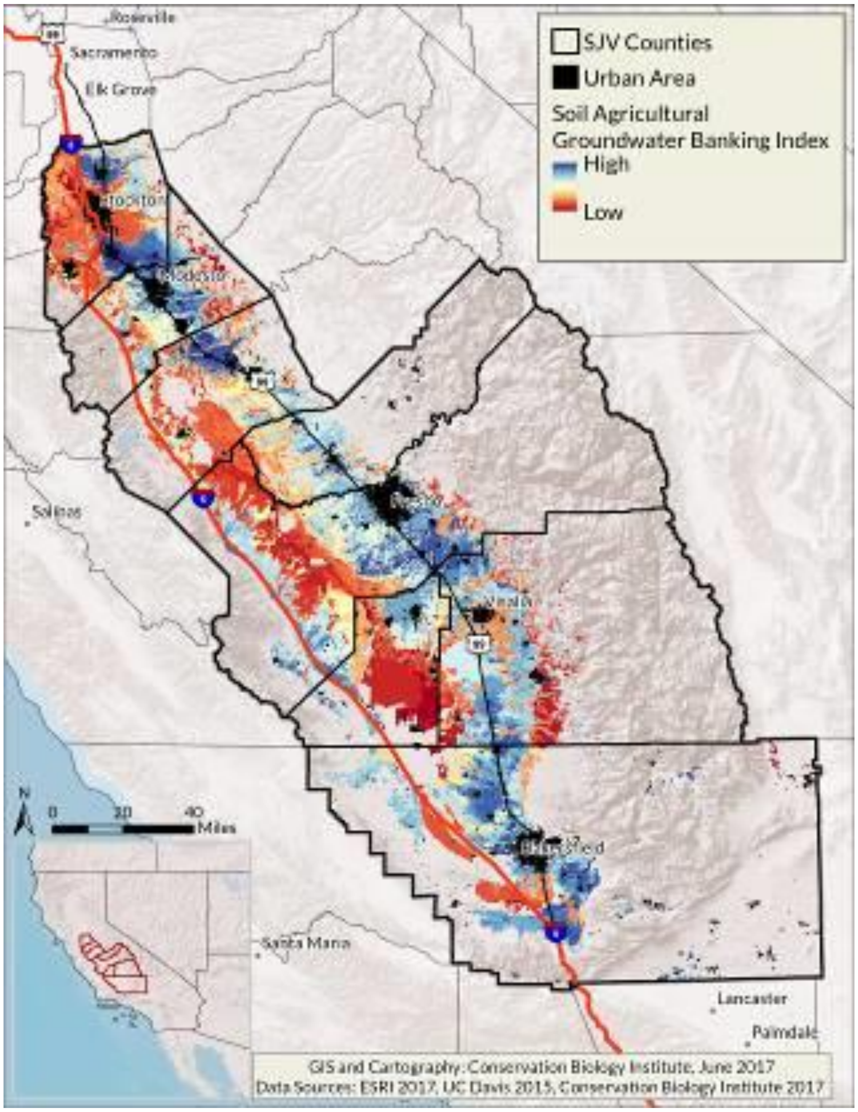
This land is generally more productive and versatile, and it has few limitations, making it the most important land to retain in agricultural use if the goal is to sustain agricultural production. It will simply be more expensive and difficult to do so if agriculture has to rely on lower quality land. Most of this land is found along the Highway 99 corridor on the east side of the Valley with a smaller band along I-5 on the western side. (Figure 5) The fact that most of the Valley's cities are located on or near high quality agricultural land is a reflection of the fact that the original agrarian settlers of the Valley were aware of the superior nature of this land. But this is now working at cross purposes with the goal of sustaining agricultural production as the cities grow and permanently remove high quality land from production.

Figure 5 – Geography of Agricultural Land Quality in the San Joaquin Valley



A special subset of agricultural land serves as groundwater recharge areas that are critical to the water supply of both agriculture and cities. This land is generally high quality, prime farmland with well-drained soils that easily allow precipitation and irrigation water to percolate down into the water table. It, too, is concentrated around the Valley's cities where it is vulnerable to development. (Figure 6)

Figure 6 – Aquifer Recharge Areas in the San Joaquin Valley
(High Groundwater Banking Index)



Water Resources

Land, of course, is only half of the equation for agricultural production in the semi-arid San Joaquin Valley. Irrigation water is its lifeblood and the quality of the land in this region matters little if it does not have water. Thus, as the recent drought has underscored, it is crucial to understand where and to what extent agricultural water supplies are under stress or subject to uncertainty that could affect future agricultural production. The second focus of our inquiry attempted to answer this question.

Our assessment of the degree of water stress relied on a logic model that took into account both the extent of reliance on different sources and the variability of the supply of these sources. The major sources of irrigation water in the Valley that we considered were:

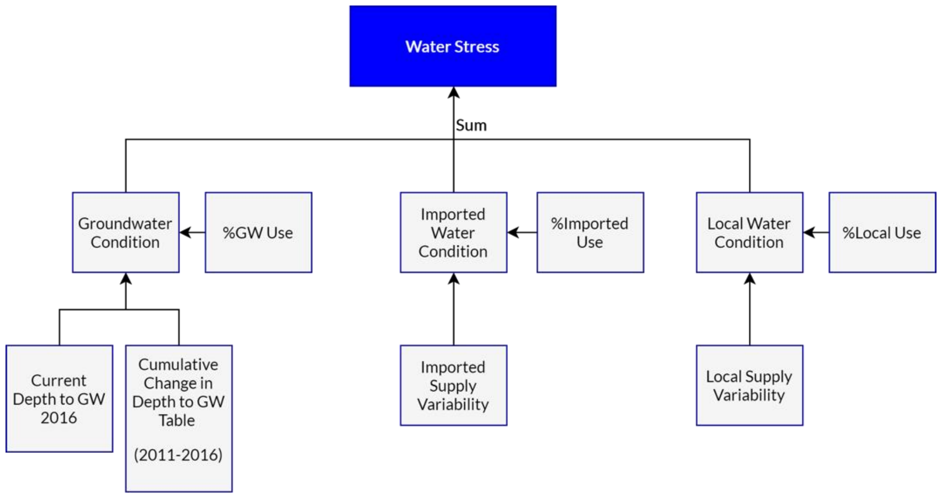
- Local surface water (from watersheds that drain into the San Joaquin Valley)
- Imported surface water (from watersheds outside the Valley, e.g., through the Delta)
- Groundwater

For surface water, we used Department of Water Resources data to measure both the percentage of total agricultural water supplies in any given region[4] that come from local and imported sources, as well as the variability of those supplies over the longest and most recent period for which data were available. Variability was defined as the extent of deviation from the mean using a variable called the coefficient of variation, with higher scores representing the greatest deviation, i.e., less reliability.

For groundwater, we measured stress levels by considering both the depth to groundwater and the change in depth to groundwater, again for the most recent period for which data were available. The former reflects the cost of pumping irrigation water to the surface, while the latter is a direct indicator of the extent to which groundwater is being drawn down and, in many cases, depleted. Each of the three data sets were, like those for land, converted to a scale of one to zero in this case, then added to produce a water stress index. (Figure 7) The Jenks method was also used to identify natural breaks in the data to define high, medium and low water stress levels. A high stress level generally means that a sub-region relies heavily on sources of water that are highly variable or unreliable, while a lower stress level reflects less reliance on variable sources, greater reliance on relatively stable sources or both.

Figure 7 – Water Stress Logic Model

[4] Surface water data are collected for each of 22 DWR water management regions in the Valley. They are not available for individual parcels of land as with land quality data. Thus, our analysis of surface water reliability could not be as fine-grained as our land quality analysis. Groundwater data from wells are available on a more detailed basis but require interpolation and, thus are useful only for large-scale analysis.

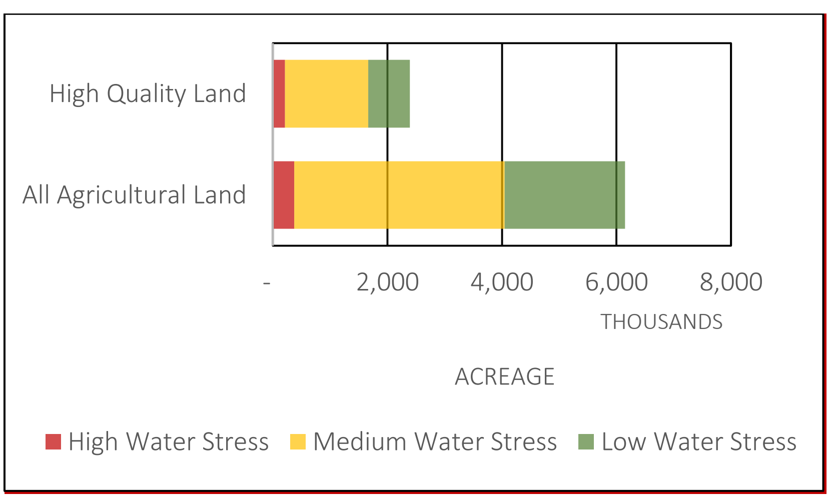


Major Findings About Agricultural Water Stress

The portion of the Valley currently experiencing high water stress is relatively limited, with only about 374 thousand acres or six percent of the total agricultural acreage falling into this category. However, more than 60 percent (3.7 million acres) of the agricultural land in the region is subject to medium stress levels – with significant variability of, and uncertainty about, at least one of its sources of supply. And only about one-third (2.1 million acres) of the land is experiencing low stress on its water supplies. (Figure 8 and Table 1)

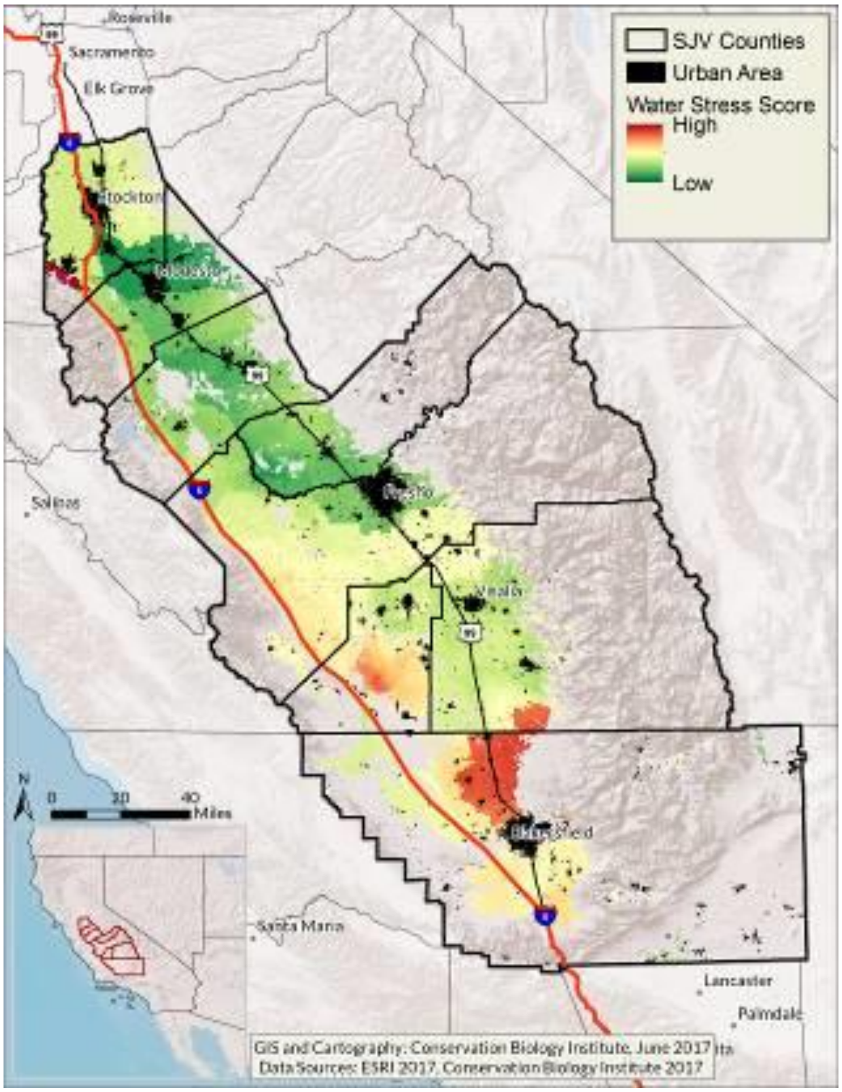
Water stress on high quality agricultural land is disproportionately greater. Nine percent of this land is subject to high water stress levels, and 56 percent of all highly water-stressed acreage in the Valley is high quality agricultural land.

Figure 8 – Profile of Water Stress on Agricultural Land in the San Joaquin Valley



Again, there are fairly dramatic geographic distinctions between highly water stressed land and that experiencing lower water stress. Generally, water stress increases from north to south and from east to west, owing to a number of factors, including lower precipitation, variability of deliveries through the Delta and greater reliance on groundwater. This geography is well-known and tends to confirm that our analysis of water stress closely approximates actual conditions.

Figure 9 – Geography of Water Stress in the San Joaquin Valley



The water stress profile of the Valley's agricultural land is likely to change, perhaps dramatically, because of climate change and pending state regulatory decisions. These include implementation of the Sustainable Groundwater Management Act – an estimated 13 percent of all agricultural water in the Valley comes from over-drafted groundwater sources[5] – and a proposal by the state Water Resources Control Board to require significant new limits on irrigation withdrawals from the Stanislaus, Merced and Tuolumne Rivers. AFT and CBI are using Data Basin to model the potential impact of each of these scenarios on the Valley's water resources and will report their findings in the final report.

Intersection of Agricultural Land and Water Resources

By themselves, our findings about the quantitative profile and spatial distribution of agricultural land and water resources shed light on the value, importance and stress on those resources. But it when these findings are combined – when the intersection is plotted – that a more interesting and useful, if not unique, perspective emerges. By dividing the Valley's agricultural acreage into nine separate categories, representing all the possible combinations of land quality and water stress level in our logic model, we obtained a much more refined picture of its resources. (Table 1)

Table 1 – Profile of the Intersection of Agricultural Land and Water Resources
All figures in acres unless otherwise indicated.

	Water Stress				
Land Quality	Low	Medium	High	Total	Pct Low Water Stress
High	727,493	1,457,726	209,326	2,394,545	30%
Medium	1,034,920	1,425,622	82,564	2,543,106	41%
Low	336,503	791,384	81,982	1,209,869	28%
Total	2,098,916	3,674,732	373,872	6,147,520	34%
Pct High Land Quality	35%	40%	56%	39%	

The overall picture that emerges is that higher quality land tends to be experiencing disproportionately more water stress than lower quality land. A greater proportion of high water stressed land (56%) than of lower water stressed land (35%) is high quality land. And a greater percentage of high quality land (70%) is experiencing medium to high water stress levels than medium and low quality land (63%). Areas subject to high stress levels are likely to expand if regulatory decisions and climate change further limit water availability.

The intersection of land that is both of high quality and is experiencing low water stress – the "best of the best" – appears to be extraordinarily small. Of the roughly six million acres of agricultural land in the Valley, only 39 percent is of high quality. But of the high quality land, only 30 percent also has low water stress levels. This 727 thousand acres (1,137 square miles) represents only 12 percent of all the agricultural land in the Valley. On the other hand, the land that either has high water stress or is of low quality amounts to 1.5 million acres or one quarter of all agricultural land in the Valley. That leaves about

[5] Hanak, Lund, et al., *Water Stress And A Changing San Joaquin Valley*, Public Policy Institute of California, March 2017, at 16.

3.9 million acres "in the middle" with relatively good land and fairly reliable water supplies.

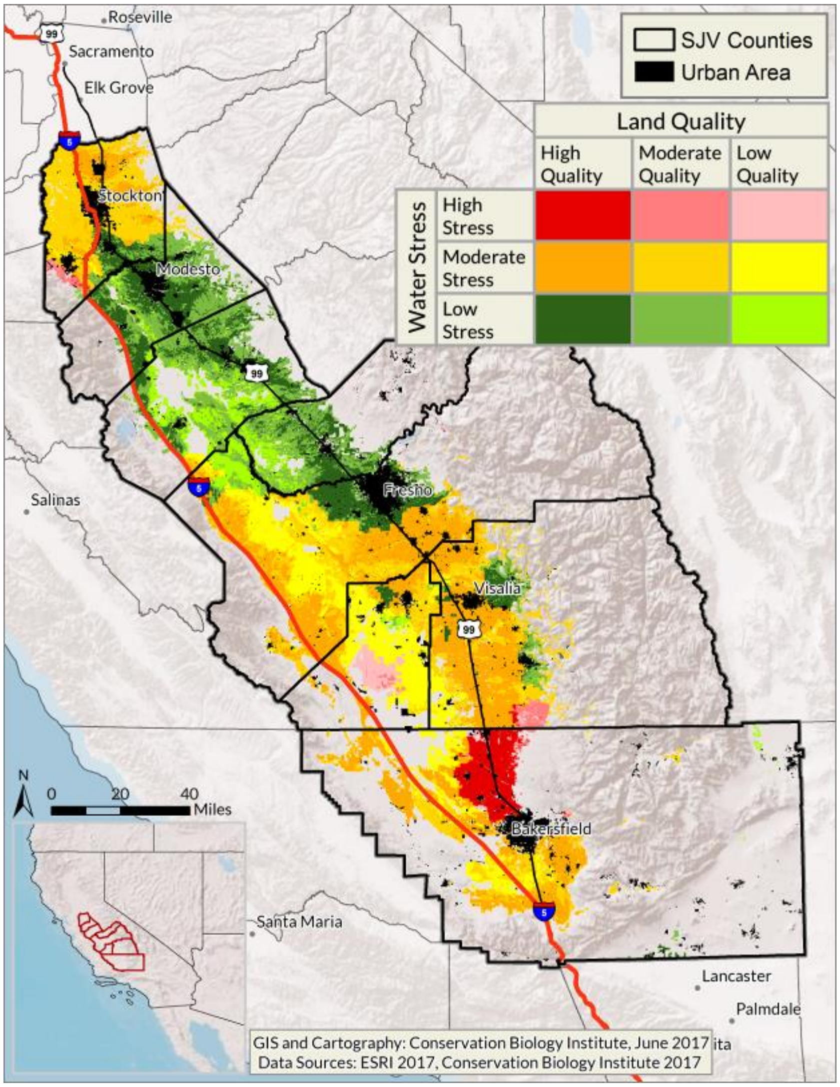
These findings suggest that different management strategies will be needed to address the challenges associated with different types of land-water intersection. For high quality land with low water stress – the "best of the best" – the most important priorities should be to prevent the land from being converted to non-agricultural use and to assure that it continues to have adequate water supplies. For high and medium quality land with medium to high water stress, the priority should be to augment water supplies through conservation, transfers, active groundwater recharge and other strategies. (Of course, this won't make any difference if this land is converted to urban use, so that should also be a priority.) For low quality land, particularly with medium to high water stress, consideration should be given to finding alternatives to agricultural use – large-scale solar is one option[6] – and transferring water (to the extent possible) to higher quality agricultural land. While controversial, this choice may be forced upon the Valley by climate change and regulatory decisions further limiting water supplies.

The geography of the land-water intersection paints an even more dramatic picture of the differences that exist in this region. (Figure 10) On this map, the degree of water stress is represented by the basic colors: green for low, yellow-orange for medium and red for high. The quality of the land is represented by variations within this color scheme with the darkest and most intense colors connoting high quality land, the more muted hues medium quality and the lightest hues the lower quality land.

Much of the "best of the best" land is located around and between Modesto and Fresno on the east side of the Valley with smaller concentrations in western Stanislaus and east of Visalia. South of Fresno, again on the east side, there are large expanses of high quality land experiencing medium to high water stress levels, especially in Kern County. In San Joaquin County, the high value land on the east side, as well as in the Delta, appears to have water supplies that have not been as reliable as they are just to the south. Obviously, the resource management challenges and strategies noted above will play out differently in the various sub-regions of the Valley, depending on the land-water intersection profile in a given sub-region.

[6] See, *A Path Forward: Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley*, University of California Berkeley Center for Law, Energy & Environment and Conservation Biology Institute, May 2016.

Figure 10 – Geography of the Intersection of Agricultural Land Quality and Water Resources in the San Joaquin Valley



Development Risk

Another stress factor to be considered in managing agricultural land for sustainable agricultural production is the conversion of the land to non-agricultural, mostly urban uses. Since records were first kept in 1984, almost 200,000 acres of agricultural land have been developed in the Valley, roughly one-third of all the land urbanized since the region was first settled. In addition, about 160,000 acres have been converted to rural residential development (1.5 to 10 acre lots), comprising about one-quarter of all the acreage converted to non-agricultural use.

Methodology for Assessing Development Risk

To assess future development risk to agricultural land, we again used a logic model that included data on various indicators of the likelihood of conversion to non-agricultural use. These data included:

- City limits and spheres of influence (reflecting a government intention to convert these lands)
- General plan designation of land for development
- Forecast of urban growth by California Department of Natural Resources

Land falling within city limits or spheres of influence, or designated for development in general plans was all categorized as having a high risk of conversion. Land outside these areas but forecast for urban growth by DNR was considered at medium risk of conversion, while all other land was deemed at low risk of conversion. (Figure 11)

Figure 11 – Logic Model for Development Risk

Major Findings About Development Risk to Agricultural Land

Based on our analysis, about 725,000 acres (12%) of San Joaquin Valley agricultural land are subject to high to medium development risk. (Table 2) High quality agricultural land is disproportionately more at risk – 16% or one out of six acres -- largely because so much of it is located around cities. Land that is both of high quality and with low water stress has an even higher risk of development with 131,000 acres (18%) at high to medium risk of conversion. By contrast, 11 and six percent respectively of the medium and low quality land appears to be at risk of development. Our analysis also found that almost one-quarter of the land with high water stress levels is at high risk of development, primarily in Kern County. But the spheres of influence (one indicator of development risk) in that county are exceptionally large, so they probably overstate the potential extent of future development. With this exception, land with lower water stress had a higher risk of development (13%) than land with higher water stress.

Table 2 – Development Risk Distributed Among Land Quality and Water Stress Categories

Development Risk	Land Quality			Water Stress		
	High	Medium	Low	High	Medium	Low
High	274,149	210,605	60,180	80,954	276,379	187,601
Medium	113,160	59,373	7,169	9,504	90,052	80,146
Low	2,007,236	2,273,128	1,142,520	283,414	3,308,301	1,831,169
Total	2,394,545	2,543,106	1,209,869	373,872	3,674,732	2,098,916
Pct High & Med	16%	11%	6%	24%	10%	13%

Combining the effects of water stress and development risk yields another perspective on the Valley's agricultural land. Of all the land in the Valley, more than a million acres – one out of every six acres – is subject to either high water stress or high to medium development risk. (Table 3) of the Valley's high quality agricultural land, more than one out of five acres is subject to one or both of these influences that jeopardize future agricultural production.

Table 3 – Cumulative Impact of High Water Stress and Development Risk

	All Land	High Quality Land
High/Medium Dev Risk	724,636	387,309
High Water Stress	373,872	209,326
Both	90,458	69,649
Total Risk & Stress	1,008,050	526,986
All Valley Agricultural Land	6,147,520	2,394,545
Pct of Valley Agricultural Land	16%	22%

Observations

Our analysis of the San Joaquin Valley's agricultural land and water resources offers a new perspective on the viability and sustainability of food production in California's and the nation's premier agricultural region. Mapping the intersection of the quality of land, reliability of water supplies and development pressure offers a more detailed picture of the distinctions among the resources across the landscape. These finer-grained distinctions should be useful in planning and have important implications for policy decisions and strategies for conserving and managing land and water resources.

The results of this analysis are quite sobering. The coincidence of high quality land and low water stress is quite small, encompassing only one-eighth of the total agricultural acreage – an area only 80 percent the size of Kings County. The opposite conditions, lower quality land and/or high water stress, are twice as extensive, comprising one quarter of the Valley's acreage. One-sixth of the total acreage, and more than one-fifth of high quality land, is subject to high water stress or high to medium development risk. Significantly, almost twice as much land in the Valley is subject to development risk than is currently experiencing high water stress.

These figures do not take into consideration the potential impacts of climate change and pending regulatory decisions that could further reduce irrigation water supplies. Based on further analysis we are conducting – and will present in our final report – all of these could have a very dramatic impact on agriculture, significantly expanding water stressed areas with the likely result that more agricultural land will be taken out of production. This will place a premium on trying to assure that the higher quality land retains – or obtains – adequate irrigation water and, in general, taking steps to increase water supplies through innovative means such as active groundwater recharge.

On the other hand, our analysis of urban development suggests that a considerable amount of agricultural land, particularly high quality land, could be saved by pursuing the alternative of more compact, efficient growth patterns. As other land is taken out of production because of shrinking water supplies, it will become even more important to minimize conversion of the highest quality farmland by implementing strategies such as those encouraged by the San Joaquin Valley Blueprint and the Sustainable Communities Strategies designed by the councils of government under SB 375.

Perhaps the most important lesson to be drawn from our findings is that the San Joaquin Valley faces a stark choice. This choice isn't necessarily between this land or that land, or this use of water or that one, though such choices probably will have to be made. However, the ultimate choice – the one that could make or break agriculture in the Valley – is between acknowledging and forthrightly addressing the differences in agricultural land and water resources across the Valley landscape with pro-active, effective conservation and management strategies; or simply allowing a random pattern of land development and retirement to occur regardless of the consequences.

Acknowledgments

American Farmland Trust wishes to thank the following people and institutions for their assistance and support in conducting this project:

- Edward Thompson, Jr., California Director and Senior Associate of American Farmland Trust, who authored this report and took part in the analysis.
- The Conservation Biology Institute; its director James Strittholt, the creator of Data Basin who provided valuable advice on the project; and GIS analyst Dustin Pearce who led the analytical work and produced the maps for the report.
- Fresno Council of Governments and the state Strategic Growth Council which provided most of the funding for the project, as well as the Kern County Planning Department for additional funding.
- Jay Lund, Josué Medellin-Azuara, Ellen Hanak and other technical experts for their sound advice, but who bear no responsibility for the conclusions we have drawn.
- The agricultural, local government and other stakeholders from whom we learned much in our workshops and webinars.

This project was conducted under the auspices of, and with additional financial support from, the Helen K. Cahill Center for Farmland Conservation Policy Innovation. The Cahill Center is is the research and educational arm of American Farmland Trust in California. Its namesake, Helen Kennedy "Peggy" Cahill (1916-2013), was a proud fourth generation descendant of California pioneers who in 1849 founded the City of Stockton. A teacher, outdoors enthusiast and philanthropist, Peggy had an abiding interest in the conservation of farmland, especially in the San Joaquin Valley. In her memory, her family has endowed the Cahill Center as a living legacy for future generations who will depend on the land that feeds and sustains us.