Energy, Greenhouse Gas and Water Use Outcomes from the 2016 State Water Efficiency and Enhancement Program (SWEEP)

Final Results from Remote Monitoring by AgMonitor

CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

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Report Summary

This report presents the findings from three years of energy and water use monitoring for a sample of the California Department of Food and Agriculture's (CDFA) State Water Efficiency and Enhancement Program (SWEEP) projects funded from the 2016 appropriation. The energy use, water use, and GHG emissions for 24 different ranches were tracked on the AgMonitor platform to obtain a comprehensive understanding on the benefits of SWEEP funded projects over three years. The report compares water and energy resources used in the post project years (2017, 2018 and 2019) to the baseline (before SWEEP project completion). Projects were included in the comparison if they had complete sets of data from the baseline year and treatment years. This selection criteria resulted in 12 projects being compared for energy and greenhouse gas (GHG) change, and 5 projects being compared to estimate water consumption change. Table 1 provides summary results comparing the baseline year to the third year after project implementation (2019).

Table 1 Summary of the change in energy use, water use, and GHG emissions. 2019 change compares usage in 2019 to baseline years; for energy and GHG this was the change for 12 projects and for water this was the change from 5 projects.

Variable	Net energy use (MWh) change from 2015	GHG emissions (MT CO_2e) change from 2015	Water use (acre-feet) change from 2016
2019 total change	-2,548	-780	-2,346
2019 change (%)	-93%	-93%	-51%
Average 2019 change per project	-212	-65	-469

Main findings from the analysis are listed below:

- Net energy use and GHG emissions were reduced by 93% in 2019 for 12 projects representing a change of -2.5 GWh or -780 MT CO_2e
- The majority (97%) of energy/GHG changes were from 5 projects that installed solar arrays to offset power used by irrigation pumps.
- Water use change was -51% or -2,346 acre-feet for 5 projects.
- The majority (99%) of water savings were from a single project.
- Benefits and challenges of using the remote monitoring strategy are also discussion throughout this report in the Energy and Water Savings sections.

The change in resource consumption in 2019, 2018 and 2017 for these same projects are displayed in Table 2. The annual change in all three variables was the largest in 2019, with very minimal variation in energy use and GHG production and more substantial variation in water consumption. These trends are expected as the energy and GHG change were driven by solar energy installations (which offset energy used for irrigation water pumping), which remain relatively constant in annual energy generation, whereas water use fluctuates due to water availability, crops grown, water demand and other factors. Based on the findings in these analyses, increased investment in solar systems to offset pumping energy will result in predictable energy and GHG savings. Water savings are consistently achievable, although less predictable and subject to external agronomic and climate factors.

Table 2. Total change in energy use, GHG emissions, and water use across the three years of analysis in this project. These were calculated by comparing each year to the 2015 baseline for energy and GHG and the 2016 baseline for water.

Variable	2017 change	2018 change	2019 change	Cumulative change
Net energy use (MWh)	-2,513	-2,508	-2,548	-7,569
GHG emission (MT CO_2e)	-769	-767	-780	-2,316
Water use (acre-feet)	-1,559	-1,824	-2,346	-5,729

The savings for a given year across the project were extrapolated to explore what the total savings would be if all 127 SWEEP projects funded in the 2016 Round 1 had saved the average amount of energy, GHG and water based on the 24 projects analyzed. The average annual change per project was calculated by taking the mean savings across all projects with a full set of data (12 for energy/GHG and 5 for water). Over three years the total energy savings was estimated at 26.6 GWh, the GHG savings of 8,166 MT CO_2e and water savings of 44,698 ac-ft (Table 3). Overall, from a programmatic perspective, these savings are significant. Annual energy records have illuminated that these savings are influenced by a few projects that were responsible for high savings in water, and large energy reductions from solar energy systems used to offset energy consumed by water pumps.

Table 3. Estimation of the cumulative savings from all 127 projects across the three years of analysis.

Variable	Average annual change per project	Total projects	Average annual change for all 127 projects	Total 3-year change for all 127 projects
Net energy use (MWh)	-210.2	127	-26,695	-80,085
GHG emission (MT CO_2e)	-64.3	127	-8,166	-24,498
Water use (ac-ft)	-351.95	127	-44,698	-134,094

Introduction

AgMonitor was contracted to monitor water, energy and greenhouse gas (GHG) data across a subset of awarded projects from the SWEEP 2016 first solicitation (Round 1) and to quantify the change in energy, water and GHG consumption from SWEEP projects over time. In this report, the energy, GHG and water data are compared between the baseline year and the three years following project installation (treatment years). The “baseline” for energy and GHG consists of 2015[1] energy records submitted by growers to CDFA in their SWEEP grant application. The “baseline” for water consists of 2016 water use records monitored on the AgMonitor platform. It was not possible, due to reasons explained below, to use the same baseline year for energy and water use comparison because a complete set of baseline data was not available.

[1] When a year is mentioned in this document it refers to the calendar year, unless otherwise specified

The initial workplan called for historical data to be available through the AgMonitor platform so that the baseline year (2016) and treatment years (2017-2019) would be comprised of real data gathered through and stored on the AgMonitor platform. However, there were considerable delays in the onboarding process (getting growers to sign on to the online monitoring platform) because growers were occupied by harvest when the onboarding process began. As a result, the 13 months of historical energy data that is available when a grower signs up with AgMonitor was not sufficient (in many cases) to provide a complete year of data for 2016. For these reasons, the 2015 energy use records that were submitted by growers were used for the energy use and GHG baseline. Water use data tracked by AgMonitor in 2016 was used as the water baseline. This report highlights the results from 2019 while including cumulative savings from the entire project timeframe (2017-2019).

Energy use and GHG Emissions

Selection of projects

AgMonitor tracked the change in energy use of each of the 24 projects using data transmitted from utility-owned smart meters to the AgMonitor platform. In this analysis, growers' submitted records from 2015 (baseline) are compared with real energy use data gathered from smart meters in 2017, 2018, and 2019 (treatment years) on the AgMonitor platform.

For the comparison of energy savings and GHG reductions each year, only those projects that had a complete set of baseline data and a complete set of data across the treatment years (2017 through 2019) were included. Of the 24 projects tracked, only 12 had complete data for all three treatment years (2017, 2018 and 2019) and thus only these 12 projects were included in the energy/GHG analysis described in this report.

The following criteria and assumptions were considered in evaluating data completeness for the energy and GHG analysis.

- Projects were only included in the comparison if the service account identifications of the utility smart meters submitted in the baseline records matched the service account identifications of the pumps tracked on the AgMonitor platform.
    - There are some cases in which the grower confirmed that a meter was switched to a different meter number during project installation, and that the monitored meter and the meter submitted for baseline measurements are indeed tracking the same irrigation pump. In these cases, the pump was still included in the analysis.
- Several projects were missing energy data from winter months in the baseline records that were submitted to CDFA (i.e. November, December, January, February). It was assumed that there was no significant energy use in these months since they are outside the typical irrigation season for most crops.
    - If either baseline or treatment data were missing for any month, the missing months were omitted from both the treatment and baseline so that the same time interval was compared. For instance, if the baseline data from Project A did not include data from November or December in 2015, the November and December treatment data from the AgMonitor online system in 2019 were also excluded as to not bias the data.

Energy Report

Table 4 below illustrates the total electricity use from all pumps in the baseline year (2015) compared with the third treatment year (2019) for the 12 projects[2] with complete data. Treatment year energy use is the net use of electricity consumed and solar electricity generated. There was no solar energy generation in the baseline year.

Table 4. Summary of total annual electricity consumption (kWh) across 12 SWEEP projects in 2015 (Baseline) and 2019 (Treatment year 3) tracked through the AgMonitor platform.

SWEEP Project	Baseline Energy Use (kWh)	Treatment Energy Use (kWh)	Treatment Solar (kWh)	Treatment net energy usage (kWh)	Change in Net energy use (%)
A	65,859	78,638	-	78,638	19%
B	168,361	124,138	415,200	-	-100%
C	32,207	20,166	-	20,166	-37%
D	23,093	9,300	46,400	-	-100%
F	1,814,831	1,003,578	1,723,700	-	-100%
H	18,801	9,319	-	9,319	-50%
K	22,365	15,863	-	15,863	-29%
N	158,950	240,925	445,063	-	-100%
O	26,178	24,100	-	24,100	-8%
Q	295,770	229,085	1,035,050	-	-100%
U	37,181	3,288	-	3,288	-91%
V	89,314	53,217	-	53,217	-40%
Total	**2,752,910**	**1,811,617**	**3,665,413**	**204,591**	**-93%**

In 2019, net energy consumption was reduced by 93% between baseline and treatment years (Table 4). This represents a reduction of 2.54 GWh across the 12 projects analyzed. The average annual reduction of energy use was estimated at 212 MWh per project. Assuming this average reduction is consistent for

[2] Throughout the report individual projects have been labeled with letters to protect sensitive project-level information.

all the 127 projects in this funding round, this round of investment would be responsible for an estimated 27 GWh (212 MWh/project * 127 projects) of electricity savings in 2019. Approximately 97% of the energy reduction were from 5 projects that installed solar energy systems to offset power used by irrigation pumps. One project was responsible for a reduction of 1.8 GWh or 71% of total energy reduction from these 12 projects. This project included the installation of a 1 MW solar array that generated approximately 1.7 GWh of electricity in 2019.

Cumulative Energy Savings

Table 5 below shows the total change in energy use between the baseline year data (2015 utility data), Treatment year 1 (2017 AgMonitor platform data), Treatment year 2 (2018 AgMonitor platform data) and treatment year 3 (2019 AgMonitor platform data). Projects were included only if they had a complete set of data in both the baseline and all three treatment years.

Table 5. Total change in energy use in 2017, 2018 and 2019. Negative numbers represent a reduction in energy use and positive numbers represent an increase in energy use.

SWEEP Project	Change in Energy Use in 2017 (kWh)	Change in Energy Use in 2018 (kWh)	Change in Energy use in 2019 (kWh)
C	-8,954	-1,191	-12,041
D	-23,093	-23,093	-23,093
H	-8,302	-8,723	-9,482
N	-158,950	-158,950	-158,950
O	2,522	122	-2,078
U	-20,695	-9,981	-33,893
V	-29,506	-35,414	-36,097
A	17,775	12,159	12,779
F	-1,814,831	-1,814,831	-1,814,831
K	-5,156	-3,553	-6,502
Q	-295,770	-295,770	-295,770
B	-168,361	-168,361	-168,361
Total	**-2,513,321**	**-2,507,586**	**-2,548,319**

The total change in energy use in the three treatment years had little variation, with the biggest change being a 2% increase between the savings in 2018 and 2019 (Table 5). Similar annual energy savings is expected because the bulk of the savings were driven by solar energy installations. These savings offset 100% of the baseline line energy use of irrigation pumps in treatment years. This complete offset of baseline energy use from solar generation caused five projects (Projects B, D, F, N, and Q) to have the same change in energy use reduction in all three treatment years (Table 5). In all the projects involving solar installation, solar energy generation was significantly higher than the energy use of the electricity meters they are offsetting. This means that change of solar generation due to system malfunctions or dirt on the panels would have to be quite significant to have any impact on the energy savings. These results validate that solar installations will results in consistent energy savings in agricultural projects. However as solar deployment grows in the central valley, investment will be needed in other sources of energy savings

GHG Report

The same 12 projects analyzed in the energy report were used to estimate GHG emission reductions. Energy use was converted to GHG emissions by multiplying the total energy use (kWh) by an emissions factor of 0.306 kg CO_2e/kWh. This emissions factor is specified by the California Air Resources Board (CARB) GHG Quantification Methodology (QM) as the constant that should be used for calculating and reporting on SWEEP GHG emissions and emissions reduction.

Table 6. Summary of total annual greenhouse gas (GHG) emissions (kg CO_2e) for 12 SWEEP projects in treatment year 3.

SWEEP Project	Baseline (2015) GHG Emissions (kg CO_2e)	Treatment Year #3 (2019) GHG Emissions (kg CO_2e)	Change (%)
C	9,855.37	6,170.80	-4%
D	7,066.46	0.00	-100%
H	5,753.11	2,851.61	-46%
N	48,638.70	0.00	-100%
O	8,010.60	7,374.60	0%
U	11,377.39	1,006.13	-27%
V	27,329.94	16,284.40	-40%
A	20,152.85	24,063.23	18%
F	555,338.29	0.00	-100%
K	6,843.69	4,854.08	-16%
Q	90,505.62	0.00	-100%
B	51,518.47	0.00	-100%
Total	**842,390.47**	**62,604.85**	**-93%**

There was a total GHG reduction of 93% or 779,785 kg CO_2e between baseline and treatment year #3 (Table 6). This represents an average annual reduction of 64,982 kg CO_2e per project. Assuming this average is representative of the entire investment, the annual emission reductions for the entire group of SWEEP 2016 Round 1 awarded projects would account for 8.25 million kg CO_2e of GHG emission reduction (63,943 kg CO_2e/project * 127 projects).

The GHG calculations in 2017, 2018 and 2019 were based on the same projects listed in cumulative energy section above (Table 5). Relative differences in GHG from previous years also match the relative energy difference. Total GHG reduction in 2019 was 779,785 kg CO_2e compared to 767,321 kg CO_2e in 2017 and 769,076 kg CO_2e in 2017 for the 12 projects.

Water Use Report

The PumpMonitor product offered through AgMonitor converts energy use records from utility smart meters into water use records using patented algorithms. There are some cases where PumpMonitor is not able to accurately convert energy into water use records, these include: (1) pumps with solar on the same electricity meter, (2) two pumps with the same or similar horsepower on the same meter or (3) more than two pumps on the same meter. While these cases are not common among farms, there were some instances in this contracted project where PumpMonitor was not able to provide water records.

Unlike energy and GHG emissions, water data was gathered exclusively on the AgMonitor platform through the PumpMonitor product to analyze the annual change in water use. PumpMonitor tracks the total water pumped from booster pumps, well pumps and lift pumps but it does not specify to which field the water is delivered (this is a feature of their CropMonitor product). A complete set of data was collected for all pumps at 5 different SWEEP projects for the baseline year (2016) and treatment years (2017, 2018 and 2019). Other sites were omitted due to incomplete data (7 projects), missing pump tests (3 projects), inability to measure water (7 projects) or exclusion from 2017 analysis (2 projects). Table 7 below provides details as to why each project was excluded from the 2019 annual report analysis of water savings. It should be noted that one additional site was removed in 2019 from the analysis (Project I) since existing pump tests could no longer accurately provide water records on a pump at the site.

Table 7. List of all SWEEP projects that were excluded for analysis of 2019 water savings and the associated reason for exclusion.

SWEEP Project	Reason for omission	Detail
D	Unable to measure water	Solar array on same utility meter as irrigation pump and therefore determining the energy use by the pump was not possible with the AgMonitor platform
L	Unable to measure water	2 irrigation pumps on 1 utility smart meter
X	Unable to measure water	3 irrigation pumps on 1 utility smart meter
M	Unable to measure water	Solar array on the same utility meter as the irrigation pumps and therefore determining the energy use by the pump was not possible with the AgMonitor platform
T	Unable to measure water	2 pumps on 1 utility smart meter
W	Unable to measure water	3 pumps on 1 utility smart meter
E	Incomplete data	Utility meter was changed and customer did not have the information to sync the new meter to AgMonitor
P	Incomplete data	Utility sent inaccurate data in 2018
R	Incomplete data	Property sold resulting in no access to a full year of 2018 data
Y	Incomplete data	Missing data in baseline year due to late onboarding
U	Incomplete data	Missing data in baseline year due to late onboarding
A	Incomplete data	Missing data in baseline year due to late onboarding
B	Incomplete data	Missing data in baseline year due to late onboarding
Q	No pump tests	Several pumps were added with no pump tests.
J	No pump tests	Onboarding process not completed; no pump tests.
G	No pump tests	Onboarding process not completed after utility meters were added; no pump tests.
C	Project not included in 2017 analysis	Full set of data in 2017 missing, therefore excluded in 2017.

SWEEP Project	Reason for omission	Detail
F	Project not included in 2017 analysis	Full set of data in 2017 missing, therefore excluded in 2017.
I	Not included in 2019	Pump operation was outside the pump test range therefore water measurement was not possible on pump.

The data for water consumption of the 5 sites with complete data are presented in Table 8 below.

Table 8. Summary of total water usage in acre-feet and inches in 2016 and 2019 for 5 SWEEP projects tracked through the AgMonitor platform. The acres of all fields mapped on the AgMonitor platform were aggregated and listed.

SWEEP Project	Monitored Acreage	2016 water use (inches per acre)	Total 2016 water use (acre-feet)	2019 water use (inches per acre)	Total 2019 water use (acre-feet)	Change (%)
V	49	18	74	12	49	-34%
O	16	67	91	69	94	3%
K	54	18	82	13	61	-26%
H	27	25	56	12	28	-51%
N	142	366	4,319	173	2,045	-53%
Total	**288**	**494**	**4,622**	**280**	**2,276**	**-51%**

The change in water use varied on these 5 sites from 3 acre-feet to -2,274 ac-ft when comparing the baseline year (2016) with treatment year #3 (2019). The relative change in percentage varied from 3% to -53%. Across all 5 sites the mean change in water use was a reduction of 469 acre-feet per project per growing season. Assuming this trend is representative of the average water savings of the entire set of 127 projects in this investment round, the investments would be responsible for 59,563 acre-feet of reduction per growing season (469 acre-feet/project * 127 projects). This estimation of total project savings could be improved if water management had been possible at additional project sites. One project, Project N, resulted in water savings two orders of magnitude greater than the savings from other projects in 2019. This data point appears to be an outlier.

Similar to the reductions in energy and GHG emissions, most of the measured water savings (99%) are from Project N. Water use was reduced by 2,274 ac-ft or 53% when comparing 2019 to 2016. This project implemented three changes that may have resulted in a reduction of water use including converting flood irrigation to drip irrigation on 141.6 acres, the implementation of a smart irrigation controller and installing soil moisture sensors. These results demonstrate that considerable savings can be achieved by combining multiple water savings strategies and by targeting high volume pumps. However, the inches per acre for this project is 366 in 2016 and 173 in 2019 (Table 8). We can assume with high confidence from this datapoint that the pump was used on other fields that were not part of the SWEEP project.

Cumulative Water Savings

The 5 projects with a complete set of data in the baseline year (2016) and all treatment years (2017, 2018 and 2019) are compared in Table 9 below.

Table 9. Change in total water use per project when comparing treatment years (2017, 2018 and 2019) with the baseline year (2016) using data from the AgMonitor platform. Negative values represent reductions in water use; positive values represent increases in annual water use.

SWEEP Project	2017 change in total water use (acre-feet)	2018 change in total water use (acre-feet)	2019 change in total water use (acre-feet)
V	-17	-24	-25
O	20	12	3
K	-17	-14	-21
H	-20	-22	-28
N	-1,058	-1,793	-2,274
Total	**-1,092**	**-1,841**	**-2,346**

Water use across these 5 projects resulted in a total savings of 5,279 acre-feet of water across the three years (Table 10). This change can be largely attributed to the decrease in water use for Project N of 5,125 ac-ft. If Project N was not considered in the analysis, the total saved water would be 154 acre-feet across 4 projects. SWEEP projects vary in amount of water reductions, but overall resulted in water savings.

Influence from External Factors

Previous research done for the California Energy Commission (CEC) by AgMonitor highlighted the importance of considering all the factors that might influence energy or water use.[3] In this analysis, there were 9 factors identified that were the most likely to significantly affect the amount of water or energy used on a farm when doing an annual comparison (Table 10). Due to the high probability of influence of these factors, the CEC-sponsored study concluded that to accurately estimate the impact in energy or water use from an agronomic system, one should perform the analysis in the same year, on the same field and with the same crop.

[3] Jerphagnon et al (2019). Decision Support Tool to Reduce Energy and Water Consumption in Agriculture. California Energy Commission. March 2019. CEC-500-2019-022. Available online at: https://ww2.energy.ca.gov/2019publications/CEC-500-2019-022/CEC-500-2019-022.pdf

Table 10. External factors identified to have a potential significant influence on water or energy use on a farm.

Energy/Water Factors
Temperature
Rainfall
Surface Water Allocation
Other Field Irrigation
Pump Issues
Overall Pump Efficiency
Distribution Uniformity
Soil Variability
Water Table Level

In addition to the list above, some factors that may affect energy and water use on SWEEP projects for annual comparison include changing crops and aging crops, particularly on those fields outside the scope of the SWEEP project that are irrigated by irrigation pumps impacted by the SWEEP project. There is no efficient way to track the influence from these external factors, though through measuring water, energy and GHG data for many years, the external impact from many of these should average out over time. There is a vast amount of data available to track influence from climate factors on crops. An analysis of the potential impact from reference evapotranspiration and precipitation is discussed below.

Impact of External Factors in This Project

As stated above, a detailed analysis of each of these factors was outside the scope of this project. However, there was an analysis completed precipitation and evapotranspiration using public data. A common driver in annual variance of water use and energy use is an unpredictable climate. The 2017 year marked the end of a multi-year drought, 2018 water year was defined by dry conditions and the 2019 water year was marked by more rainfall, providing surface water access to many growers in California. State snowpack on April 1, 2019 was 175% of the annual average, compared to 58% in 2018 and 163% in 2017.[4] Statewide reservoir storage in September 2019, 128% of the average at that time, also indicated grower access to surface water in that year, which takes much less energy to deliver to fields than groundwater.[5]

California continued its trend of above average temperatures in 2019. Higher temperatures result in greater demand of water for crops. To estimate the atmospheric demand of water on crops, reference evapotranspiration (ET_o) data was analyzed. Evapotranspiration (ET) is a measure of the total water that evaporates from land surface and transpires through the plants. Reference evapotranspiration or ET_o is a calculation of how much water would be lost from ET on a grass crop with 100% canopy cover over a given time period. Models used to estimate ET_o incorporate many climatic factors including air

[4] Water Year 2020 Begins with Robust Reservoir Storage. California Department of Water Recourses. October 2019. Retrieved from: https://water.ca.gov/News/News-Releases/2019/October-19/Water-Year-2020-Begins-with-Robust-Reservoir-Storage#:~:text=Water%20Year%202019%20highlights%20include,approximately%2029.7%20million%20acre%2Dfeet.

[5] Ibid.

temperature, air humidity, wind speed and sunshine/radiation.[6] Comparing ET_o from year to year provides an estimate of crop water demand. To calculate crop specific water demand, the ET_o would need to be multiplied by a crop coefficient (Kc). Crop Kc is the ratio of a specific crop's observed evapotranspiration under controlled conditions over the reference crop evapotranspiration.

Data on ET_o was gathered from Department of Water Resources (DWR) California Irrigation Management Information System (CIMIS) web application to understand how ET_o changed in each year of the SWEEP analysis.[7] Three SWEEP projects were considered, which represent the spatial range for this round of projects. The three project zip codes were used to generate ET_0 data in CIMIS: Project I (north of Sacramento; 95993), Project F (Central Valley; 93627) and Project V (Coastal; 93446) (Figure 1). Zip codes were used to get estimates for spatially interpolated ET_0 data from CIMIS.

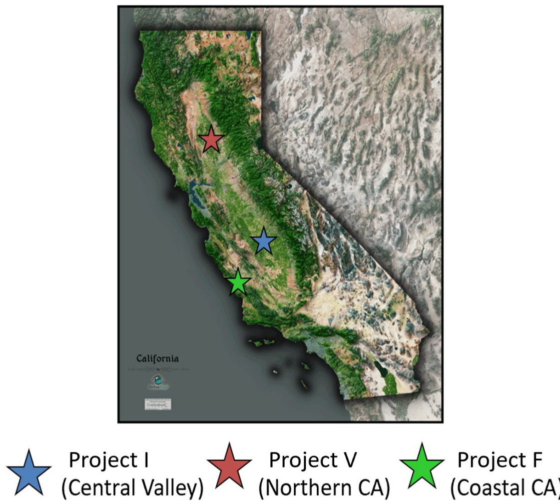

Figure 1. Map of the location for the three SWEEP projects selected to represent the geospatial spread of the 24 projects analyzed in this report.

ET_o was analyzed for these three projects from 2015 – 2019 and graphed in Figure 2 below.

[6] Allen, Richard G., et al. "Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56." *FAO, Rome* 300.9 (1998): D05109.

[7] https://cimis.water.ca.gov/SpatialData.aspx

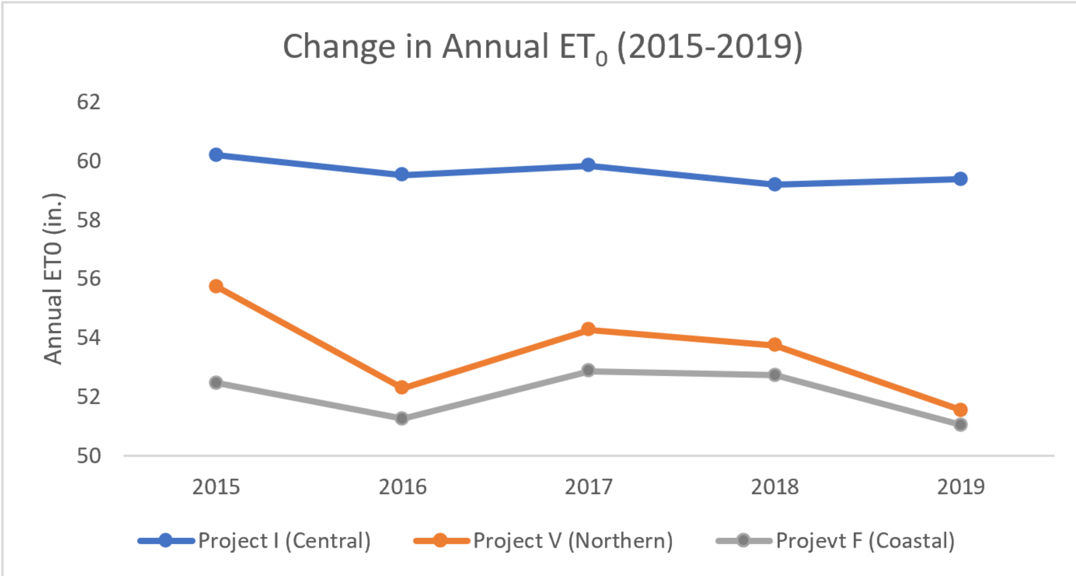

Figure 2. Annual reference evapotranspiration (ET_0) for three SWEEP 2016 round 1 projects (2015–2019). ET_0 was calculated as the zip code average for each location. ET_0 data was retrieved CIMIS online web application.

The ET_o from crops in the three different areas have relatively similar trends over time and minimal variation. Project V (coastal) remained consistent across time ranging from 51-52.8 inches ET_o over the 6-year period. The ET_o demand in the location of Project F (central) trended downward over the 6-year period with an average water demand of 59.6 inches. Project I (northern) showed a decreasing trend as well, with the most dramatic drop between 2015 and 2016 when it dropped by 3 inches. When compared with the baseline year (2015), Project V decreased demand by 3%, Project I decreased demand by 1% and Project F decreased demand by 8%.

Annual precipitation data were also gathered from the AgMonitor platform for the three projects analyzed in the above section (Figure 3).

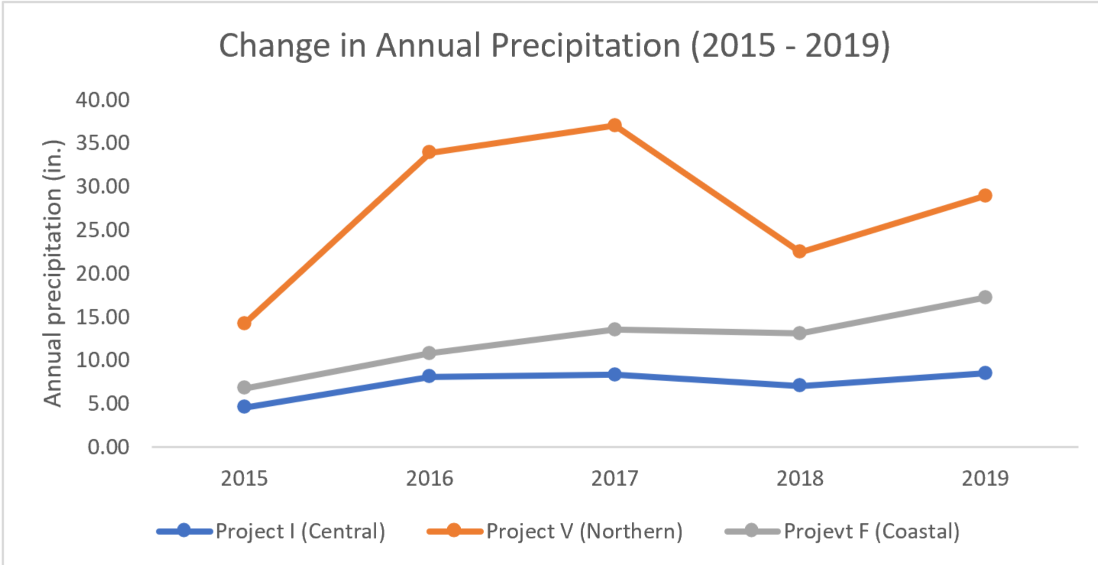

Figure 3. Annual precipitation data (inches) for three SWEEP projects representing different sub-climates in California (2015 – 2019)

Total annual precipitation for Project F increased by 0.39 inches and Project V increased by 6.42 inches, while the precipitation at Project I decreased by 5 inches (15% when comparing 2019 to 2016 years). Historically, Project I (most northern) has received the most rainfall and therefore is most influenced by dry or wet years in terms of precipitation. 2019 was a wet year compared to 2018 and at all three sites there were increases that averaged 27% between over these two years. The bulk of precipitation fell during the off season (Nov-Apr), which serves well to fill the soil profile for the growing season but should not have a significant influence on total water application to crops.

Analysis of these two factors revealed they likely had insignificant influence on the results of this study. Evapotranspiration did decrease by 8% of between 2015 and 2019 on the coast, however the majority of the projects were not located on the coast. Precipitation increased for all three project sites, though the majority of it fell in the off-season limited the impact on results. Greater access to surface water in the central valley may have increased energy savings at some sites because growers could rely on cheap lift or booster pumps instead of wells to get water.