Evaluation of Crop Coefficients and Crop ET for Mature Pecans Grown in the Northern Sacramento Valley of California

Preliminary Summary of 2018 and 2019 Data

Prepared by Allan Fulton
UC Irrigation and Water Resources Advisor, Emeritus
July 2, 2020

Background

Pecan production has increased in California and in particular in the Sacramento Valley in the last two decades. As a result, an increased interest in scientific information on the irrigation needs of pecans has also occurred. Beginning in 2018, low cost simple applied research was initiated to help understand the water demand of pecans. In 2019, the applied research was expanded by using state of the art, residual energy balance techniques (Tule Technologies) in two northern Sacramento Valley pecan orchards to measure the actual evapotranspiration (ETa) in two mature, bearing pecan orchards.

Objectives

There were two principle objectives for this research:

1. Document the crop evapotranspiration and closely associated crop coefficients for pecans grown in California. Up to this point, most of the information for pecan has originated from other production regions in the US such as New Mexico. Once reliable Kc values for pecan have been established, pecans could be added to the list of orchard crops produced in California where weekly regional estimates of crop evapotranspiration are reported to irrigation managers to help guide real-time irrigation scheduling decisions.
2. Evaluate midday stem water potential (SWP) levels measured with a pressure chamber to better understand the potential range in tree water status that can be expected for fully irrigated, mature pecan trees. Defining fully irrigated baseline conditions for pecans would be useful for establishing interpretive guidelines for pressure chamber measurements taken in pecans.

Research Methods

In 2018, an effort was made to monitor the irrigation practices of one mature, bearing pecan orchard in Tehama County of the northern Sacramento Valley. This orchard was located southeast of Corning, CA. The predominant soil series included the Arbuckle gravelly loam, Tehama silt loam, and Tehama gravelly loam. In this summary this orchard is identified as the "Vance" orchard. Very basic data were collected weekly in this orchard during the growing season. Data included: measured applied water with in-line flow meters, volumetric soil moisture change with a neutron probe hydraprobe, and midday stem water potential measured with a pressure chamber.

In 2019, the research effort was expanded to include a second, mature bearing pecan orchard located on the California State University Chico farm located southwest of Chico, CA. The entire orchard consisted of the Almendra loam soil series. This orchard is identified as "CSUC" in this report. Applied water with in-line flow meters, volumetric soil moisture change with a neutron probe hydraprobe, and midday stem water potential was measured with a pressure chamber at both the CSUC and Vance

orchards in 2019. However, Tule Technologies ET (evapotranspiration) stations were also installed at each of the orchards to measure actual evapotransporation (ETa) occurring in each orchard. A residual energy balance technique was used to measure incoming solar radiation and sensible heat transfer in and out of the orchard at a very high frequency of one measurement every ten seconds. From these highly frequent thermodynamic measurements, the latent heat of evaporation or the residual energy to change water to water vapor from the soil and tree canopy was calculated.

In 2018, the measured applied water records, change in stored soil moisture storage, and midday stem water potential (SWP) measurements were used to establish how closely crop evapotranspiration (ETc) rates were supplied. For weekly measurements when it was evident that soil moisture was not limiting and causing tree water stress, the SWP was correlated to mid-afternoon vapor pressure deficit. VPD is a function of mid-afternoon air temperature and relative humidity. Then, the best fit, linear regression model with VPD as the independent variable and SWP as the depended variable was used to predict baseline, SWP levels under fully irrigated conditions over a range of weather conditions. Using this predictive model, a table of fully irrigated baseline SWP levels was developed to assist with interpretation of field measurements of SWP.

Results and Discussion

Select results are provided to keep this preliminary report brief and some tables and graphics may have double titles to expedite the drafting of this report. Figure 1 shows the cumulative actual crop evapotranspiration (ETa) measured at both the CSUC and Vance orchards in 2019. It is noteworthy that ETa was not measured for the entire 2019 irrigation season as measurements were limited to the period of May 10 through October 2, 2019 so the total ETa measured in each orchard does not represent a full season but it does reflect most of the season and the key periods of crop water use and irrigation management. Second, it is also notable that the cumulative ETa was 20 percent higher at the Vance orchard than levels measured at the CSUC orchard.

Figure 2 provides crop coefficient curves for both Sacramento Valley orchards. There is a clear difference in the average semi-monthly crop Kc values between the two orchards from mid-July through September. This probably reflects differences in the intensity of irrigation management meaning that irrigation was more intensive at Vance orchard and resulted in higher rates of evapotranspiration. Possibly, mild or modest levels of crop stress was reducing the actual ET rates at the CSUC orchard. However, it may also indicate hotter and drier weather conditions which drive higher ET rates. In all likelihood it may have been a combination of both factors. This difference between orchards needs to be examined further by additional evaluation of the applied water data, midday stem water potential levels, and soil moisture extraction trends. It would also be insightful to assess production trends for the past three to five years to understand the possible implications of this difference in orchard ET.

Figure 1. Comparison of cumulative actual ET (ETa) measured in two northern Sacramento Valley pecan orchards during the 2019 season.

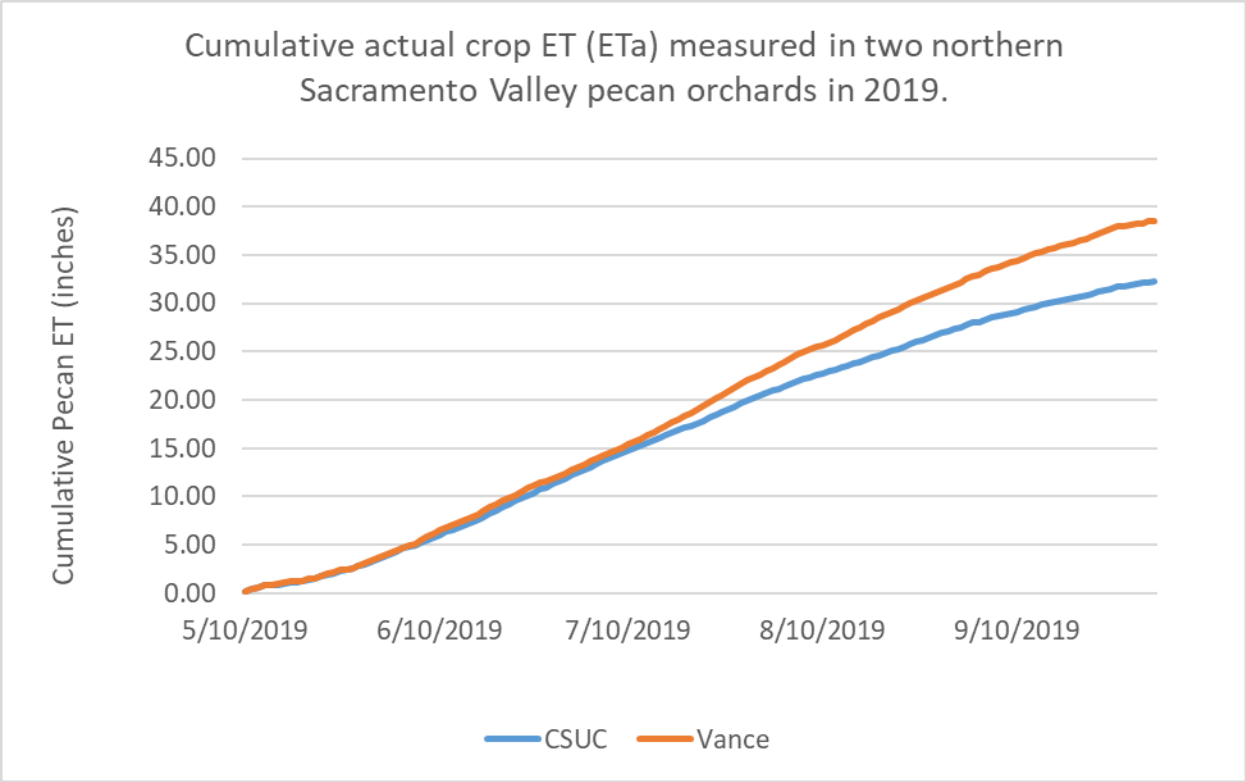

Figure 2. Average semi-monthly crop coefficient (Kc) measured in two measured in two mature pecan orchards in 2019.

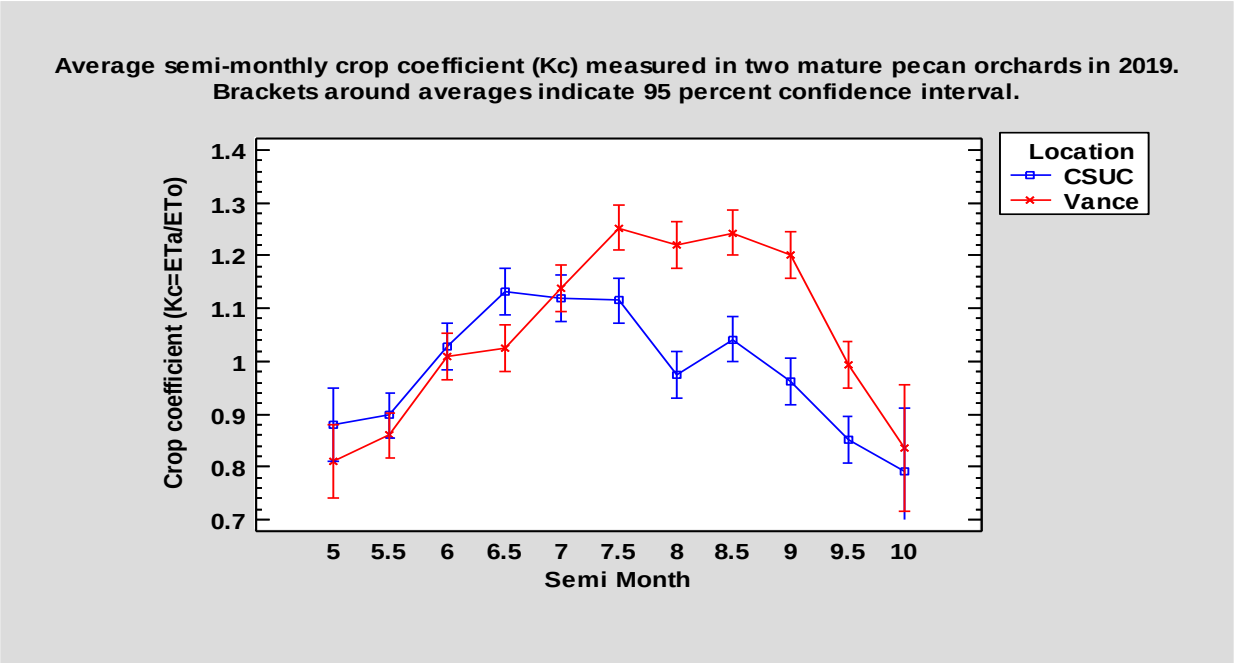

Figure 3 shows the average crop coefficient curve resulting from the 2019 monitoring in these two orchards. A typical bell shaped Kc curve is shown where Kc values are low in the spring while the canopy develops, highest in late spring and mid-summer when the canopy is full and before leaf canopy age and other factors begin to influence the KcThe brackets around the average semi-monthly Kc values (Figure 3) indicate a 95 percent probability that the actual Kc for a specific orchard will fall within the reach of these brackets for each two week period. They also show more range or variability in the early part of May and early part of October.

Figure 3. Average semi-monthly crop coefficients for two pecan orchards measured in 2019. Mean Kc values are bracketed by 95 percent confidence intervals.

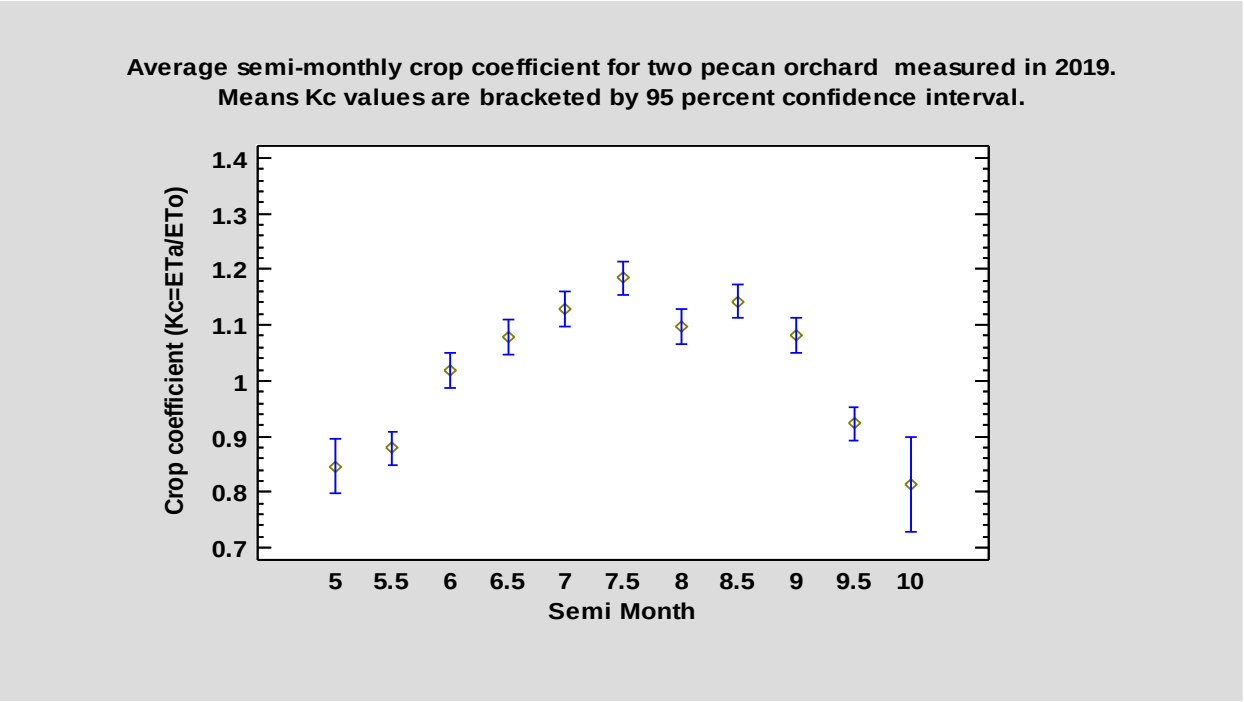

Table 1 shows the average semi-monthly Kc levels range from a low of about 0.81 or 0.85 in the spring and fall periods and a high of 1.18 in mid-summer. Table 1 also demonstrates how the Kc values can be paired with CIMIS estimates of grass reference ETo to estimate historic rates of water use or paired with real-time, regional estimates of grass ETo to estimate real-time, weather dependent crop ET rates for pecans in specific production regions throughout California.

.

Table 1. Average semi-monthly Kc values for mature pecans measured in two northern California pecan orchards in 2019. Also, shown is the estimated semi-monthly, rate of crop ET for pecans based upon these 2019 average Kc values and historic CIMIS averages for short grass reference ET in Glenn and Butte Counties (CIMIS Region 12).

Semi Monthly Period	N=Field measurements	2019 Avg Semi-monthly Pecan Kc (crop coefficient)	CIMIS Region 12 Avg Semi-Monthly Grass Reference ETo (inches)	CIMIS Regional Avg Semi-Monthly Pecan ETc (inches)
May 1-15	12	0.85	3.41	2.90
May 16-31	32	0.88	3.41	3.00
June 1-15	30	1.02	3.90	3.98
June 16-30	30	1.08	3.90	4.21
July 1-15	30	1.13	4.03	4.55
July 16-30	32	1.18	4.03	4.76
August 1-15	30	1.10	3.57	3.93
August 16-31	32	1.14	3.56	4.06
September 1-15	30	1.08	2.70	2.92
September 16-30	30	0.92	2.70	2.48
October 1-15	4	0.81	1.86	1.51
Total	292	1.02	37.24	38.3

Figure 4 displays a scatter plot, the best fit regression line and linear regression model for the relationship between vapor pressure deficit (VPD) and midday stem water potential (SWP) measured with a pressure chamber. The correlation between the variables is statistically significant despite a fair amount of scatter among the data points and a moderately weak coefficient of determination (R^2= 0.37). It suggests other factors influence SWP in addition to air temperature and relative humidity as only 37 percent of the variance is correlated with VPD.

Figure 4. The observed correlation between vapor pressure deficit (VPD) and midday SWP potential in pecans in one northern California pecan orchard, 2018 data only. (Note: when second title in graphic below refers to “Both Sites” it is referring to two monitoring locations within the same orchard.)

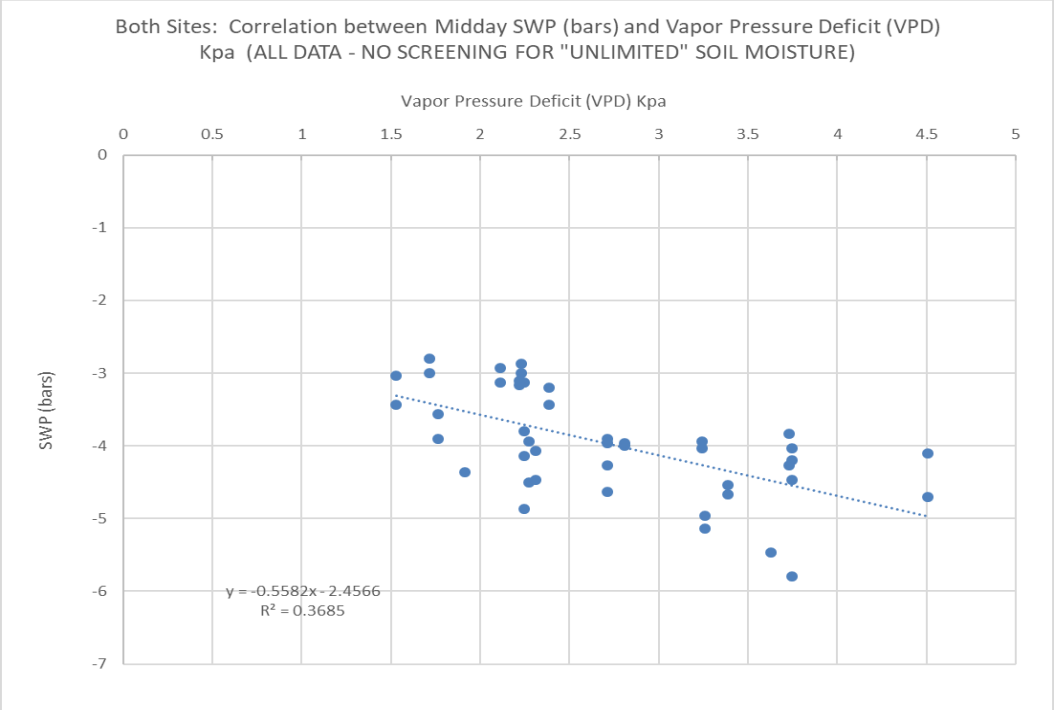

Table 2 provides a draft table of fully irrigated baseline SWP predictions over a range of weather conditions. The fully irrigated baseline prediction is an estimate of the least stressed level of tree water status that would be expected under specific weather conditions. These results suggest that SWP levels for pecan are most similar to walnut and much different than almond, prune, or olive. The table suggests that very low levels of tree water stress (less negative) of -3.0 bars may be anticipated when air temperatures are low and relative humidity are high (e.g. at 70°F and 65 percent relative humidity). When temperatures are extremely high and relative humidity is very low (e.g. 110°F and 10 percent relative humidity) the anticipated least stressed level of tree water status for pecan would be about -6.9 bars tension.

Table 2. Draft table of predicted midday stem water potential (SWP) levels across a range of weather conditions for pecans grown in California.

Air	Air Relative Humidity															
Temp (F)	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
60	-3.34	-3.30	-3.25	-3.20	-3.15	-3.10	-3.05	-3.00	-2.95	-2.90	-2.85	-2.80	-2.75	-2.70	-2.65	-2.60
62	-3.41	-3.36	-3.30	-3.25	-3.20	-3.14	-3.09	-3.04	-2.99	-2.93	-2.88	-2.83	-2.77	-2.72	-2.67	-2.62
64	-3.48	-3.42	-3.37	-3.31	-3.25	-3.20	-3.14	-3.08	-3.02	-2.97	-2.91	-2.85	-2.80	-2.74	-2.68	-2.63
66	-3.55	-3.49	-3.43	-3.37	-3.31	-3.25	-3.19	-3.13	-3.07	-3.00	-2.94	-2.88	-2.82	-2.76	-2.70	-2.64
68	-3.63	-3.57	-3.50	-3.44	-3.37	-3.30	-3.24	-3.17	-3.11	-3.04	-2.98	-2.91	-2.85	-2.78	-2.72	-2.65
70	-3.71	-3.64	-3.57	-3.50	-3.44	-3.37	-3.30	-3.23	-3.16	-3.09	-3.02	-2.95	-2.88	-2.81	-2.74	-2.67
72	-3.80	-3.73	-3.65	-3.58	-3.50	-3.43	-3.35	-3.28	-3.20	-3.13	-3.05	-2.98	-2.91	-2.83	-2.76	-2.68
74	-3.90	-3.82	-3.74	-3.66	-3.58	-3.50	-3.42	-3.34	-3.26	-3.18	-3.10	-3.02	-2.94	-2.86	-2.78	-2.70
76	-4.00	-3.91	-3.83	-3.74	-3.65	-3.57	-3.48	-3.40	-3.31	-3.23	-3.14	-3.06	-2.97	-2.88	-2.80	-2.71
78	-4.10	-4.01	-3.92	-3.83	-3.74	-3.64	-3.55	-3.46	-3.37	-3.28	-3.19	-3.10	-3.00	-2.91	-2.82	-2.73
80	-4.21	-4.12	-4.02	-3.92	-3.82	-3.73	-3.63	-3.53	-3.43	-3.33	-3.24	-3.14	-3.04	-2.94	-2.85	-2.75
82	-4.33	-4.23	-4.12	-4.02	-3.91	-3.81	-3.71	-3.60	-3.50	-3.39	-3.29	-3.19	-3.08	-2.98	-2.87	-2.77
84	-4.46	-4.35	-4.23	-4.12	-4.01	-3.90	-3.79	-3.68	-3.57	-3.46	-3.35	-3.23	-3.12	-3.01	-2.90	-2.79
86	-4.59	-4.47	-4.35	-4.23	-4.11	-4.00	-3.88	-3.76	-3.64	-3.52	-3.40	-3.29	-3.17	-3.05	-2.93	-2.81
88	-4.73	-4.60	-4.48	-4.35	-4.22	-4.10	-3.97	-3.84	-3.72	-3.59	-3.47	-3.34	-3.21	-3.09	-2.96	-2.84
90	-4.88	-4.74	-4.61	-4.47	-4.34	-4.20	-4.07	-3.93	-3.80	-3.67	-3.53	-3.40	-3.26	-3.13	-2.99	-2.86
92	-5.03	-4.89	-4.75	-4.60	-4.46	-4.32	-4.17	-4.03	-3.89	-3.74	-3.60	-3.46	-3.31	-3.17	-3.03	-2.89
94	-5.20	-5.04	-4.89	-4.74	-4.59	-4.43	-4.28	-4.13	-3.98	-3.83	-3.67	-3.52	-3.37	-3.22	-3.07	-2.91
96	-5.37	-5.21	-5.05	-4.88	-4.72	-4.56	-4.40	-4.24	-4.07	-3.91	-3.75	-3.59	-3.43	-3.27	-3.10	-2.94
98	-5.55	-5.38	-5.21	-5.04	-4.86	-4.69	-4.52	-4.35	-4.18	-4.00	-3.83	-3.66	-3.49	-3.32	-3.14	-2.97
100	-5.74	-5.56	-5.38	-5.20	-5.01	-4.83	-4.65	-4.47	-4.28	-4.10	-3.92	-3.74	-3.55	-3.37	-3.19	-3.00
102	-5.95	-5.75	-5.56	-5.37	-5.17	-4.98	-4.78	-4.59	-4.40	-4.20	-4.01	-3.81	-3.62	-3.43	-3.23	-3.04
104	-6.16	-5.96	-5.75	-5.54	-5.34	-5.13	-4.93	-4.72	-4.52	-4.31	-4.10	-3.90	-3.69	-3.49	-3.28	-3.07
106	-6.39	-6.17	-5.95	-5.73	-5.51	-5.30	-5.08	-4.86	-4.64	-4.42	-4.20	-3.99	-3.77	-3.55	-3.33	-3.11
108	-6.62	-6.39	-6.16	-5.93	-5.70	-5.47	-5.23	-5.00	-4.77	-4.54	-4.31	-4.08	-3.85	-3.61	-3.38	-3.15
110	-6.87	-6.63	-6.38	-6.14	-5.89	-5.65	-5.40	-5.16	-4.91	-4.66	-4.42	-4.17	-3.93	-3.68	-3.44	-3.19
112	-7.13	-6.87	-6.61	-6.36	-6.10	-5.84	-5.58	-5.32	-5.06	-4.80	-4.54	-4.28	-4.02	-3.76	-3.50	-3.24
114	-7.41	-7.13	-6.86	-6.58	-6.31	-6.03	-5.76	-5.48	-5.21	-4.93	-4.66	-4.38	-4.11	-3.83	-3.56	-3.28
116	-7.70	-7.41	-7.12	-6.83	-6.53	-6.24	-5.95	-5.66	-5.37	-5.08	-4.79	-4.50	-4.20	-3.91	-3.62	-3.33
118	-8.00	-7.69	-7.39	-7.08	-6.77	-6.46	-6.15	-5.85	-5.54	-5.23	-4.92	-4.61	-4.31	-4.00	-3.69	-3.38
120	-8.32	-7.99	-7.67	-7.34	-7.02	-6.69	-6.37	-6.04	-5.71	-5.39	-5.06	-4.74	-4.41	-4.09	-3.76	-3.43

Predicted SWP for more common weather conditions