Consumptive Use and Irrigation Water Requirements for Washington

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Introduction

The competition and demand for Washington State's already limited water resources will increase steadily over time due to the following emerging issues: (1) the water demand to produce food to feed a growing population, (2) increased summer water shortages predicted as a result of climate change, (3) increased water demand to irrigate and grow biofuel crops, and (4) the need to maintain and restore in-stream flows for aquatic and riparian wildlife habitat. Washington's water resources are already over-allocated. Good data is required to manage these water resources.

Irrigation and evaporation are responsible for the large majority of water diversion and consumptive water use in the western United States. The Washington evapotranspiration (ET) and consumptive irrigation water requirements tables (crop water use tables) that are currently published in the Washington Irrigation Guide, published and maintained by the USDA Natural Resource Conservation Service. These numbers are used extensively throughout the state for irrigation system design and planning, irrigation scheduling and management, evaporation pond and wetland designs, water rights discussions, water rights transfers, river basin planning and management, and hydrologic studies. The crop water use estimates currently being used were created in the early 1980's using, what would now be considered, outdated methods. The data and methods used to calculate the values in these nearly 30 year old tables, including crop coefficients, are not well documented. With changes in climate, crops, and irrigation systems, these values may have changed. Since the original 1985 publication, more accurate methods of calculating evapotranspiration have been developed that use more detailed weather data elements. In the past 25 years, the weather data needed by these models have been collected with greater accuracy and spatial density and are much more readily available. The existing tables are not available in electronic format and are therefore difficult for the public to access and use.

These consumptive crop water use and irrigation water requirements tables were updated using current weather data, and more current and accurate methods, evapotranspiration equations and crop coefficients. Additional locations and crops were added to expand the existing tables. The data and methods used are described here. This updated and more accurate data should be the basis for more equitable and informed water rights decisions, irrigation system designs, evaporation pond design, and irrigation water management decisions. Decisions made on more accurate data should result in better decisions for water quality and quantity management as well as improved profitability for agricultural producers.

Evapotranspiration Calculation Approach

Crop water use is composed of the water evaporated from wet soil and leaves and that transpired through the leaves of the plant. Together these are called evapotranspiration (ET) and represent the amount of water that is required to grow and maintain healthy plants. The rate of evapotranspiration (ET) from soil and vegetated surfaces is dependent on the atmospheric demand for water and the surface characteristics (local conditions) (Doorenbos and Pruitt 1977). The most common and cost-effective way to estimate crop ET (ET_c) over a large area is by using an energy balance based on meteorological data to calculate the ET of a reference crop (ET_r) at a standard growth stage and then multiply this by a coefficient or crop factor (K_c) that takes into account a particular crop's growth characteristics and growth stage (Allen et al., 1998).

$$ET_c = K_c \times ET_r \tag{1}$$

Reference Evapotranspiration

Reference evapotranspiration (ET_r) is defined as an evapotranspiration rate from a fully vegetated reference crop that is actively growing, is not short of water, and is of a standardized uniform height. There are two different reference crops that are commonly used: alfalfa, and grass (Doorenbos and Pruitt, 1977). Grass reference ET is commonly referred to as ET_o to differentiate it from alfalfa reference ET_r. Alfalfa reference ET is about 1.1 to 1.4 times that of grass reference ET, due to its increased height, surface roughness, and leaf area compared to grass. However alfalfa reference ET is most commonly about 20% higher than grass reference ET. The calculation of reference ET has been extensively studied and there are numerous, and varied methods for doing it. The nine most well known methods are: 1963 Penman, FAO24 Penman, 1982 Kimberly Penman, CIMIS Penman (Pruitt, 1991), ASCE Penman-Monteith (Jensen, 1990), FAO56 Penman-Monteith (Allen, 1998), Jensen-Haise (Kruse and Haise, 1974), 1985 Hargreaves (Hargreaves and Samani, 1982), and evaporation. Some of these methods use only temperature data, but the Penman-based equations, which are more accurate and adaptable across different climates required temperature, wind speed, humidity, and solar radiation data. These equations are rather drawn out and complicated.

Because there are differences in the results from these various equations, crop coefficients are not directly transferrable from one equation to the other. This is problematic as the development of accurate crop coefficients is expensive and time consuming. Therefore, to help create a standard method for calculating reference ET, an American Society of Civil Engineers (ASCE) technical committee on Evapotranspiration in Irrigation and Hydrology (ASCE EWRI, 2005) reviewed many papers and analyses on ET in an attempt to find a standard. Based on a review of the reference ET calculated at over 49 sites in the United States, they selected a revised version of the FAO56 Penman-Monteith equation as the standard (Allen et al., 2005) and recommended to use it across the United States. The report of this committee is included as Appendix 5. It was revised to be easily convertible from grass to alfalfa reference. The standardization helps facilitate the transferability of crop coefficients among different climate conditions. *The Standardized ASCE Penman-Monteith method was used in this study to calculate ETr.*

Importance of Weather Station Location

Reference ET equations were developed using weather measurement stations sited in the center of green, well-watered fields, with nothing but the crop to limit wind speed or to cause wind turbulence. Therefore accurate estimation of reference ET requires weather stations surrounded by green, well-watered and clipped grass for long distances surrounding the station and with uninterrupted wind.

Weather Data Sources

To calculate crop water requirements for different areas of Washington State long term historical weather data was needed that included temperature, humidity, wind speed, and solar radiation. Because of the variability in weather and seasons, whenever possible 30 years of data were used to give representative averages as well as estimates of variability around that average. Historical weather data came from five different data sources:

COOP (Cooperative Observer Program): This data is collected by mostly volunteers and is overseen by the National Weather Service (NWS). It consists primarily of maximum and minimum air temperatures, snowfall and 24 hour precipitation totals. Because of this they are sometimes referred to as maximum/minimum temperature stations (MMTS). There are more of these stations than any other data set and these stations tend to have the longest recorded history. This data was obtained directly through the National Climate Data Center (NCDC) website (http://cdo.ncdc.noaa.gov/CDO/dataproduct). These are often located in good locations to represent agricultural conditions. However, humidity, wind, and solar radiation data had to be estimated for these stations to use the ASCE Penman-Monteith Equation.

Agrimet (US Bureau of Reclamation): The U.S. Bureau of Reclamation maintains a network of weather stations throughout the Pacific Northwest. These stations are specifically for agricultural weather data collection and the computation of evapotranspiration rates and are therefore mostly located in locations that represent areas that crops are grown in. These stations contain a complete data set for calculating the full ASCE Penman-Monteith equation. The stations are well maintained and the data is manually viewed and errors are corrected on a daily basis. However, there aren't very many of these stations in Washington compared to other networks. 30 year historical data was obtained from the Agrimet Website (www.usbr.gov/pn/agrimet accessed on 8/27/2008). Because of this, no data error checking or corrections were necessary with this data set.

AgWeatherNet (Washington State University): Washington State University sponsors a newer network of weather stations within Washington whose main purpose is to collect data for agricultural production purposes (weather.wsu.edu). They are generally well located for the accurate data collection for calculating evapotranspiration. These stations contain a complete data set for calculating the full ASCE Penman-Monteith equation. The drawback to these stations is that they have limited data history (5-20 years) and no data quality or error checking system in place. Data was obtained directly from the active database.

ASOS/AWOS (Automated Service Observation System - Automated Weather Observation System): Most of these are automated weather stations located at airports. The main customers of this data are for airport traffic safety, and for weather forecasting. It is also overseen by the National Weather Service (NWS). A download of this data was obtained from the Washington State Climatologist. We wanted to get a longer history so after consulting with the climatologist we obtained the data directly through the National Climate Data Center (NCDC) website (http://cdo.ncdc.noaa.gov/CDO/dataproduct). By doing this we added some stations that the climatologist hadn't included, and also wasn't able to get some stations that the climatologist sent. The data set has everything necessary to calculate ET except for solar radiation. Since most of these are located at airports, the temperature data and humidity data is likely compromised by the large tarmacs and buildings that surround them.

After collecting as much data as possible, many stations were removed or combined with other data sets using the following criteria:

- Stations in remote locations with little agricultural significance were not included (such as mountain tops).
- Stations that were redundant were combined with other datasets.
- COOP and ASOS stations with very short histories < 20 years were discarded.
- Stations whose data ended over 30-40 years ago were sometimes used, but if more recent data was available then the more recent data was used instead.
- The AgWeatherNet data set included data from some private weather stations. These stations were removed.

AgWeatherNet Data Error Checking and Corrections

The AgWeatherNet data sometimes had significant errors in it. Data errors are caused by faulty sensors, broken or damaged weather stations, data collection mishaps, and human errors. These data errors are not uncommon and would greatly throw off the calculations and make the calculated ET data unusable unless they were corrected. Therefore all data had to be manually reviewed and either corrected, or set to "missing". Methods of data review and correction are described below.

Solar Radiation: The evapotranspiration equations are very sensitive to solar radiation. The solar radiation for each year was plotted against the theoretical clear sky radiation. If the measured data is accurate then some days should be equivalent to the clear sky solar radiation, with cloudy days less than that theoretical maximum. The data was corrected by multiplying by a factor to adjust it so that clear days (maximums) matched theoretical clear sky radiation for that latitude, and elevation. The corrections made are given in Appendix 2.

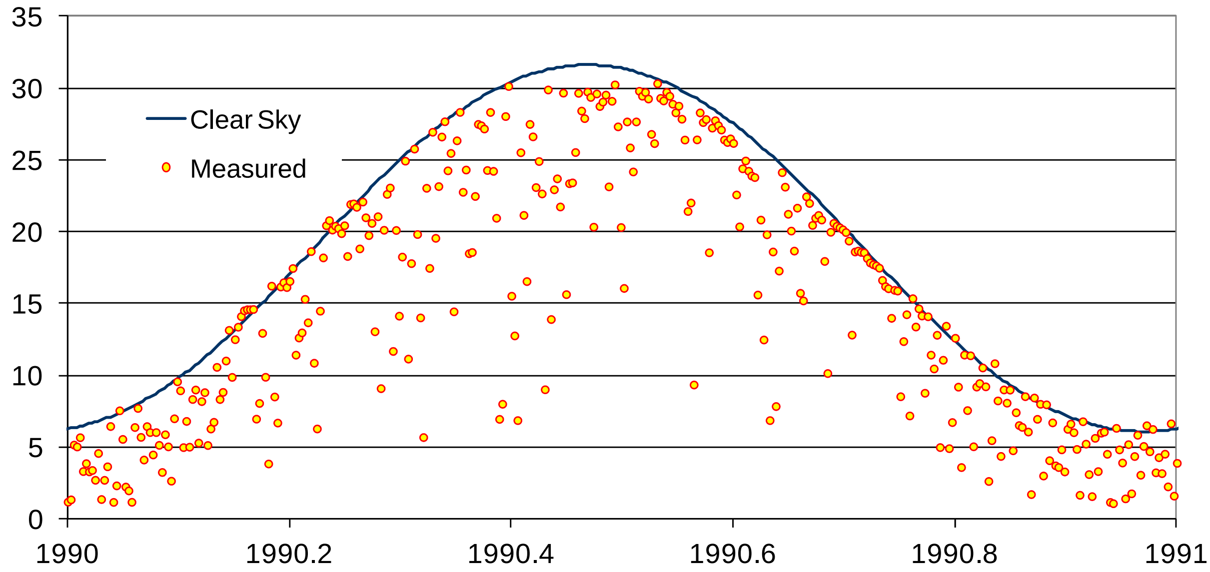


Figure 1. Example of comparing measured solar radiation to calculated clear sky solar radiation.

Temperatures and Humidity: The daily maximum and minimum temperatures were plotted to look for unbelievable values (Tmax > 200 deg F, etc...). Humidity data was converted to the dew point temperature and plotted on the same graph. Dew point shouldn't be significantly lower than the daily minimum temperature. If unbelievable values were found they were set to "missing" instead of trying to correct them.

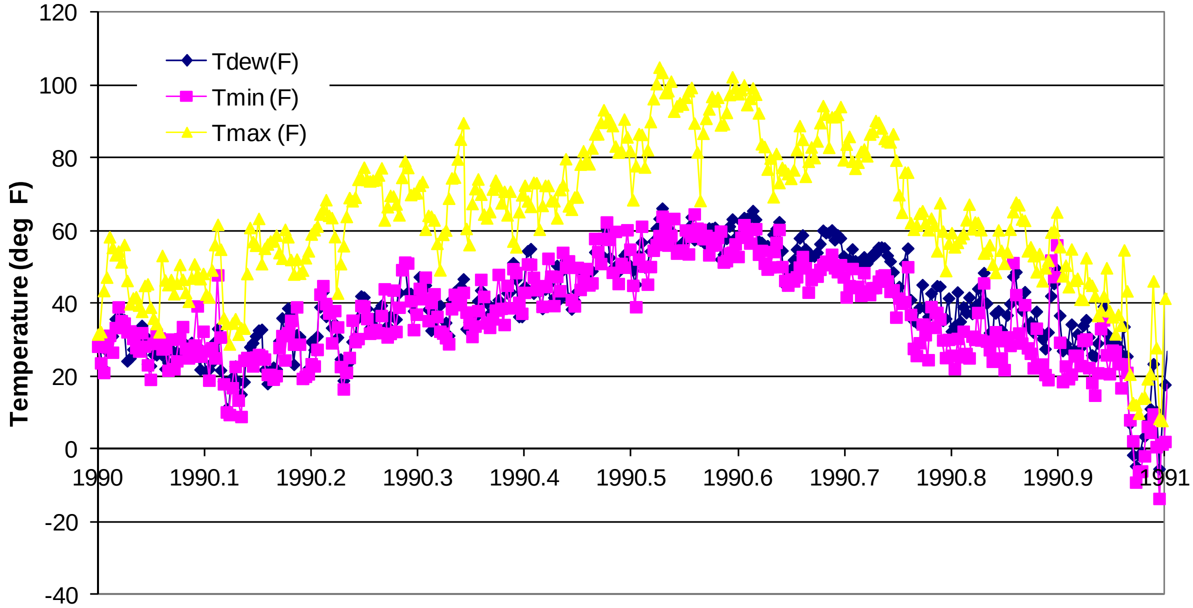


Figure 2. Example of daily maximum, minimum, and dew point temperatures plotted to look for anomalies and obvious errors.

Wind Speed: These values were mostly left alone since it is difficult to determine if the values were errant due to the highly variable nature of windspeed.

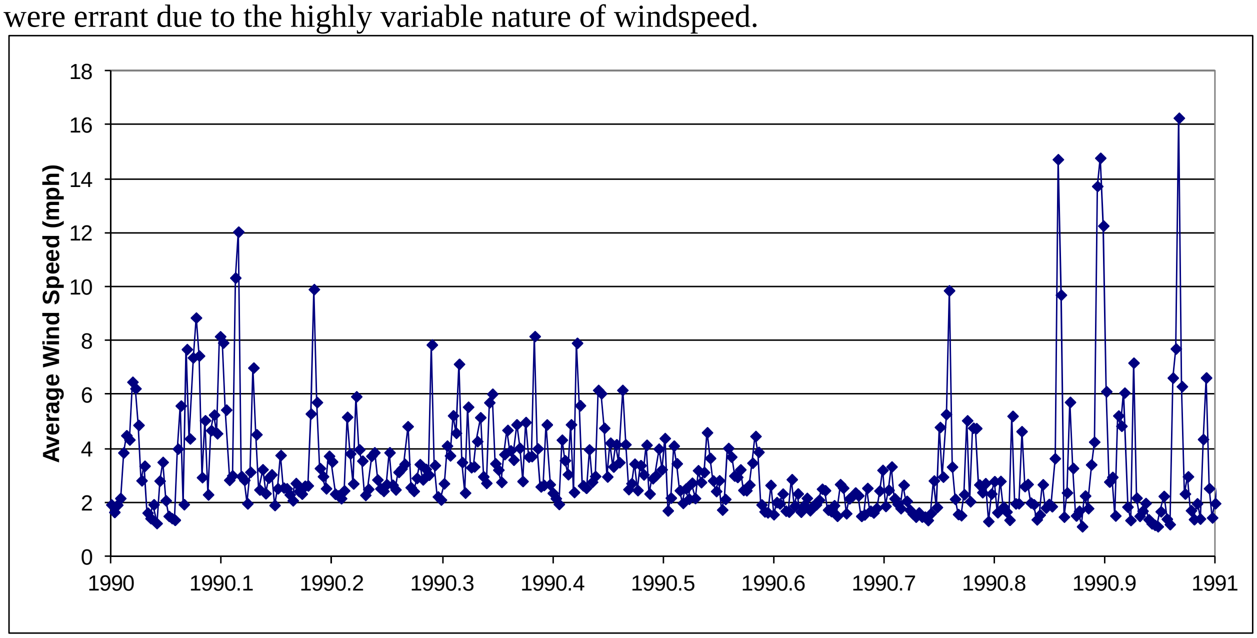


Figure 3. Example of daily wind speed plotted to look for anomalies and obvious errors in the data.

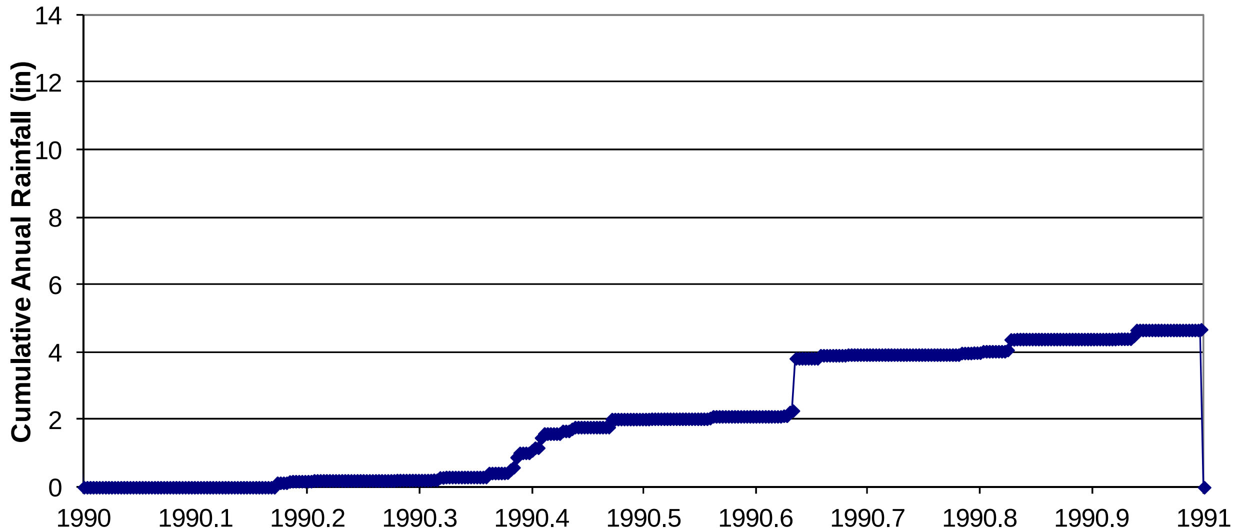


Figure 4. Example of annual cumulative precipitation plotted to look for anomalies and data errors.

After this data was cleaned up, it was handed off to Roger Nelson who assisted greatly using custom programmed procedures implemented within the ClimGen program that was developed by Claudio Stockle and Roger Nelson (available at http://www.bsyse.wsu.edu/ CS_Suite/ ClimGen/index.html).

COOP and ASOS Data Error Checking

The COOP and ASOS weather data was checked visually and progamatically using ClimGen and out-of-bounds data was set to missing if:

- solar radiation was visually different from the theoretical clear sky radiation,
- the relative humidity was greater than 100% or less that 0, or
- there were temperatures were greater than 160 degrees F or less than -60 degrees F.

If data for the entire day was missing, it was left as missing and was not included in the long term historical average for that station and for that day of year.

Estimating Missing Data Parameters

In order to use the full ASCE Penman-Monteith equation, the missing solar radiation, wind, and humidity data had to be estimated for all of the COOP stations. Also in the case of data errors or omissions in the AgWeatherNet or AgriMet data sets, other missing or errant data parameters had to be estimated.

Missing data was spatially interpolated from any station within a 50 km (30 mile) radius that had a measured value for that parameter. The spatial interpolation used Shepard's Inverse Distance Method (Shepard, 1968). This resulted in a weighted average of each weather element was taken based on distance from the contributing stations to the target station, such that the closer stations were more heavily weighted than the further stations. Maximum and minimum temperatures were also adjusted for lapse rate.

Because of the biases in the ASOS weather stations, they were only used as a data source for average dew point interpolations for stations that didn't have humidity data.

In the COOP data set and especially in Eastern Washington there were a large number of days where precipitation was left as missing. This was most likely because precipitation is very uncommon in Eastern Washington and it was not recorded as zero on the typical day that it didn't rain. Because of this, and because of the unpredictable and highly spatially variable nature of precipitation, precipitation data was not interpolated, but was assumed to be zero.

Many COOP (MMTS) stations weren't close enough (within the 50km radius) to be comfortable with interpolating data from "full data" stations. This caused a few holes in the station coverage in some areas of the state, notably the far western shore of Washington. In these cases a calibrated for of the Hargreaves equation was used which is a temperature-only reference ET equation. These Hargreaves equations were individually calibrated using the nearest "full data" weather station to find a constant correction coefficient for that climatic region. This calibrated Hargreaves equation was used to make reference ET estimates for these stations.

The data analysis included over 200 weather stations and 30 years of daily historical data for each station. When necessary the described interpolations were made for each day and for each station using data from the nearby stations. Including the trouble-shooting, this constituted a large amount of computing time. From these data the 30 year historical average reference ETr values for each day of the year at each station were calculated, along with statistical measures of variability of this estimate.

Review and Comparison of Reference ET.

To review the results a pasture crop coefficient with constant season start and end dates was used with the 30 year average reference ET from each station and the totals were plotted on a map and reviewed by Troy Peters and Leigh Nelson. After reviewing these stations some additional stations were chosen to be removed from the data set. This is because either the stations were redundant with other nearby stations, or because there was obvious problems with the data, most likely due to the weather station siting. In general the "best" station of a close group was retained based on the most robust data source, more representative location, and the longest data history. Station data was not modified or "tweaked" in any way, the stations were simply removed. Based on the variability between stations that should have been the same, we feel that the accuracy of the results are within 10-15%.

Currently, the Washington Irrigation Guide (WIG by Washington State Conservation Engineering) contains 76 selected National Weather Service (NWS) stations. In this revised project, weather data from 211 stations from NWS, Agrimet and Washington AgWeatherNet were used in our calculations. Table 1 in Appendix 1 gives the weather stations that were used in this project.

Crop Coefficients

The crop coefficient (K_c) represents the effects of crop growth stage, soil resistance, crop height, and surface reflectance on a plant's water use. It changes as plants grow and develop. There are two approaches for applying K_c values. The first approach uses a mean (average) K_c where evaporation of water from the soil and plant surface is averaged into the K_c value on a particular day, with an assumption of an average wetting interval. The second approach is the dual K_c method, where the K_c value is divided into evaporation (K_e) and transpiration or a basal crop coefficient (K_b) that represents the actual plant water use and a separate component which represents evaporation from the soil and plant that changes with the wetting cycle. These are then used together to represent the total crop coefficient where $K_c = K_b + K_e$. Because evaporation is calculated separately, using the dual crop coefficient method requires an accurate estimation of irrigation or rainfall wetting cycles. This in turn requires knowledge of the daily soil water balance, and therefore multiple assumptions about the soil water holding capacity, soil depth, rooting depth, and irrigation system type and capability. Because of the great variability of these physical property variables across Washington State and unpredictability of their changes over time (crop rotations and irrigation system changes), we have chosen to use the mean K_c value (e.g. Allen and Brockway, 1983).

Sources of Error and Variability in Crop Coefficients

- Historically crop coefficients have been developed using different reference ET equations that produce different reference ET values. Because of this crop coefficients are not directly transferrable from one equation to the other.
- Some crop coefficients were developed using grass reference ET, while others were done using alfalfa reference. Washington State has historically used alfalfa reference similar to most western states.
- Crop coefficients must change over time to accommodate the growing crop and its changing height, ground cover, and phenological stage. Just- emerged corn uses much less water than fully grown corn for example. Many crop coefficients are defined by planting, development, and harvest dates based on a day-of-year (DOY). However, these dates vary quite widely depending on the climate. Planting and harvest dates for the mountain valleys near Omak, WA are quite different from the Pasco, WA area for example.
- There are large varietal differences in crops. For example, there are short-season corn varieties, and long-season varieties with very different planting, and harvest dates. However, there is typically only a single curve for corn available.
- The research required to develop new crop coefficients is time consuming and expensive. It involves directly measuring actual crop water use. There are several methods to do this, but the most accurate is to use a weighing lysimeter. However, even with these there are large residuals (errors) between the measured data and the fitted K_c curves.
- Various sources use different methods to define crop coefficient curves. These include using the 4-stage method as outlined in FAO 56 (Allen, 1998), others use polynomials as done by Wright (1982), and some use the percentage of growth stage between important crop development stages. Most are defined based on the day-of-year (1-365), but some are defined based on percent crop cover, or growing degree day (GDD; as defined below).
- Theoretically reference ET is purely a function of weather and climate (location), while K_c is climate independent and is only a function of the crop and that crop's growth stage. In reality however, crop coefficients vary slightly by location and K_c values developed in one climate may not be accurate in another climate. Certainly, the day-of-year time basis for most curves is not directly transferrable across different climates.
- The evaporation component of evapotranspiration is very dependent on the irrigation system and irrigation frequency. Irrigation frequency is highly dependent on the soil type which is highly variable.

Commonly a crop coefficient is needed and an appropriate, research-based value from a similar climate, and created using the same reference equation is not available. In these cases values are estimated from crops with similar growth habits, or a value is used from a source that wasn't developed using similar reference ET or climate.

Sources of Crop Coefficients

The most relevant sources of crop coefficients for Washington State are as follows:

Jim Wright: These crop coefficients were developed by Jim Wright in Kimberly Idaho using a weighing lysimeter. They are based on the Kimberly Penman Equation, for use with alfalfa reference ET (ET_r), and the K_c curve is defined by polynomials (Wright, 1982).

California: These crop coefficients are compiled and used in the state of California. They are for use with the grass reference ET (ET_o), and based on a modified Penman equation (Cooperative extension University of California division of agriculture and natural resources, leaflet 21427 and 21428) with a wind function that was developed at the University of California, and is commonly referred to as the CIMIS Penman Equation. ET_o values based on the Penman-Monteith equation were also provided for the interested user. The K_c curves are defined by straight lines in four stages as outlined in FAO 56 (Allen, 1998).

Agrimet: This set of compiled crop coefficients (gathered by The Pacific Northwest Cooperative Agricultural Weather Network), for use with the alfalfa reference (ET_r), were based and developed using the Kimberly Penman-Monteith equation (Wright, 1982). The K_c curve is defined as a series of 21 points at various percentage-of-growth stages and straight line interpolation between these points. The zero percentage represents plant emergence or the break of dormancy, and it is set to start date and start point of crop coefficient curve. 100% represents the full cover date, and 200% is the termination date of the curve which can represent harvest or dormancy.

WISE: This set of crop coefficients is currently being used in Washington State and were compiled by Brian Leib for use with the Washington Irrigation Scheduling Expert (WISE) computer software tool. However, the values do not have a clear origin. The K_c curves are straight line interpolations between 6 points (B. G. Leib and T. V. Elliott).

FAO56: These coefficients are for use with grass reference ET (ET_o) and are defined in a 4-stage straight line. They are also for use with the FAO56 Penman-Monteith equation (Allen, 1998).

In Figure 5, an attempt was made to compare these different sources of crop coefficients by standardizing them to the same season start date, converting them all to % of growth season, and converting all grass-based Kc values to alfalfa-based values by multiplying by 0.80. The variability between the crop coefficients from different sources is clear.

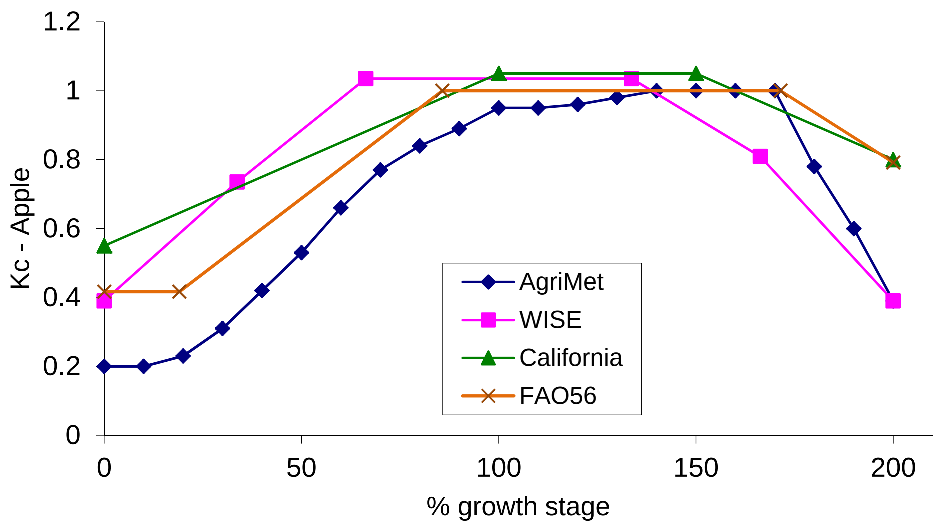


Figure5. An example comparison between Apple crop coefficients showing the variability between different sources.

Crop Coefficients Materials and Methods

After a thorough review of the existing literature, it was decided to primarily use Agrimet as a source of crop coefficients for Washington State (available at www.usbr.gov/pn/agrimet), with some noted modifications as necessary. The reasons for this choice are as follows:

- Most of the crop coefficients used by Agrimet were developed by careful field research, from weighing lysimeters by the USDA Agricultural Research Service at Kimberly, Idaho.
- Agrimet Kc values were well–documented, showing the origin of each crop coefficient.
- Most of these were developed in Kimberly, Idaho which has a fairly similar climate to Eastern Washington compared to other crop coefficient sources.
- Agrimet crop coefficients have been used for years in the Pacific Northwest and have gained a degree of acceptability.

Agrimet crop coefficients are defined by percentages of the growth stage with 0% being planting, and 100% typically being the full cover date, or date when the crop is fully grown. The interval between 0 and 100% is evenly divided into 10% increments with a crop coefficient defined at each of these. 200% is typically defined as the termination date when the crop is harvested, freezes, or goes into dormancy. The interval between 100 and 200% is also evenly divided into 10% increments. The crop coefficient curve is therefore defined by a series of 21 different points and three dates: the planting date, the full cover date, and the termination date.

Conversion for Use with the ASCE Penman-Monteith Equation

Agrimet crop coefficients were developed for use with the 1982 Kimberly Penman method of calculating reference ET (Wright, 1982). These crop coefficients must be adjusted for use with the ASCE Penman-Monteith reference equations. The methods used by Allen and Wright (2002) where followed where they converted Wright (1981) and Wright (1982) alfalfa-based crop coefficients, for use of the ASCE standardized Penman-Monteith reference evapotranspiration equation. They used the original historical weather data that was used to develop the crop coefficients in Kimberly, Idaho. However, we used historical weather data for Eastern Washington. Since

$$ET_c = K_c(Agrimet) \times ET_r(Kimberly) \tag{2}$$

where $K_c(Agrimet)$ are crop coefficients from Agrimet developed for use with the Kimberly Penman-Monteith equation or $ET_r(Kimberly)$, and since

$$ET_c = K_c(ASCE) \times ET_r(ASCE) \tag{3}$$

where $K_c(ASCE)$ are crop coefficients for use with the ASCE standardized Penman-Monteith equation or $ET_r(ASCE)$, then these equations can be combined to solve for new crop coefficients for use with the ASCE Penman-Monteith equation $K_c(ASCE)$ as shown below:

$$K_c(ASCE) = \frac{ET_r(Kimberly)}{ET_r(ASCE)} \times K_c(Agrimet) \tag{4}$$

We can simplify this ratio of the Kimberly ET_r to ASCE ET_r to a value R, as

$$R = \frac{ET_r(Kimberly)}{ET_r(ASCE)} \tag{5}$$

such that

$$K_c(ASCE) = R \times K_c(Agrimet) \tag{6}$$

R will change over the season and may change with climate.

To find R, the reference evapotranspiration based on the Kimberly Penman and the ASCE standardized Penman-Monteith, were computed on a daily time step for the 30 year average seasonal data for each station where available. We categorized the stations based on the different climate regions of the state: the eastern central, cascade, mountain east, northeast and west part, to check the variation of R values with climatic regions (Figure 6). The differences between these daily R values for different regions were small and within the variability of the station-to-station variability within the same region. Therefore, we chose to use the average R of *all* the weather stations in Washington State, to convert crop coefficients based on Kimberly reference equation to the ASCE standardized method. Because the continuous averaged R values still showed quite a bit of variability or unstability, 14 day rolling averages were taken to smooth the curve out as shown in Figure 7 below.

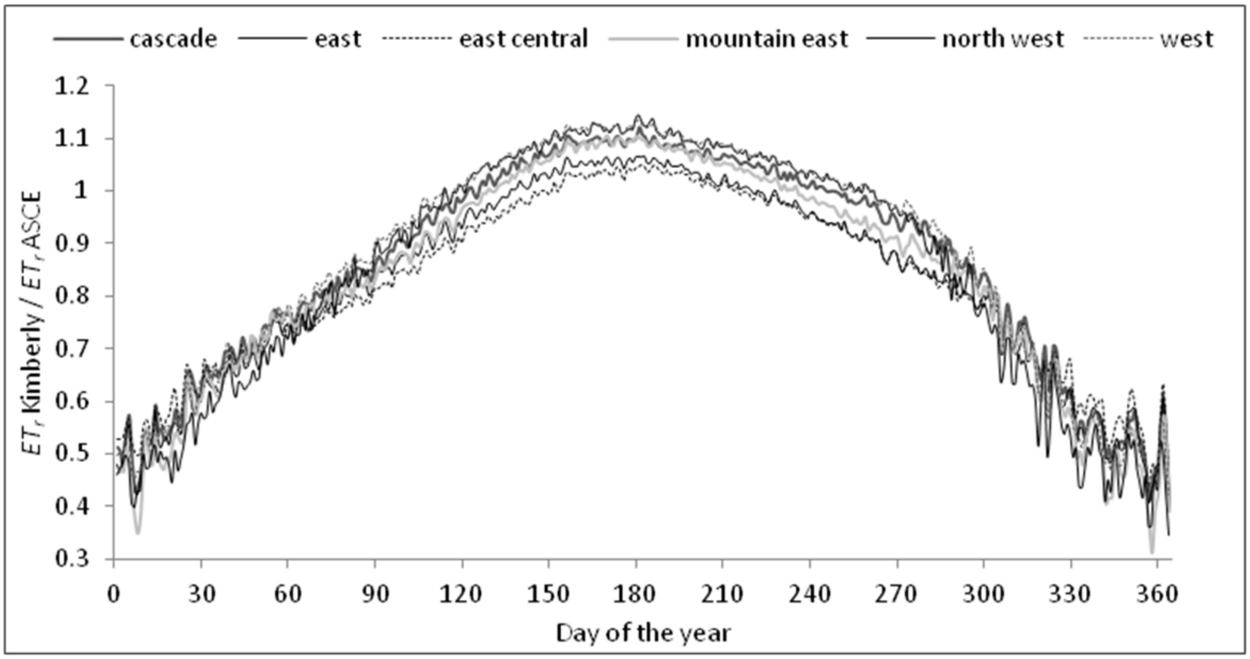


Figure 6. Daily *R* during a year for six different climate regions in Washington State.

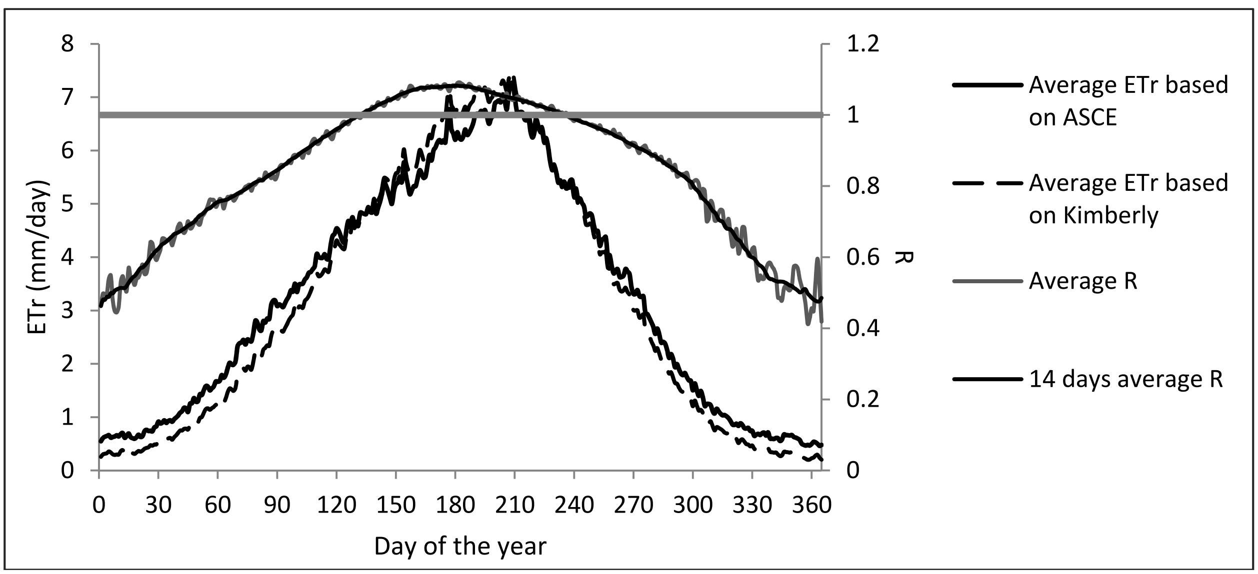


Figure 7. Comparison of reference evapotranspiration (ETr) based on the ASCE and Kimberly equations, and the ratio of ETr (Kimberly) / ETr (ASCE).

Figure 7 also shows the average calculated daily *ETr* values based on the Kimberly and ASCE standardized reference equations. During a summer and active growing period for most crops, *R* exceeds 1 which means the new ASCE crop coefficient becomes higher than the original Agrimet coefficient. However, during the winter, and early spring and fall *R* is less than 1, and the new crop coefficient becomes less than its previous value. By multiplying each crop's coefficients during its growth period by the corresponded daily *R* value for that date, crop coefficients based on the Kimberly equation were converted for use with the ASCE standardized method.

For those crops that are not included in Agrimet, FAO56 was used as a secondary source for crop coefficients. We also used original crop coefficients for a few crops that were developed by Wright (1982), based on lysimeter measurements in Kimberly, Idaho. For cheatgrass and sagebrush, we used the crop coefficients developed by Allen (2006), based on the vegetation index (NDVI) trends from LandSat images in the Minidoka area.

Table 3.1 in Appendix 3 gives the crops that were considered in this project and the source of crop coefficients for each crop. Also presented in Table 3.1 are three growth stage dates, which are: planting, full cover, and the harvest date.

Therefore, for the first step of developing crop coefficients based on days of the year, we considered the eastern central regions of Washington State. They were determined for each crop by considering the eastern central regions in Washington State (Prosser, Othello and Moses Lake).

Since different parts of Washington State have very different climates, it follows that they also have different planting, full cover, and termination dates in each region.

To determine growth stage in this region, we used the historical database of season growth dates for various crops in Washington State that was given to us by Agrimet. For those crops that are not included in Agrimet database, growth stage dates were obtain by contacting county extensions agents and experienced experts in these regions.

For those crops that are not in Agrimet, we primarily used crop coefficients from FAO56, which are based on the grass-reference FAO56 Penman-Monteith equation. The FAO56 Penman-Monteith equation is mathematically equivalent to the grass-based version of the ASCE Standardized Penman-Monteith equation. Therefore, to convert these grass-based crop coefficients to alfalfa-based, we used a similar method as was used to convert Kimberly Penman Kc values to ASCE Penman-Monteith Kc values. We calculated the reference ET based on FAO56 for grass and alfalfa, for all the stations. Then we multiplied the ratio of

$$\frac{ET_o(FAO56)}{ET_r(ASCE)}$$

by the grass-based Kc, to obtain new crop coefficients based on alfalfa reference ET. Our calculation shows the total average of this ratio is almost a constant value of 0.80, especially during the active growing season. This value is also recommended by FAO56 to use for converting grass-based crop coefficient to alfalfa-based. The FAO56 ET calculation method is essentially the same as the ASCE standardized method, and after converting from grass to alfalfa based crop coefficients there was no need to convert FAO56 to ASCE.

Conversion from day-of-year to GDD

Climates vary widely across Washington State. Western Washington has an oceanic climate, while the eastern central half of the state has a semi-arid climate. East of the Cascades, summers are hotter, winters are colder and precipitation is drastically less than that in western Washington. The mountainous areas of the state also have much cooler temperatures and often higher winds than other areas. The growing season start date, length, and termination date can vary widely across these different climates zones. Therefore the K_c curve doesn't translate well from one area of the state to the other if the season dates are based on the days of the year.

Natural season-to-season variability can also cause these planting, full cover, and harvest dates to be up to two weeks earlier or later from year to year due to temperature differences.

Crop growth and phenological stages are regulated mainly by temperature. The use of growing degree days (GDD, or heat units) is a widely accepted method for predicting crop development. By converting x-axis of the crop coefficient curve from day-of-year to growing degree days, we can more readily use the same K_c curves across the whole state. These will then automatically adjust the lengths of growth periods for each crop. Using K_c curves based on GDD also will help automatically account for variations in climate and year-to-year temperature differences.

GDD is related to the amount of heat that a crop experiences during its growing period. It is calculated by subtracting the daily mean temperature from a base temperature (*Tbase*), which is needed for active growth of the organism. This method had been used in previous studies for developing crop coefficient curves (Howell, 1997, Snyder, 1999, deTar, 2004, Marek, 2006). The basic equation for the GDD is:

$$GDD = max(\frac{Tmax+Tmin}{2} - Tbase, 0) \tag{7}$$

where *Tmax* and *Tmin* are the daily maximum and minimum temperatures. Depending on the crop *Tbase* is either 0, 5, or 10 degrees C. These base temperatures (*Tbase*) for each crop were obtained by literature review. Corn has its own standard method to calculate GDD:

$$\text{GDDcorn} = \frac{\max(\min(\text{Tmax},30),10)+\max(\min(\text{Tmin},30),10)}{2} - 10 \tag{8}$$

The standard corn equation has a maximum threshold of 30 degrees C and minimum threshold of 10 degrees C.

To demonstrate how the crop coefficients were converted from being based on day-of-year to GDD, let us follow the process for sugar beets. Three close stations in the eastern central part of Washington were selected (WSU Othello, Moses Lake and Prosser) and an average planting, full cover, and harvest dates nearby those stations for sugar beets was made. Historical dates came from a database of historical dates in this region from the Agrimet program and were confirmed through consultations with county extensions agents and other experts with experience in the region. We selected those three stations in eastern central parts, because the planting dates of sugar beets are identified in this area and because the climate in these locations is similar to where the crop coefficients were developed. GDD and then cumulative GDD (CGDD) were calculated from the 1st of January, based on the average weather data in these stations.

The 21 points of the crop coefficient curve were then correlated with the CGDD at that corresponding day of year. This CGDD date then became the basis for the new K_c curve. This method was used to convert all crop coefficients that were based on percentage of growth stage and day of the year to a CGDD base. The planting dates and durations of growing seasons for all crops in western parts were determined by CGDD, and corroborated against historical records provided by WSU extension agents from the respective regions. In some stations the CGDDs is not enough to fully mature some crops in that area.

The results are included in Appendix 4. Each crop has a table that shows the previous AgriMet and the new converted crop coefficients using *R*. The fitted CGDD dates are also given for each crop that corresponds with the day of year (DOY) from central Washington. For each crop, two curves were developed to demonstrate the difference between Kimberly or FAO based crop coefficients.

The new converted ASCE standardized based crop coefficients and crop coefficients based on CGDD can be used in areas with different climates in Washington State. Growing degree days were computed based on an average of 30 years of historical data for each station, by using the specific base temperature which is necessary for crop growth.

Conclusion

Accurate estimates of consumptive use and irrigation water requirements are useful and important to the state of Washington. Reference ET was calculated using the Standardized ASCE Penman-Monteith Equation. All Crop coefficients for computing crop evapotranspiration (water use) in Washington State, have been updated for the irrigated agricultural areas. All of the crop coefficients for the most important crops in Washington State were collected and converted for use with the ASCE standardized Penman-Monteith equation and some of them to FAO56 alfalfa based. We used the changing ratio of $\frac{\text{ETr (kimberly)}}{\text{ETr (ASCE)}}$ and $\frac{\text{ETr (FAO56)}}{\text{ET0 (FAO56)}}$to do the conversion.

All crop coefficients that were based on the day-of-year in eastern central parts of Washington, were converted to be based on cumulative growing degree days, to make them applicable to all climatic areas of the state. We checked planting dates (planning, full cover and harvest/termination) for all the crops in eastern central Washington with the county extensions agents, irrigation designers and/or commodity commission personnel to make sure of its validation. Also the total water use, for a few stations in different parts of Washington, were calculated for those crops that were in the previous water requirement report.

References/Bibliography

1. Allen, R. G., Pereira, L. S., Raes, D., and Smith, M. 1998. Crop evapotranspiration: Guidelines for computing crop requirements. Irrigation and Drainage Paper No. 56, FAO, Rome, Italy.
2. Allen, R. G., Walter, I. A., Elliott, R., Mecham, B., Jensen, M. E., Itenfisu, D., Howell, T. A., Snyder, R., Brown, P., Eching, S., Spofford, T., Hattendorf, M., Cuenca, R. H., Wright, J. L. and Martin, D. 2000. Issues, requirements and challenges in selecting and specifying a standardized ET equation. Proc., 4th National Irrig. Symp., ASAE, Phoenix, AZ.
3. Allen, R.G. and C. E. Brockway. 1983. Estimating Consumptive Irrigation Requirements for Crops in Idaho, Research Technical Completion Report, Idaho Water and Energy Resources Research Institute, University Idaho, Moscow, ID
4. Allen, R.G., I.A. Walter, R. Elliott, T. Howell, D. Itenfisu, and M. Jensen. 2005. The ASCE Standardized Reference Evapotranspiration Equation. Prepared by the Task Committee on Standardization of Reference Evapotranspiration of the Environmental and Water Resouces Institute of the American Society of Civil Engineers.
5. Allen, R.G. and J.L. Wright. 2002 and 2006. Conversion of Wright 1981 and Wright 1982 alfalfa based crop coefficients for use with the ASCE Standardized Penman-Monteith Reference Evapotranspiration Equation. Unpublished Univ. of Idaho report.
6. Allen, R.G., M. Tasumi, J.L. Wright, R. Trezza, I. Lorite, C. Robison. 2006. Satellite based ET mapping for agricultural water management: Estimating evapotranspiration by NDVI. In preparation for submission to Ag. Wat. Man.
7. Allen, R.G., Robinson, C.V. 2006 (revised 2007). Evapotranspiration and consumptive irrigation requirements for Idaho.
8. Allen, R.G., W.O. Pruitt, J.L. Wright, T.A. Howell, F. Ventura, R. Snyder, D. Itenfisu, P. Steduto, J. Berengena, J. Baselga Yrisarry, M. Smith, L.S. Pereira, D. Raes, A. Perrier, I. Alves, I. Walter, R. Elliott. 2005b. A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO56 Penman-Monteith method. Agricultural Water Management. 81:1–22.
9. ASABE Pap. No: 062206, 2006 ASABE Ann. Int. Mtg, Portland, Oregon, 9–12 July 2006, 11 p.
10. ASCE EWRI 2005. The ASCE Standardized reference evapotranspiration equation. ASCE EWRI Standardization of Reference Evapotranspiration Task Committee Report.
11. B. G. Leib and T. V. Elliott. Washington irrigation scheduling expert (WISE) software.

12. Boegh, E., H. Soegaard, and A. Thomsen. 2002. Evaluating evapotranspiration rates and surface conditions using Landsat TM to estimate atmospheric resistance and surface resistance. Remote Sensing Environ. 79(2–3): 329–343.
13. Calendar and heat unit based crop coefficients in the Texas High Plains Evapotranspiration Network.
14. Chehbouni, A., D. Lo Seen, E. G. Njoku, and B. A. Monteny. 1996. Examination of the difference between radiative and aerodynamic surface temperatures over sparsely vegetated surfaces. Remote Sens. Environ. 58(2): 176–186.
15. Choi, M., and J. M. Jacobs. 2007. Soil moisture variability of root zone profiles within SMEX02 remote sensing footprints. Adv. Water Resources 30(4): 883–896.
16. DeTar, W. R. 2004. Using a subsurface drip irrigation system to measure crop water use. Irrigation Science 23(3): 111–122.
17. Doorenbos, J., and Pruitt, W. O. 1977. Crop water requirements. Irrigation and Drainage Paper No. 24, FAO, Rome.
18. Evett, S. R., and G. W. Parkin. 2005. Advances in soil water content sensing: The continuing maturation of technology. Vadose Zone J. 4(4): 986–991.
19. Food and Agriculture Organization 1998. Crop evapotranspiration: Guidelines for computing crop requirements. http:// www.fao.org/docrep/X0490E/X0490E00.htm, accessed November 10, 2004.
20. Hargreaves, G. H., and Z. A. Samani. 1982. Estimating potential evapotranspiration.
21. Heilman, J. L., and E. T. Kanemasu. 1976. An evaluation of the resistance form of the energy balance to estimate evapotranspiration. Agron. J. 68(4): 607–611.
22. Howell, T. A., Steiner, J. L., Schneider, A. D., Evett, S. R., and Tolk, J. A. 1997. Seasonal and maximum daily evapotranspiration of irrigated winter wheat, sorghum, and corn. Southern High Plains. Trans. ASAE, 40(3), 623–634.
23. http://texaset.tamu.edu/coefs.php
24. http://www.cimis.water.ca.gov/cimis/infoEtoCropCo.jsp
25. http://www.kimberly.uidaho.edu/water/asceewri/
26. http://www.usbr.gov/pn/agrimet/cropcurves/crop_curves.html

27. Irmak, S., T. A. Howell, R. G. Allen, J. O. Payero, and D. L. Martin. 2005. Standardized ASCE Penman-Monteith: Impact of sum of hourly vs. 24 hour time step computations at reference weather station sites. Trans. ASAE 48(3): 10631077.
28. Jensen, M.E., Burman, R.D., and Allen, R.G. (ed). 1990. Evapotranspiration and Irrigation Water Requirements. ASCE Manuals and Reports on Engineering Practices No. 70., Am. Soc. Civil Engrs., New York, NY, 360 p
29. Kruse, E. G., and R. H. Haise. 1974. Water use by native grasses in high altitude Colorado meadows. Western Region report ARS W–6–1974. Washington, D.C.: USDA ARS.
30. Marek, T., P. Colaizzi, T.A. Howell, D. Dusek, and D. Porter. 2006. Estimating seasonal crop ET using
31. Moran, M. S., W. P. Kustas, A. Vidal, D. I. Stannard, J. H. Blanford, and W. D. Nichols. 1994. Use of ground-based remotely sensed data for surface energy balance evaluation of a semi arid rangeland. Water Resour. Res. 30(5): 1339–1349.
32. Nachabe, M., N. Shah, M. Ross, and J. Vomacka. 2005. Evapotranspiration of two vegetation covers in a shallow water table environment. SSSA J. 69(2): 492–499.
33. Payero, J. O., C. M. U. Neale, J. L. Wright, and R. G. Allen. 2003. Guidelines for validating Bowen ratio data. Trans. ASAE 46(4): 1051–1060.
34. Penman, H. L. 1963. Vegetation and Hydrology. Tech. Comm. No. 53. Harpenden, England: Commonwealth Bureau of Soils
35. Pruitt, W. O. 1991. Development of crop coefficients using lysimeters. Lysimeters for Evapotranspiration and Environmental Measurements, Proc. of the ASCE Int. Symp. On Lysimetry, 182–190. R. G. Allen, T. A. Howell, W. O. Pruitt, I. A. Walter, and M. E. Jensen, eds., New York, N.Y.: American Soc. Civil Engineers.
36. Schneider, A. D., and T. A. Howell. 1991. Large, monolithic, weighing lysimeters. In Proc. Intl. Symp. Lysimetry, 37–45. R. G. Allen et al., eds. New York, N.Y.: ASCE.
37. Shepard, Donald (1968). "A two-dimensional interpolation function for irregularly-spaced data". Proceedings of the 1968 ACM National Conference. pp. 517–524. doi:10.1145/800186.810616.
38. Snyder, R. L., Spano. D., Cesaraccio, C., and Duce, P. 1999. Determining degree day thresholds from field observations Int. J. Biometerology, 42:177–182.
39. Tech. Note. J. Irrig. Drain. Eng. 108(3): 225–230. & Hargreaves, G. H., and Z. A. Samani. 1985. Reference crop evapotranspiration from temperature. Appl. Eng. Agric. 1(2): 96–99.

40. Wright, J. L. 1990. Comparison of ET measured with neutron moisture meters and weighing lysimeters. In Irrigation and Drainage, 202-209. S. R. Harris, ed. New York, N.Y.: ASCE.
41. Wright, J.L. 1982. New Evapotranspiration Crop Coefficients. J. Irrig. and Drain. Div., ASCE, 108:57–74.
42. Wright, J.L. 2001. Growing degree day functions for use with evapotranspiration crop coefficients. CDROM. American Society of Agronomy. Agronomy Abstracts.
43. Wright, J.L., 1981. Crop coefficients for estimates of daily crop evapotranspiration Irrig. Sched. For Water and Engergy Conserv. In the 80's, ASAE, p. 18–26. Wright, J.L. 1982. New Evapotranspiration Crop Coefficients. Journal of Irrigation and Drainage Division, ASCE, 108:57–74.
44. Wright, J.L., R.G. Allen, and T.A. Howell. 2000. Conversion between evapotranspiration references and methods. p. 251–259, Proc., 4th Decennial National Irrigation Symposium, Phoenix, AZ ,ASAE, St. Joseph, MI.

Appendix 1

Table 1.1. Stations used in Washington State

Station ID	Station Name	Latitude	Longitude	Elevation
100031	McNary	45.969	-119.258	247.050
100037	Coffin	46.041	-119.309	399.606
100039	Triple-S	46.214	-119.501	489.173
100059	Carlson	46.143	-119.461	490.157
100062	Paterson	45.939	-119.488	134.514
100064	Station 4	46.049	-119.413	393.701
100065	Wheelhouse	46.025	-119.528	290.026
100066	Station 2	45.967	-119.458	187.664
100067	Fourmile	45.990	-119.330	240.486
100069	FishHook	46.294	-118.741	253.281
100071	K2H	46.287	-118.643	367.126
100113	Finley	46.139	-119.059	162.402
100114	Benton City	46.269	-119.451	221.785
100128	Touchet	46.019	-118.678	180.774
100129	Horrigan	46.077	-119.769	456.365
100134	Eby	46.066	-119.075	498.360
100139	Gramling	46.124	-119.219	439.633
100140	Hundred Circles	45.934	-119.805	127.297
100147	CBC Pasco	46.253	-119.127	132.546
100148	WSU TC	46.329	-119.267	129.265
109	Royal City	46.913	-119.624	382.874
110029	WSU Hamilton	46.251	-119.739	271.325
300045	Roza	46.749	-120.466	328.084
300070	Welland	46.217	-118.733	313.648
300118	McWhorter	46.317	-119.617	731.955
300122	WSU Othello	46.793	-119.041	400.262
310102	WSU Puyallup	47.188	-122.327	19.685
310111	Gleed	46.697	-120.616	621.719
310112	Ahtanum	46.549	-120.714	543.963
310120	Port Of Sunnyside	46.283	-120.009	222.769
310132	Parker	46.517	-120.479	309.383
310135	Outlook	46.423	-120.131	419.948
310137	Cowiche	46.667	-120.718	580.052
310142	Pomona	46.691	-120.473	409.121
330061	Nooksack	48.921	-122.327	26.903
330063	Lynden	48.936	-122.514	22.310
330073	Quincy	47.225	-119.957	483.924

330074	Paws Brewster	48.060	-119.871	258.202
330104	New Pogue Flat	48.435	-119.528	417.651
330121	Mattawa	46.701	-119.800	272.310
330127	Moses Lake	47.004	-119.238	372.375
330145	Ellisforde	48.793	-119.397	309.383
450176	Anacortes	48.517	-122.617	6.100
450217	Appleton	45.817	-121.283	712.000
450482	Battle Ground	45.783	-122.533	86.600
450564	Bellingham 2 N	48.783	-122.483	43.000
450574	Bellingham Intl Ap	48.800	-122.533	45.400
450587	Bellingham 3 SSW	48.717	-122.517	4.600
450628	Benton City 2 NW	46.283	-119.500	207.000
450668	Bickleton 3 ESE	45.983	-120.233	844.300
450729	Blaine	49.000	-122.750	18.300
450872	Bremerton	47.567	-122.683	33.500
450945	Buckley 1 NE	47.167	-122.000	208.800
450969	Bumping Lake	46.867	-121.300	1049.100
451113	Carbonado 8 SSE	46.983	-121.967	499.900
451233	Cedar Lake	47.417	-121.733	475.500
451276	Centralia	46.717	-122.950	56.400
451350	Chelan	47.833	-120.033	341.400
451362	Cheney	47.483	-117.583	732.100
451381	Chesaw	48.950	-119.050	875.100
451385	Chesaw 4 NNW	49.000	-119.067	1207.900
451395	Chewelah	48.283	-117.717	509.000
451474	Clarkston Heights	46.383	-117.083	363.000
451484	Clearbrook	48.967	-122.333	19.500
451504	Cle Elum	47.183	-120.950	585.200
451586	Colfax	46.883	-117.350	603.500
451630	Colville	48.550	-117.900	505.100
451654	Colville basic	48.583	-117.800	914.400
451666	Conconully	48.550	-119.750	707.100
451690	Connell 1 W	46.667	-118.883	310.900
451767	Coulee Dam 1 SW	47.950	-119.000	518.200
451783	Coupeville 1 S	48.200	-122.700	15.200
451934	Cushman Dam	47.417	-123.217	231.600
451939	Cushman Powerhouse 2	47.367	-123.167	6.400
451968	The Dalles Municipal Arpt	45.617	-121.150	73.200
451992	Darrington Ranger STN	48.250	-121.600	167.600
452007	Davenport	47.650	-118.133	743.700
452030	Dayton 1 WSW	46.317	-118.000	474.600

452066	Deer Park 2 E	47.967	-117.433	670.900
452493	Electron Headworks	46.900	-122.033	527.900
452505	Ellensburg	46.967	-120.533	451.100
452508	Ellensburg Bowers FI	47.033	-120.517	527.000
452531	Elma	47.000	-123.400	21.300
452542	Eltopia 8 WSW	46.400	-119.150	213.400
452563	Entiat Fish Hatchery	47.700	-120.317	292.600
452614	Ephrata AP FCWOS	47.300	-119.517	383.700
452675	Everett	47.983	-122.183	18.300
453050	Garden City Heights	46.083	-118.317	320.000
453160	Glacier R S	48.883	-121.950	285.000
453184	Glenwood 2	46.000	-121.283	563.900
453226	Goldendale	45.817	-120.817	518.200
453284	Grapeview 3 SW	47.300	-122.867	15.500
453333	Grays River Hatchery	46.383	-123.567	30.500
453357	Greenwater	47.133	-121.633	527.300
453512	Harrington 1 N	47.483	-118.250	665.100
453529	Hartline	47.683	-119.100	582.200
453546	Hatton 9 SE	46.717	-118.650	460.200
453883	Ice Harbor Dam	46.250	-118.883	112.200
453903	Inchelium 2 NW	48.317	-118.217	515.100
454154	Kennewick	46.217	-119.100	118.900
454159	Kennewick 10 SW	46.133	-119.300	458.100
454169	Kent	47.400	-122.233	9.100
454201	Kid Valley	46.367	-122.617	210.000
454286	Kosmos	46.500	-122.183	238.000
454338	Lacrosse	46.817	-117.883	442.000
454360	La Grande	46.833	-122.317	292.900
454394	Lake Cle Elum	47.250	-121.067	688.800
454406	Lake Kachess	47.267	-121.200	691.900
454414	Lake Keechelus	47.317	-121.333	755.900
454486	Landsburg	47.383	-121.967	163.100
454601	Lemanasky Lake 3	48.717	-119.617	1158.800
454679	Lind 3 NE	47.000	-118.567	496.800
454702	Little Goose Dam	46.583	-118.033	214.000
454769	Longview	46.150	-122.917	3.700
454835	Lower Granite Dam	46.650	-117.433	195.100
454841	Lower Monumental DAM	46.567	-118.533	139.900
454935	Malott	48.283	-119.717	259.100
455028	Marietta 3 NNW	48.833	-122.600	6.100
455224	MC Millin Reservoir	47.133	-122.267	176.500

455231	Mcnary Dam	45.950	-119.300	110.000
455326	Methow 2 S	48.100	-120.017	356.600
455525	Monroe	47.850	-121.983	36.600
455608	Moses Lake	47.100	-119.250	359.700
455613	Moses Lake 3 E	47.117	-119.200	369.100
455678	Mount Vernon 3 WNW	48.450	-122.367	4.300
455688	Moxee City 10 E	46.500	-120.167	472.400
455704	Mud Mountain Dam	47.150	-121.933	398.700
455832	Nespelem 2 S	48.133	-118.983	576.100
455946	Northport	48.917	-117.783	411.500
456011	Oakville	46.833	-123.233	24.400
456039	Odessa	47.333	-118.700	466.300
456096	Olga 2 SE	48.617	-122.800	24.400
456109	Olympia Priest Pt Park	47.067	-122.883	9.100
456114	Olympia Aapt	46.967	-122.900	62.800
456121	Omak	48.417	-119.533	259.400
456123	Omak 4 N	48.467	-119.517	396.500
456188	Oroville 3 NW	48.967	-119.500	323.100
456295	Palmer 3 ESE	47.300	-121.850	280.400
456534	Plain	47.783	-120.650	591.300
456610	Pomeroy	46.467	-117.583	579.100
456678	Port Townsend	48.117	-122.750	21.000
456747	Priest Rapids Dam	46.650	-119.900	140.200
456768	Prosser	46.200	-119.750	253.000
456784	Pullman Exp Stn	46.733	-117.167	787.000
456789	Pullman 2 NW	46.767	-117.167	775.700
456846	Quilcene 2 SW	47.817	-122.917	37.500
456880	Quincy 1 S	47.217	-119.850	388.300
456892	Rainier Carbon River Ent	47.000	-121.917	528.800
457010	Richardson 3 SE Lopez	48.433	-122.833	9.100
457015	Richland	46.317	-119.267	113.700
457038	Rimrock Tieton Dam	46.650	-121.133	833.000
457180	Rosalia	47.233	-117.367	731.500
457223	Ruff 3 SW	47.133	-119.050	438.900
457342	Satus Pass 2 SSW	45.967	-120.667	795.500
457456	Seattle Boeing Field	47.533	-122.300	6.100
457459	Seattle Jackson Park	47.733	-122.333	112.800
457473	Seattle Seattle-Tacoma Intla	47.467	-122.317	121.900
457478	Seattle Univ Of Washingt	47.650	-122.283	29.000
457507	Sedro Woolley	48.500	-122.233	18.300
457538	Sequim	48.083	-123.100	54.900

457584	Shelton	47.200	-123.100	6.700
457696	Skamania Fish Hatchery	45.617	-122.217	134.100
457708	Skykomish	47.700	-121.367	284.100
457727	Smyrna	46.833	-119.667	170.700
457773	Snoqualmie Falls	47.550	-121.833	134.100
457871	South Olympic Tree Farm	47.233	-123.583	177.100
457956	Sprague	47.300	-117.983	600.500
458034	Startup 1 E	47.867	-121.717	51.800
458115	Stockdill Ranch	48.367	-120.333	670.900
458278	Tacoma 1	47.250	-122.417	7.600
458442	TietonI Intake	46.667	-121.000	694.900
458500	Toledo Winlock Muni AP	46.483	-122.817	115.500
458508	Tolt South Fork Reser	47.700	-121.800	548.600
458520	Tonasket 4 NNE	48.767	-119.417	292.600
458579	Trinidad 2 SSE	47.217	-120.000	171.000
458773	Vancouver 4 NNE	45.683	-122.650	64.000
458802	Vashon Island	47.450	-122.500	70.100
458926	Walla Walla 3 W	46.050	-118.400	244.100
458928	Walla Walla City County Ap	46.100	-118.283	355.400
458931	Walla Walla WSO	46.033	-118.333	289.300
458959	Wapato	46.433	-120.417	256.300
458999	Washougal 8 NE	45.600	-122.183	232.000
459021	Wauna 3 W	47.367	-122.700	5.200
459024	Wawawai	46.650	-117.400	214.000
459058	Wellpinit	47.900	-118.000	759.000
459079	Wenatchee Exp Stn	47.433	-120.350	243.800
459082	Wenatchee Pangborn Field	47.400	-120.200	374.600
459171	White River Ranger STN	46.900	-121.550	1068.000
459185	White Salmon 8 NNE	45.817	-121.400	627.900
459191	White Swan Ranger Stn	46.383	-120.717	296.000
459200	Whitman Mission	46.050	-118.450	192.600
459238	Wilbur	47.750	-118.683	679.700
459327	Wilson Creek	47.417	-119.117	390.100
459376	Winthrop 1 WSW	48.467	-120.183	534.900
459460	Yakima Terrace H	46.617	-120.433	366.100
459463	Yakima NO 2	46.583	-120.533	350.500
999126	Naches	46.704	-120.659	449.147
999144	Loomis Grade	48.778	-119.428	387.139
999146	East Oroville	48.980	-119.413	371.719
BNDW	Bonneville Dam	45.648	-121.931	26.247
CJDW	Chief Joseph Dam	47.991	-119.636	324.803

FOGO	Forest Grove	45.553	-123.084	59.055
HOXO	Hood River	45.684	-121.518	167.323
HRHW	Harrah	46.385	-120.574	278.871
KFLW	Kettle Falls	48.595	-118.124	439.633
LBRW	Lake Bryan-Rice Bar	46.697	-117.654	206.693
MASW	Manson	47.917	-120.124	646.982
ODSW	Odessa	47.309	-118.879	541.339
SILW	Silcott Island	46.419	-117.185	270.669
727827	Moses Lake N	47.200	-119.310	364.000
727840	Hanford	46.560	-119.600	223.000
727855	Fairchild AFB	47.630	-117.650	743.000

Appendix 2

Corrections made to the AgWeatherNet stations used.

AWN Station	Correction	Comments
Royal City	Changed Tmax, Tdew, Rs measured to MISSING	Values in the thousands not probable
	9/25 - 9/27/01, 10/22 - 10/23/01, 10/25/01, 10/27 - 10/28/01,	
	10/30 - 10/31/01, 9/1/03, 9/5 - 9/6/03, 9/9 - 9/12/03, 1/2 - 1/3/05,	
	1/17 - 1/19/05	
	Changed Tmax and Tdew to MISSING	Values of 99999 & 44110 not probable
	3/11 - 6/2/05 Increased measured Rs by 150%	
	5/29 - 8/17/07 Reduced measured Rs by 4%	
McNary	Changed Rainfall to 0: 6/28/92, 11/30/92, 12/1/92, 12/10/92, 12/27/92, 12/31/92, 1/21-22/93, 3/20/93, 7/29/94, 10/27/94, 4/25/95, 11/19/98,	Values in the thousands
	1/1/2000, 1/5/00, 1/9/00, 2/4/00, 2/8/00, 9/7/00, 9/9/00, 1/20/02,	
	4/4/2004	
	11/19/1998 Changed Windspeed to MISSING	Values in the thousands
	1/1/2000 Changed Windspeed to MISSING	Values in the thousands
	1/5/2000 Changed Windspeed and Tdew to MISSING	Values in the thousands
	1/8/2000 Changed Windspeed to MISSING	Values in the thousands
	1/9/2000 Changed Windspeed and Tdew to MISSING	Values in the thousands
	2/4/2000 Changed Windspeed to MISSING	Values in the thousands
	2/8/2000 Changed Windspeed to MISSING	Values in the thousands
	5/9/2000 Changed Windspeed to MISSING	Values in the thousands
	6/1/2000 Changed Windspeed to MISSING	Values in the thousands
	8/9/2000 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	9/7/2000 Changed Windspeed to MISSING	Values in the thousands
	9/9/2000 Changed Windspeed and Tdew to MISSING	Values in the thousands
	10/8/2000 Changed Windspeed to MISSING	Values in the thousands
	1/2/2001 Changed Tdew to MISSING	Values in the thousands
	1/4/2001 Changed Tmax and Tdew to MISSING	Values in the thousands
	1/29/2001 Changed Windspeed and Tdew to MISSING	Values in the thousands
	2/4/2001 Changed Tmax and Tdew to MISSING	Values in the thousands
	3/5/2001 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	9/4/2001 Changed Tmax and Tdew to MISSING	Values in the thousands
	12/4/2001 Changed Tmax and Tdew to MISSING	Values in the thousands
	1/18 - 1/21/2002 Rs measured changed to MISSING	Values from 95 to 3500
	1/19/2002 Changed Tdew to MISSING	Values in the thousands
	1/20/2002 Changed Tdew to MISSING	Values in the thousands
	1/21/2002 Changed Tmax and Tdew to MISSING	Values in the thousands
	1/27 - 8/15/2002 Reduced Rs measured by 30%	
	5/22-23/2002 Changed Rs measured to MISSING	Values of 122 and 212
	10/2/2002 Changed Windspeed and Tdew to MISSING	Values in the thousands
	12/2/2002 Changed Windspeed and Tdew to MISSING	Values in the thousands
	12/25-31/2002 Changed Rs measured to MISSING	Values between 700 and 2000
	12/25/2002 - 1/11/2003 Changed Tmax and Tdew to MISSING	
	12/27/2002 Changed Tmin to MISSING	

	1/1 - 1/11/2003 Changed Windspeed to MISSING	Values in the thousands
	1/2 - 1/11/2003 Change Tmin to MISSING	Values in the thousands
	1/28 - 2/25/2003 Reduced Rs measured by 28%	
	2/4/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	2/6/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	2/8/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	3/3/2003 Changed Windspeed, Tmax, Tdew to MISSING	
	3/5/2003 Changed Windspeed, Tmax, Tdew to MISSING	
	3/10/2003 Changed Windspeed, Tmax, Tdew to MISSING	
	4/5-6/2003 Changed Windspeed, Tmax, Tdew to MISSING	
	5/2/2003 Changed Windspeed, Tmax, Tdew to MISSING	
	5/29/2003 Changed Tdew to MISSING	Values in the thousands
	6/4/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	8/4/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	8/8/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	9/2/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	9/8/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	10/4/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	10/6-8/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	10/10/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	11/2/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	11/4/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	12/2/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	12/6/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	12/8/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	12/10-11/2003 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	1/28/2004 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
	4/4/2004 Changed Windspeed, Tmax, Tdew to MISSING	Values in the thousands
Coffin	Changed Rs to MISSING: 5/6-7/2002, 5/10-11/02, 5/13-16/02, 5/22/02, 5/28/02, 5/31/02, 6/6/02, 6/8/02, 6/10/02, 6/30 - 7/1/02, 7/3-5/02, 8/1/02, 8/3/02	
	3/23 - 8/28/2002 Reduced Rs measured by 4%	
	3/19 - 9/8/2001 Reduced Rs measured by 5%	
	7/31 - 8/18/2002 Reduced Rs measured by 4%	
	1/1 - 2/2/2003 Changed Tmax, Tmin, Tdew, Windspeed, Rainfall to MISSING	
	4/1-2/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	4/4/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	4/27/2003 Changed Windspeed and Rainfall to MISSING	
	6/2/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	8/4/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	8/6/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	8/8/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	10/2-4/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	10/10/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	11/8/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	11/10/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	12/3/2003 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	

	1/4/2004 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	1/8/2004 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	5/2/2004 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	5/8-15/2007 Reduced Rs measured by 8%	
	7/24 - 9/26/2007 Reduced Rs measured by 7%	
	7/28/2008 Changed Tdew to MISSING	
Triple-S	8/28/2001 Changed Tmax and Tdew to MISSING	
	8/14/2003 Changed Tmax and Tdew to MISSING	
	2/16 - 4/30/2006 Reduced Rs measured by 38%	
	5/1 - 7/5/2006 Reduced Rs measured by 20%	
	6/7/2007 Changed Tdew to MISSING	
Carlson	4/25/1989 - 2/9/2007 Changed Rs measured to MISSING	Values mostly 8000+ but all 1000+
	3/20/2004 Changed Tdew, Windspeed, Rainfall to MISSING	
	3/25/2004 Changed Tdew, Windspeed, Rainfall to MISSING	
	3/1/2005 Changed Tdew, Windspeed, Rainfall to MISSING	
	9/20/2007 - 1/2/2008 Changed Rs measured to MISSING	Values mostly 8000+ but all 1000+
	3/18/2008 Changed Tmax and Tdew to MISSING	
Paterson	12/19/1990 Changed Rainfall to MISSING	
	3/13/2000 Changed T max, Tdew, Windspeed, Rainfall to MISSING	
	1/4 - 2/20/2001 Reduced Rs measured by 40%	
	3/14/2002 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	3/16/2004 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	3/24/2004 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	3/16/2005 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	5/19/2006 Changed Rainfall to MISSING	
	5/25/2008 Changed Rs measured to MISSING	Value of 109
Station 4	7/10/1998 Changed Rainfall to MISSING	
	Changed Tmax, Tdew, Windspeed to MISSING: 1/5/2000, 2/5/2000, 4/5/2000 6/5/2000, 5/8/2000, 9/5/2000, 10/5/2000, 11/5/2000, 12/5/2000, 9/8/2001	
	Changed Windspeed to MISSING: 3/5/2000, 5/5/2000, 7/5/2000	
	Changed Tmax and Tdew to MISSING: 1/4/2001, 6/4/2001, 10/4/2001, 12/4/2001	
	6/15 - 7/31/2003 Reduced Rs measured by 4%	
	Changed Windspeed and Rs measured to MISSING: 1/7/2003, 1/7/2004, 2/7/2004, 3/7/2004, 4/7/2004, 4/9/2004, 8/7/2004, 10/7/2004, 12/4/2004	
	3/27 - 10/14/2004 Reduced Rs measured by 14%	
	2/15 - 6/20/2005 Reduced Rs measured by 13%	
	2/21 - 5/26/2006 Reduced Rs measured by 58%	
	5/4/2007 Changed Rainfall to MISSING	
Wheelhouse	5/24 - 7/21/1994 Reduced Rs measured by 4%	
	6/5 - 9/22/1996 Reduced Rs measured by 4%	
	4/11 - 9/22/1999 Reduced Rs measured by 4%	

	4/10 - 10/7/2000 Reduced Rs measured by 5%	
	5/10 - 8/27/2001 Reduced Rs measured by 5%	
	7/1 - 8/15/2002 Reduced Rs measured by 4%	
	6/2 - 9/13/2003 Reduced Rs measured by 4%	
	10/19/2003 Changed Windspeed and Rainfall to MISSING	
	10/25/2006 Tmax changed to MISSING	Value of 136 in October
	10/27-29/2003 Changed Tmax, Tdew, Rs to MISSING	
	10/28/2003 Changed Tmin to MISSING	
	8/24 - 10/31/2006 Increased Rs measured by 100%	
	11/7/2006 - 3/21/2007 Increased Rs measured by 130%	
	4/24/2007 Changed Rs measured to MISSING	
	5/4/2007 Changed Rs measured to MISSING	
	4/17 - 5/17/2007 Reduced Rs measured by 30%	
	5/23/2008 Changed Rs measured to MISSING	
Station 2	11/4-5/2001 Changed Tdew to MISSING	
	11/9-10/2001 Changed Tdew to MISSING	
	11/12/2001 Changed Tdew to MISSING	
	11/14/2001 Changed Tdew to MISSING	
	3/16 - 5/31/2005 Increased Rs measured by 100%	
	6/1 - 12/9/2005 Reduced Rs measured by 10%	
	15 - 8/23/2006 Reduced Rs measured by 8%	
Fourmile	5/9/1995 Changed Rainfall to MISSING	
	6/2/2002 Tmax, Tmin, Tdew changed to MISSING	Tmin value of 1.454 F in the Summer
	6/10/2002 Tmax, Tmin, Tdew changed to MISSING	Tmin value of -27.328 in Summer
	6/12-13/2002 Tmin and Tdew changed to MISSING	Tmin value of -25 and -26 in Summer
	7/16 - 11/3/2002 Reduced Rs measured by 10%	
	10/21/2002 Tdew changed to MISSING	
	11/10/2002 Tmax, Tdew, Windspeed, Rainfall changed to MISSING	
	2/4 - 11/6/2003 Reduced Rs measured by 11%	
FishHook	5/2/2001 Tmax and Tdew changed to MISSING	Beginning values in 2005 changed from 0 to MISSING
	1/8/2005 Tmax, Tdew, Windspeed, Rainfall changed to MISSING	
	5/19/2006 Changed Rainfall to MISSING	
	10/24/2006 - 4/11/2007 Rs measured raised by 120%	
	4/13 - 5/7/2007 Reduced Rs measured by 25%	
	5/28 - 8/10/2007 Reduced Rs measured by 4%	
K2H	6/5/1998 Changed Rainfall to MISSING	
	1/1-3/2000 Changed Rainfall and Windspeed to MISSING	
	1/3/2000 Changed Tdew to MISSING	
	1/5-6/2000 Changed Windspeed to MISSING	
	1/8-9/2000 Changed Windspeed and Rainfall to MISSING	
	4/8/2000 Changed Windspeed and Rainfall to MISSING	
	6/1/2000 Changed Windspeed to MISSING	
	7/6/2000 Changed Windspeed to MISSING	
	8/7/2000 Changed Windspeed, Tmax, Tdew to MISSING	
	8/9/2000 Changed Windspeed and Rainfall to MISSING	

9/7/2000 Changed Tdew, Windspeed, Rainfall to MISSING	
10/5-7/2000 Changed Windspeed and Rainfall to MISSING	
10/7/2000 Changed Tdew to MISSING	
11/4/2000 Changed Windspeed and Rainfall to MISSING	
11/30/2000 Changed Rs measured to MISSING	Value of 96
12/4/2000 Changed Windspeed and Rainfall to MISSING	
12/6/2000 Changed Tdew, Windspeed, Rainfall to MISSING	
1/13-14/2001 Changed Rs measured to MISSING	Values of 91 and 93
3/2/2001 Changed Rs measured to MISSING	Value of 102
4/4/2001 Changed Tmax and Tdew to MISSING	
10/4/2001 Changed Tmax and Tdew to MISSING	
12/4/2001 Changed Tmax and Tdew to MISSING	
1/2/2002 Changed Tmax, Tdew, Windspeed to MISSING	
1/4/2002 Changed Tmax, Tdew, Windspeed to MISSING	
1/6-8/2002 Changed Tmax, Tdew, Windspeed to MISSING	
1/10/2002 Changed Tmax, Tdew, Windspeed to MISSING	
1/11/2002 Changed Windspeed to MISSING	
1/30/2002 Changed Windspeed to MISSING	
2/1/2002 Changed Tmax, Tdew, Windspeed to MISSING	
2/4-7/2002 Changed Tmax, Tdew, Windspeed to MISSING	
2/5/2002 Changed Rainfall to MISSING	
2/9/2002 Changed Tmax, Tdew, Windspeed to MISSING	
3/6/2002 Changed Tmax, Tdew, Windspeed to MISSING	
3/8/2002 Changed Tmax, Tdew, Windspeed to MISSING	
4/1-2/2002 Changed Tmax to MISSING	
4/1-4/2002 Changed Tdew and Windspeed to MISSING	
4/4/2002 Changed Tmax to MISSING	
4/10-11/2002 Changed Tmax, Tdew, Windspeed to MISSING	
5/1-2/2002 Changed Tmax and Tdew to MISSING	
5/2/2002 Changed Windspeed to MISSING	
6/4/2002 Changed Tmax and Tdew to MISSING	
6/8/2002 Changed Tmax, Tdew, Windspeed to MISSING	
6/10/2002 Changed Tmax, Tdew, Windspeed to MISSING	
8/4/2002 Changed Tmax and Tdew to MISSING	
8/8/2002 Changed Tmax, Tdew, Windspeed to MISSING	
8/10/2002 Changed Tmax, Tdew, Windspeed to MISSING	
9/3/2002 Changed Tmax, Tdew, Windspeed to MISSING	
9/10/2002 Changed Tmax, Tdew, Windspeed to MISSING	
10/10/2002 Changed Tmax, Tdew, Windspeed to MISSING	
11/4/2002 Changed Tmax, Tdew, Windspeed to MISSING	
12/4/2002 Changed Tmax and Tdew to MISSING	
1/4/2003 Changed Tmax, Tdew, Windspeed to MISSING	
1/8/2003 Changed Tmax, Tdew, Windspeed to MISSING	
2/4/2003 Changed Tmax, Tdew, Windspeed to MISSING	
2/6/2003 Changed Tmax, Tdew, Windspeed to MISSING	
4/10/2003 Changed Tmax, Tdew, Windspeed to MISSING	
6/8/2003 Changed Tmax, Tdew, Windspeed to MISSING	
1/6/2004 Changed Tmax, Tdew, Windspeed to MISSING	
1/17/2004 Changed Windspeed to MISSING	
2/6/2004 Changed Tdew, Windspeed, Rainfall to MISSING	

	2/7/2004 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
	8/1/2004 Changed Rainfall to MISSING	
	1/6/2005 Changed Windspeed to MISSING	
	1/24/2006 Changed Windspeed to MISSING	
	1/26/2006 Changed Windspeed to MISSING	
	10/18/2006 - 4/11/2007 Increased Rs measured by 110%	
	1/3/2007 Changed Windspeed to MISSING	
	1/24/2007 Changed Windspeed to MISSING	
	4/13 - 5/10/2007 Reduced Rs measured by 21%	
	5/29 - 11/2/2007 Reduced Rs measured by 9%	
Finley	11/4-7/1994 Changed Rs measured to MISSING	Values of -111, -146, -126, -55
	3/25/2001 Changed Rs measured to MISSING	Value of 103
	4/5/2001 Changed Tdew to MISSING	
	7/12/2001 Changed Tdew to MISSING	
	3/31 - 6/22/2005 Increased Rs measured by 50%	
	5/19/2006 Changed Rainfall to MISSING	
	5/14/2008 Changed Rs measured to MISSING	Value of 105
Benton City	6/10 - 9/19/2006 Reduced Rs measured by 30%	
	9/22/2006 - 5/3/2007 Reduced Rs measured by 49%	
	10/17/2007 Changed Windspeed to MISSING	
	6/29/2008 Changed Tdew to MISSING	
Touchet	10/15-16/2003 Changed Tmax, Tmin, Tdew, Rs measured to MISSING	Rs value of 2000+
	8/30/2004 Changed Windspeed to MISSING	
	9/8/2004 Changed Tdew, Windspeed, Rainfall to MISSING	
	9/10/2004 Changed Tmax, Tdew, Rainfall to MISSING	
	4/2/2005 Changed Tmax, Tmin, Tdew, Windspeed to MISSING	
	1/27/2007 Changed Tdew to MISSING	
	8/4/2007 Changed Windspeed to MISSING	
	1/27/2008 Changed Tdew to MISSING	
Eby	5/17/1989 - 1/16/2008 Rs measured changed to MISSING	Most values were 8000+, all above 70
	7/5/1989 Changed Rainfall to MISSING	
	8/6/1991 Changed Rainfall to MISSING	
	7/9/1995 Changed Rainfall to MISSING	
	6/14 -7/11/2001 Changed Tmax and Tmin to MISSING	Each value was 61.682
	4/27/2004 Changed Rainfall to MISSING	
	7/19/2004 Changed Rainfall to MISSING	
	8/2/2004 Changed Rainfall to MISSING	
	8/4/2004 Changed Rainfall to MISSING	
	9/1/2004 Changed Rainfall to MISSING	
Gramling	4/26/1989 - 5/2/2008 Changed Rs measured to MISSING	Value 8000+
	6/13/2001 Changed Tdew to MISSING	
	5/19/2006 Changed Rainfall to MISSING	
100 Circles	8/15/2005 - 6/8/2006 Increased Rs measured by 60%	
	9/29/2006 - 5/7/2007 Increased Rs measured by 90%	

	8/3 - 10/1/2007 Reduced Rs measured by 5%	
CBC Pasco	10/30/1997 Changed Tdew to MISSING	
	9/4/2001 Changed Tmax to MISSING	
	9/5/2001 Changed Rs measured to MISSING	Value of 110
	5/23/2008 Changed Rs measured to MISSING	Value of 104
WSU TC	9/9/2003 Changed Tdew to MISSING	
	10/6-9/2003 Changed Tmax, Tdew, Rs measured to MISSING	Rs value 3500+
	10/12/2003 Changed Tmax, Tdew, Rs measured to MISSING	Rs value 3600
	11/26/2005 - 3/28/2006 Increased Rs measured by 60%	
	4/12 - 6/8/2006 Reduced Rs measured by 36% Changed Rs measured to MISSING: 4/24/06, 5/5/06, 5/8/06, 5/15/06, 5/19-20/06, 5/23/06, 5/26-28/06, 5/30-31/06, 6/3-5/06, 6/7/06, 6/9/06	
WSU Hamltn	7/5/2002 - 6/20/2007 Changed Rs measured to MISSING	Values from 3000 - 9000
	3/15-18/2003 Changed Tdew and Windspeed to MISSING Changed Windspeed to MISSING: 1/9/03, 2/9/03, 3/9/03, 4/9/03, 6/9/03,	
	8/9/03, 9/9/03, 10/9/03, 11/9/03, 12/9/03, 3/9/04, 9/9/04, 1/9/06 3/14/2006 Changed Tmax, Tdew, Windspeed, Rainfall to MISSING	
Ahtanum	4/8/2002 Tdew changed to MISSING	
	12/3/2003 Rs measured changed to MISSING	
	12/10/2003 Tmax, Tdew, Rs measured changed to MISSING	
	1/7/2004 Rs measured changed to MISSING	
	1/9/2004 Rs measured changed to MISSING	
	1/12/2004 Rs measured changed to MISSING	
	1/23/2004 Rs measured changed to MISSING	
	6/21-27/2004 Tmax, Tdew, Rs measured changed to MISSING	
	6/30/2004 Tmax, Tdew, Rs measured changed to MISSING	
	7/1/2004 Tmax and Tdew changed to MISSING	
	3/19 - 10/18/2005 Rs measured increased by 125%	
	10/19 - 12/31/2005 Rs measured increased by 200%	
	1/1 - 6/13/2006 Rs measured increased by 125%	
	6/14 - 10/4/2006 Rs measured increased by 5%	
	10/5 - 12/31/2006 Rs measured increased by 30%	
Cowiche	4/8/2002 Tdew changed to MISSING	
	6/25 - 9/11/2003 Rs measured increased by 30%	
	8/9/2005 - 12/31/2006 Rs measured increased by 40%	
	8/15/2005 Rainfall changed to MISSING	
	8/19/2005 Rainfall changed to MISSING	
	9/21/2005 Rainfall changed to MISSING	
	12/20-21/2005 Tdew changed to MISSING	
	12/20/2005 - 1/12/2006 Tmax and Tmin changed to MISSING	
	12/27/2005 - 1/12/2006 Tdew changed to MISSING	
	1/1 - 12/31/2007 Rs measured increased by 15%	

Pomona	10/18-19/2000 Tmax and Tdew changed to MISSING
	6/28 - 9/13/2003 Rs measured reduced by 3%
	9/30/2003 Tmax, Tdew, Rs measured changed to MISSING
	10/5-8/2003 Tmax, Tdew, Rs measured changed to MISSING
	10/16-17/2003 Tmax, Tdew, Rs measured changed to MISSING
	10/20-21/2003 Tmax, Tdew, Rs measured changed to MISSING
	8/18/2005 - 6/29/2006 Rs measured increased by 50%
Loomis Grade	7/26 - 9/12/2003 Rs measured increased by 50%
	5/24 - 9/12/2004 Rs measured increased by 20%
East Oroville	4/23/2003 Tdew changed to MISSING
	3/26/2004 Tdew changed to MISSING
	Rs measured values between x.3-x.7 (x=year) noticeably lower than clear sky value. Not altered because it is normal for this station, happening every year.

Appendix 3

Table 3.1. Planting Dates and the Primary Source for Washington State Crop Coefficients.

Num	Crop Name	Growth stage dates			Source
		Ave Initial	Ave Full cover	Ave End	
1	ALFALFA (MEAN)*	91	135	280	Agrimet, Curve developed by ARS research on lysimeter plots, Kimberly, Idaho 1969–75.
2	ALFALFA (PEAK)*	91	135	280	Agrimet, Curve developed by ARS research on lysimeter plots, Kimberly, Idaho 1969–75.
3	APPLES	110	149	278	Agrimet, (Modified per Soiltest input 1994), Curve developed by Soiltest, Inc., Moses Lake, Washington March 1994
4	APRICOTS	110	149	278	Agrimet, Cherry crop coefficients and planting date
5	ASPARAGUS	120	214	280	Agrimet, Pro Ag, Pasco, 1994
6	BLACKBERRY	90	150	278	Agrimet, Curve developed by USBR Mid Pacific Region, 1975
7	BLUEBERRY	85	150	225	Agrimet, Curve developed by USBR Mid Pacific Region, 1975
8	BLUEGRASS ESTABLISHED	72	126	192	Agrimet, Added 1994 Wright, Curve developed by ARS, Kimberly, Idaho February 18, 1994
9	BLUEGRASS FALL SEED	72	126	192	Agrimet, Added 1994 Wright, Curve developed by ARS, Kimberly, Idaho February 16, 1994
10	BROCOLLI	91	160	243	FAO56

11	CABBAGE	91	160	243	Agrimet, Curve developed by USBR Mid Pacific Region, 1975
12	CANOLA	76	141	183	Agrimet, Curve developed by Conrad, MT Experiment Station June 1994
13	CARROTS (Full Irrigation)	91	160	243	FAO56
14	Cattails, Bulrushes, killing frost	121	161	260	FAO56
15	Cattails, Bulrushes, no frost	121	161	260	FAO56
16	CHEATGRASS	60	98	160	Allen et al. (2006)
17	CHERRY W/COVER	110	149	278	Agrimet, Curve supplied by M. Hattendorf, PAWS, modified by Wright, USDA April 1998.
18	CHERRY W/o COVER	110	149	278	Agrimet, Curve supplied by M. Hattendorf, PAWS, modified by Wright, USDA April, 1998.
19	CLOVER	91	135	280	Agrimet, Alfalfa crop coefficients and planting date
20	CONCORD GRAPES	100	169	280	Agrimet, Curve developed by Pro Ag, Inc., Pasco, WA 1988
21	CUCUMBER	136	200	280	Agrimet, Melon crop coefficients and planting date
22	DRY BEANS	146	191	242	Wright, 1981

23	FESCUE GRASS HAY (MEAN)	80	137	280	Agrimet, Curve developed by ARS research on lysimeter plots, Kimberly, Idaho 1990.
24	FESCUE GRASS HAY (PEAK)	80	137	280	Agrimet, Curve developed by ARS research on lysimeter plots, Kimberly, Idaho 1990.
25	FIELD CORN	129	201	259	Wright, 1981
26	HOPS	110	230	274	Agrimet, Curve developed by Dr. Jim Wright, ARS Kimberly, Idaho 2005, using data from Washington State University Cooperative Extension Bulletin EM4816.
27	LAWN	80	127	280	Agrimet, Curve developed by ARS, Kimberly, Idaho, 1994
28	LENTIL	105	160	215	Agrimet, Curve developed by ARS research on lysimeter plots, Kimberly, Idaho 1973–77
29	MELONS	136	200	280	Agrimet, Curve developed by Pro AG, Inc. Pasco, WA, 1998
30	MINT	119	165	243	Agrimet, New Curve for NMPI from L. Tiegs 8/21/97
31	ONYN	90	170	239	Agrimet, Curve modified by ARS, Kimberly, Idaho February 16, 1994.
32	PASTURE (low management)	80	127	280	Agrimet, Modified 1994 by Wright, Curve developed by ARS, Kimberly, Idaho, February 16, 1994
33	PEACH W/COVER	110	149	278	Agrimet, Cherry crop coefficients and planting date
34	PEAR	110	149	278	Agrimet, Curve modified by Soiltest, Inc., Moses Lake, WA, March 1994

35	PEAS (green)	90	163	198	Wright, 1981
36	PEPPERS	136	220	243	FAO56
37	PEPPERMINT	86	156	280	Agrimet, Curve developed by Canyon County (Idaho) Extension Office, 1976
38	PLUM W/COVER	110	149	278	Agrimet, Apple crop coefficients and planting date
39	POPLAR Firs Year	130	150	280	Agrimet, Curve developed by Oregon State University Experiment Station, Ontario, OR June 1998
40	POPLAR Second Year	130	150	280	Agrimet, Curve developed by Oregon State University Experiment Station, Ontario, OR June 1998
41	POPLAR Third and Subsequent Years	130	150	280	Agrimet, Curve developed by Oregon State University Experiment Station, Ontario, OR Jun 1998
42	POTATOES	128	186	253	Wright, 1981
43	POTATOES (SHEPODY)	127	163	260	Agrimet, Curve developed by Malheur, Oregon County Extension, 1993
44	RADISH	95	120	125	FAO56
45	RASPBERRY	90	150	278	Agrimet, Curve developed by USBR Mid Pacific Region, 1975
46	Reed Swamp, moist soil	121	161	260	FAO56

47	Reed Swamp, standing water	121	161	260	FAO56
48	SAEBRUSH	92	120	258	Allen et al. (2006)
49	SAFFLOWER	90	165	220	Agrimet, Curve developed from Rapseed, Conrad, MT Experiment Station June 1994, Modified from FAO56, July 2007
50	Short Veg., no frost	121	161	260	FAO56
51	SPEARMINT	71	149	280	Agrimet
52	SPINACH	88	120	215	FAO56
53	SPRING GRAIN	92	168	213	Wright, 1981
54	SQUASH	136	220	280	FAO56
55	STRAWBERRY	65	135	278	FAO56
56	SUGAR BEETS	117	195	276	Wright, 1981
57	SWEET CORN	130	203	240	Wright, 1981
58	TOMATO	136	220	243	FAO56

59	WINE GRAPE	106	177	280	Agrimet, Curve developed by Pro AG, Inc., Pasco, WA 1988
60	WINTER GRAIN	66	155	196	Wright, 1981

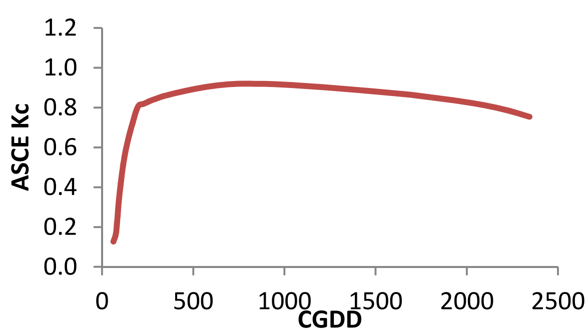
*Alfalfa mean represents 85% of peak, takes seasonal cuttings into account. Alfalfa peak represents actively growing mature, uncut alfalfa.

Appendix 4

Each crop has a table that shows the previous AgriMet and the new converted crop coefficients using *R*. The fitted CGDD dates are also given for each crop that corresponds with the day of year (DOY) from central Washington. For each crop, two curves were developed to demonstrate the difference between Kimberly or FAO based crop coefficients.. *Tbase* is abbreviated to *Tb.*

Table 4.1. Old and converted crop coefficients for alfalfa averaged over a season in eastern central WA based on day of the year and cumulative growing degree days.

Alfalfa (mean)					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	CGDD Tb=5
0	0.15	0.85	0.13	91	62
10	0.2	0.87	0.17	95	77
20	0.4	0.88	0.35	100	94
30	0.58	0.90	0.52	104	118
40	0.69	0.92	0.63	109	141
50	0.79	0.94	0.74	113	173
60	0.85	0.95	0.81	117	198
70	0.85	0.96	0.82	122	229
80	0.85	0.98	0.83	126	266
90	0.85	0.99	0.85	131	299
100	0.85	1.01	0.86	135	344
110	0.85	1.05	0.89	150	490
120	0.85	1.08	0.92	164	670
130	0.85	1.08	0.92	179	862
140	0.85	1.07	0.91	193	1093
150	0.85	1.05	0.89	208	1336
160	0.85	1.03	0.87	222	1602
170	0.85	1.00	0.85	237	1828
180	0.85	0.96	0.82	251	2043
190	0.85	0.93	0.79	266	2203
200	0.85	0.89	0.75	280	2343



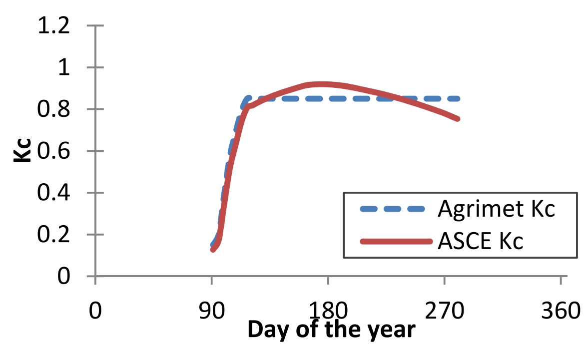
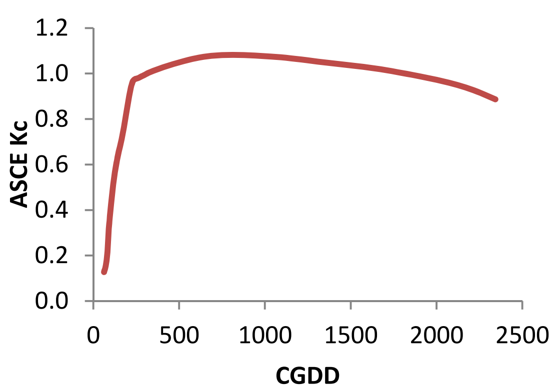


Figure 4.1. Right: Average seasonal crop coefficients for alfalfa based on CGDD. Left: comparison between Alfalfa (mean) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations..

Table 4.2. Old and converted crop coefficients for a single harvest of alfalfa during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Alfalfa (Peak)					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	CGDD Tb=5
0	0.15	0.85	0.13	91	62
10	0.2	0.87	0.17	95	77
20	0.4	0.88	0.35	100	94
30	0.58	0.90	0.52	104	118
40	0.69	0.92	0.63	109	141
50	0.79	0.94	0.74	113	173
60	0.9	0.95	0.85	117	198
70	1	0.96	0.96	122	229
80	1	0.98	0.98	126	266
90	1	0.99	0.99	131	299
100	1	1.01	1.01	135	344
110	1	1.05	1.05	150	490
120	1	1.08	1.08	164	670
130	1	1.08	1.08	179	862
140	1	1.07	1.07	193	1093
150	1	1.05	1.05	208	1336
160	1	1.03	1.03	222	1602
170	1	1.00	1.00	237	1828
180	1	0.96	0.96	251	2043
190	1	0.93	0.93	266	2203
200	1	0.89	0.89	280	2343



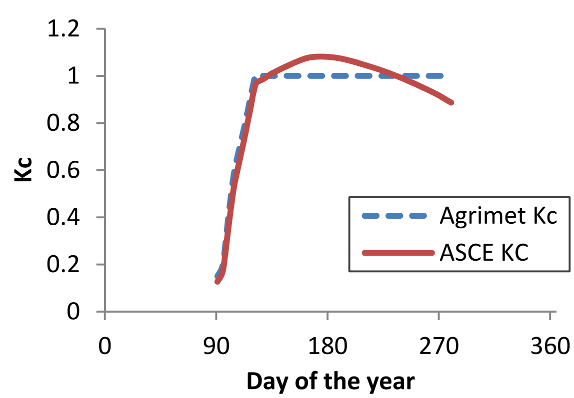


Figure 4.2 Right: Alfalfa (peak) crop coefficients based on CGDD. Left: comparison between alfalfa (peak) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.3. Old and converted crop coefficients for apples during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Apple					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	CGDD Tb=10
0	0.2	0.92	0.18	110	6
10	0.2	0.94	0.19	114	10
20	0.23	0.95	0.22	118	16
30	0.31	0.96	0.30	122	26
40	0.42	0.98	0.41	126	36
50	0.53	0.99	0.53	130	48
60	0.66	1.00	0.66	133	63
70	0.77	1.02	0.78	137	81
80	0.84	1.03	0.86	141	100
90	0.89	1.04	0.92	145	124
100	0.95	1.05	0.99	149	148
110	0.95	1.07	1.02	162	231
120	0.96	1.08	1.04	175	335
130	0.98	1.08	1.06	188	464
140	1	1.06	1.06	201	612
150	1	1.04	1.04	214	782
160	1	1.02	1.02	226	943
170	1	0.99	0.99	239	1080
180	0.78	0.96	0.75	252	1198
190	0.6	0.93	0.56	265	1281
200	0.39	0.89	0.35	278	1340

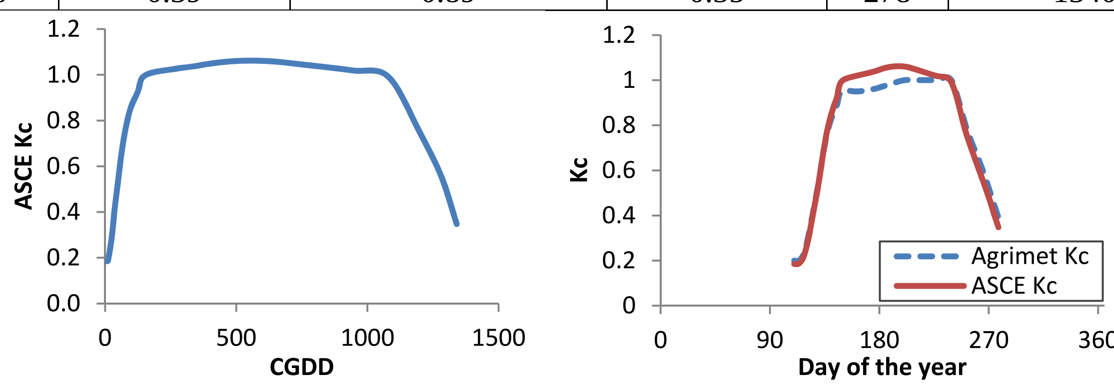


Figure 4.3. Right: Apple crop coefficients based on CGDD. Left: comparison between apple crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.4. Old and converted crop coefficients for apricots during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Apricot					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.4	0.92	0.37	110	6
10	0.45	0.94	0.42	114	10
20	0.52	0.95	0.49	118	16
30	0.58	0.96	0.56	122	26
40	0.66	0.98	0.65	126	36
50	0.76	0.99	0.75	130	48
60	0.85	1.00	0.85	133	63
70	0.94	1.02	0.95	137	81
80	1	1.03	1.03	141	100
90	1.04	1.04	1.08	145	124
100	1.04	1.05	1.09	149	148
110	1.04	1.07	1.12	162	231
120	1.04	1.08	1.12	175	335
130	1.04	1.08	1.12	188	464
140	1.04	1.06	1.10	201	612
150	1.04	1.04	1.08	214	782
160	0.97	1.02	0.99	226	943
170	0.88	0.99	0.87	239	1080
180	0.8	0.96	0.77	252	1198
190	0.66	0.93	0.61	265	1281
200	0.43	0.89	0.38	278	1340

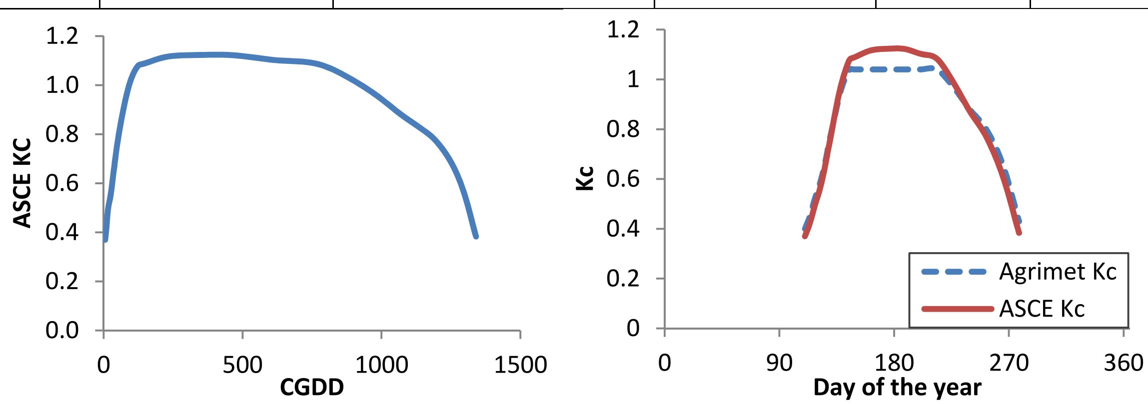


Figure 4.4. Right: Apricot crop coefficients based on CGDD. Left: comparison between apricot crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.5. Old and converted crop coefficients for asparagus during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Asparagus					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.4	0.96	0.38	120	221
10	0.43	0.99	0.43	129	291
20	0.47	1.02	0.48	139	373
30	0.5	1.04	0.52	148	479
40	0.53	1.07	0.57	158	586
50	0.57	1.08	0.61	167	708
60	0.6	1.08	0.65	176	831
70	0.7	1.08	0.76	186	967
80	0.8	1.07	0.85	195	1126
90	0.9	1.05	0.95	205	1282
100	1	1.04	1.04	214	1462
110	1	1.03	1.03	221	1566
120	1	1.02	1.02	227	1688
130	1	1.01	1.01	234	1783
140	1	0.99	0.99	240	1888
150	1	0.98	0.98	247	1989
160	1	0.96	0.96	254	2068
170	1	0.94	0.94	260	2151
180	1	0.93	0.93	267	2213
190	1	0.91	0.91	273	2285
200	1	0.89	0.89	280	2343

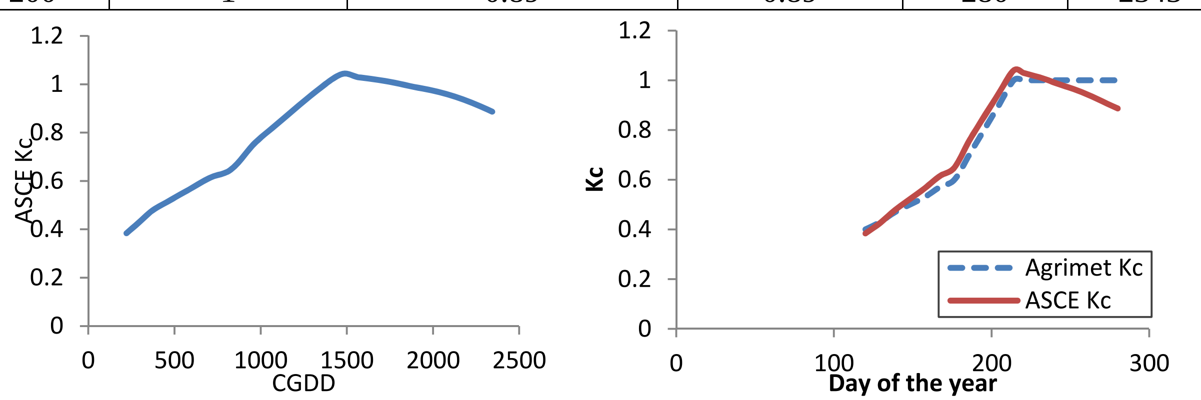


Figure 4.5. Right: Asparagus crop coefficients based on CGDD. Left: comparison between asparagus crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.6. Old and converted crop coefficients for blackberries during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Blackberry					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.15	0.84	0.13	90	59
10	0.17	0.87	0.15	96	81
20	0.23	0.89	0.21	102	107
30	0.33	0.92	0.30	108	141
40	0.46	0.94	0.43	114	179
50	0.6	0.96	0.58	120	221
60	0.73	0.98	0.72	126	266
70	0.85	1.00	0.85	132	316
80	0.95	1.02	0.97	138	373
90	1	1.04	1.04	144	435
100	1.01	1.05	1.06	150	502
110	1	1.08	1.08	163	645
120	0.99	1.08	1.07	176	816
130	0.97	1.08	1.05	188	1012
140	0.95	1.06	1.01	201	1227
150	0.92	1.04	0.96	214	1462
160	0.9	1.02	0.92	227	1671
170	0.88	0.99	0.87	240	1872
180	0.86	0.96	0.83	252	2056
190	0.83	0.93	0.77	265	2203
200	0.8	0.89	0.71	278	2328

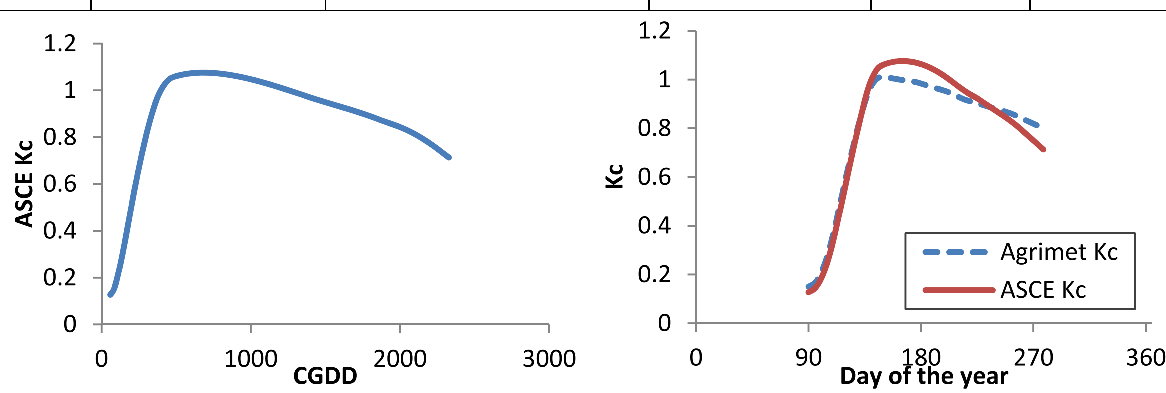
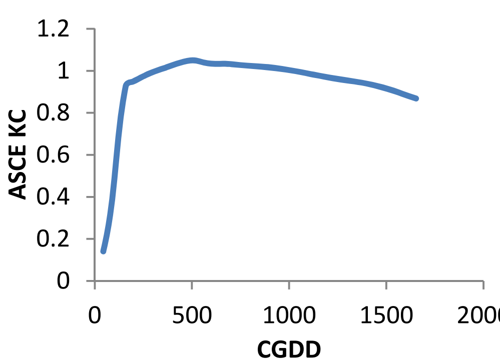


Figure 4.6. Right: Blackberry crop coefficients based on CGDD. Left: comparison between blackberry crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.7. Old and converted crop coefficients for blueberries during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Blueberry					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.17	0.83	0.14	85	44
10	0.26	0.85	0.22	92	62
20	0.44	0.88	0.39	98	90
30	0.72	0.90	0.65	105	118
40	1	0.93	0.93	111	159
50	1	0.95	0.95	118	198
60	1	0.97	0.97	124	251
70	1	0.99	0.99	131	299
80	1	1.02	1.02	137	363
90	1	1.03	1.03	144	423
100	1	1.05	1.05	150	502
110	0.97	1.07	1.03	158	586
120	0.96	1.08	1.03	165	683
130	0.95	1.08	1.03	173	774
140	0.94	1.08	1.02	180	892
150	0.93	1.08	1.00	188	996
160	0.92	1.07	0.98	195	1126
170	0.91	1.06	0.96	203	1245
180	0.9	1.05	0.94	210	1391
190	0.88	1.04	0.91	218	1514
200	0.85	1.02	0.87	225	1653



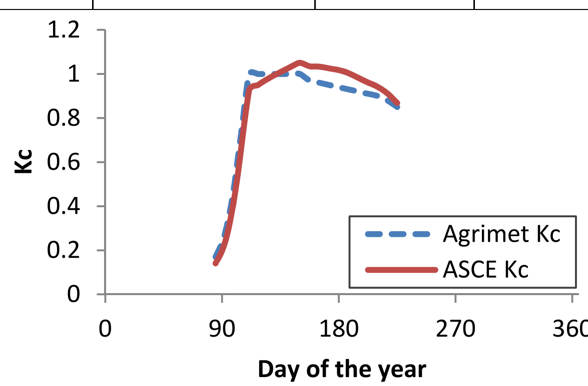


Figure 4.7. Right: Blueberry crop coefficients based on CGDD. Left: comparison between blueberry crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.8. Old and converted crop coefficients for bluegrass (established) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Bluegrass Established					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.3	0.78	0.24	72	12
10	0.36	0.80	0.29	77	23
20	0.47	0.82	0.38	83	36
30	0.63	0.84	0.53	88	51
40	0.78	0.86	0.67	94	69
50	0.88	0.88	0.77	99	94
60	0.93	0.90	0.84	104	118
70	0.96	0.92	0.88	110	147
80	0.97	0.94	0.91	115	185
90	0.97	0.96	0.93	121	221
100	0.97	0.98	0.95	126	266
110	0.96	1.00	0.96	133	316
120	0.95	1.02	0.97	139	383
130	0.93	1.04	0.97	146	446
140	0.89	1.06	0.94	152	526
150	0.8	1.07	0.86	159	610
160	0.5	1.08	0.54	166	683
170	0.35	1.08	0.38	172	774
180	0.3	1.08	0.32	179	862
190	0.27	1.08	0.29	185	967
200	0.25	1.07	0.27	192	1076

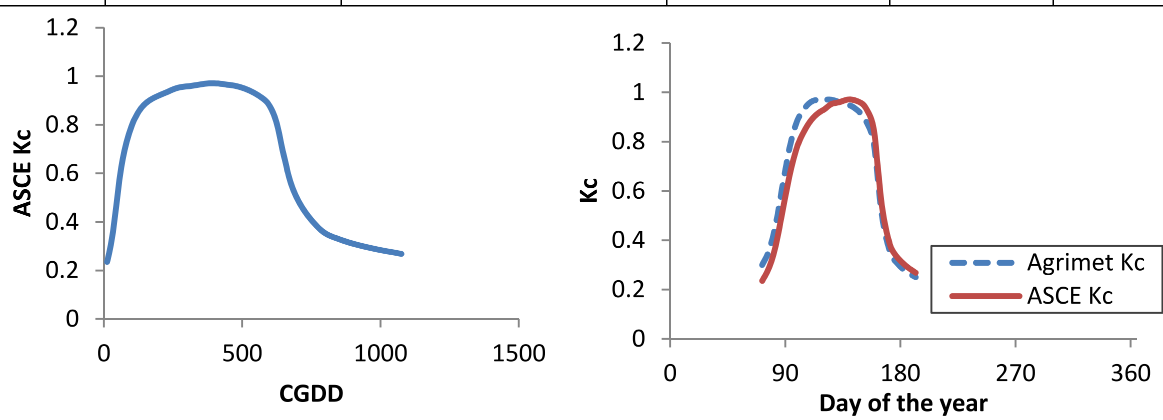
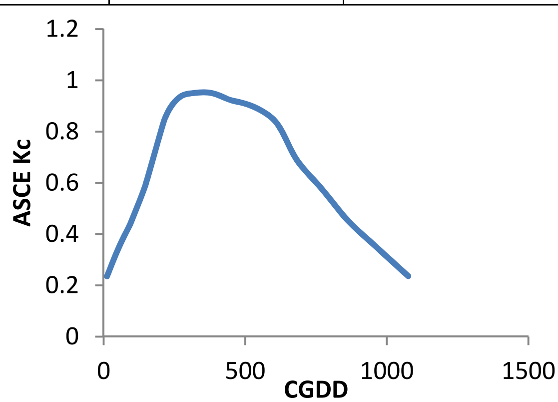


Figure 4.8. Right: Bluegrass established crop coefficients based on CGDD. Left: comparison between bluegrass established crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.9. Old and converted crop coefficients for bluegrass seed during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Bluegrass Seed					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.3	0.78	0.24	72	12
10	0.33	0.80	0.27	77	23
20	0.37	0.82	0.30	83	36
30	0.41	0.84	0.34	88	51
40	0.45	0.86	0.39	94	69
50	0.5	0.88	0.44	99	94
60	0.56	0.90	0.50	104	118
70	0.64	0.92	0.59	110	147
80	0.78	0.94	0.73	115	185
90	0.9	0.96	0.86	121	221
100	0.95	0.98	0.93	126	266
110	0.95	1.00	0.95	133	316
120	0.93	1.02	0.95	139	383
130	0.89	1.04	0.92	146	446
140	0.85	1.06	0.90	152	526
150	0.78	1.07	0.84	159	610
160	0.64	1.08	0.69	166	683
170	0.53	1.08	0.57	172	774
180	0.42	1.08	0.45	178.8	862
190	0.32	1.08	0.35	185	967
200	0.22	1.07	0.24	192	1076



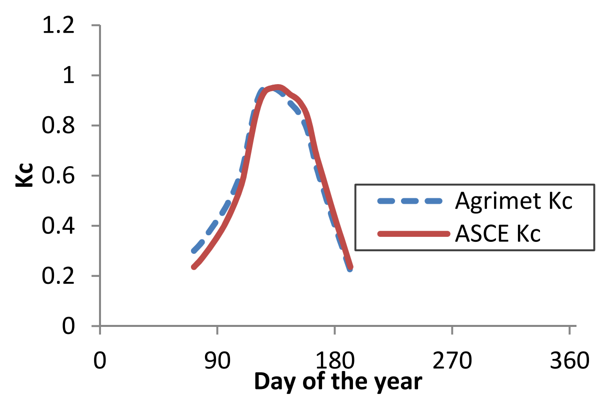
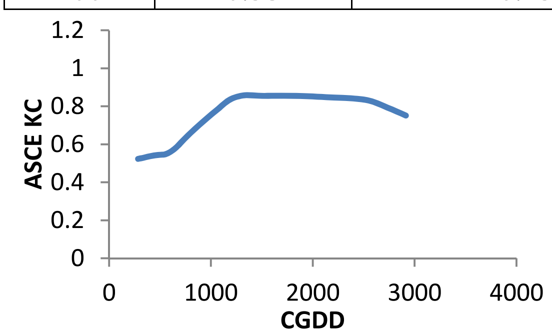


Figure 4.9. Right: Bluegrass seed crop coefficients based on CGDD. Left: comparison between bluegrass seed crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.10. Old and converted crop coefficients for broccoli during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Broccoli					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.70	0.75	0.52	91	284
10	0.70	0.76	0.53	98	338
20	0.70	0.77	0.54	105	405
30	0.70	0.78	0.54	112	481
40	0.70	0.79	0.55	119	563
50	0.73	0.79	0.58	126	650
60	0.79	0.80	0.63	132	743
70	0.85	0.80	0.68	139	845
80	0.91	0.81	0.73	146	954
90	0.97	0.81	0.79	153	1070
100	1.03	0.82	0.84	160	1189
110	1.05	0.82	0.86	168	1328
120	1.05	0.81	0.86	177	1478
130	1.05	0.81	0.86	185	1638
140	1.05	0.81	0.85	193	1825
150	1.05	0.81	0.85	202	1999
160	1.05	0.81	0.85	210	2185
170	1.05	0.80	0.84	218	2389
180	1.04	0.80	0.83	226	2568
190	1.00	0.80	0.79	235	2735
200	0.95	0.79	0.75	243	2914



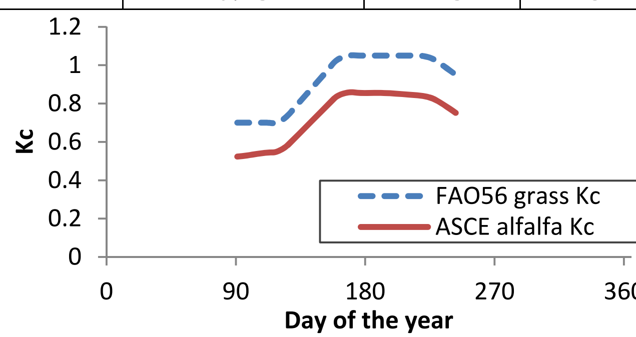


Figure 14. Right: broccoli crop coefficients based on CGDD. Left: comparison between broccoli crop coefficients based on grass FAO56 and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.11. Old and converted crop coefficients for cabbage during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Cabbage					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.15	0.85	0.13	91	284
10	0.25	0.87	0.22	98	338
20	0.35	0.90	0.32	105	405
30	0.38	0.93	0.35	112	481
40	0.45	0.95	0.43	119	563
50	0.54	0.98	0.53	126	650
60	0.65	1.00	0.65	132	743
70	0.75	1.02	0.77	139	845
80	0.84	1.04	0.87	146	954
90	0.91	1.06	0.96	153	1070
100	0.95	1.07	1.02	160	1189
110	0.94	1.08	1.01	168	1328
120	0.94	1.08	1.02	177	1478
130	0.9	1.08	0.97	185	1638
140	0.82	1.07	0.88	193	1825
150	0.68	1.06	0.72	202	1999
160	0.5	1.05	0.52	210	2185
170	0.4	1.03	0.41	218	2389
180	0.3	1.02	0.31	226	2568
190	0.25	1.00	0.25	235	2735
200	0.2	0.98	0.20	243	2914

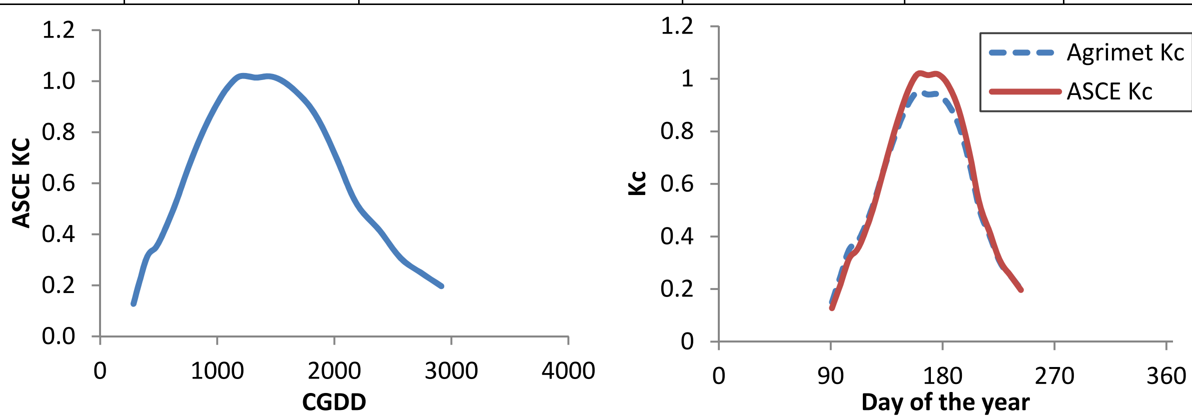
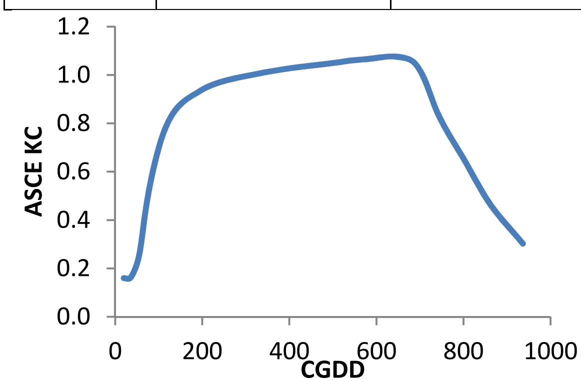


Figure 4.11. Right: cabbage crop coefficients based on CGDD. Left: comparison between cabbage crop coefficients based on Kimberly & ASCE standardized Penman-Monteith equations

Table 4.12. Old and converted crop coefficients for canola during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Canola					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.2	0.80	0.16	76	20
10	0.2	0.82	0.16	83	36
20	0.3	0.84	0.25	89	55
30	0.6	0.87	0.52	96	77
40	0.83	0.89	0.74	102	107
50	0.94	0.92	0.86	109	141
60	0.98	0.94	0.92	115	185
70	1	0.96	0.96	122	229
80	1	0.99	0.99	128	282
90	1	1.01	1.01	135	335
100	1	1.03	1.03	141	402
110	1	1.04	1.04	145	446
120	1	1.05	1.05	149	490
130	1	1.06	1.06	154	537
140	1	1.07	1.07	158	586
150	1	1.08	1.08	162	645
160	0.96	1.08	1.03	166	695
170	0.76	1.08	0.82	170	747
180	0.6	1.08	0.65	175	802
190	0.43	1.08	0.46	179	862
200	0.28	1.08	0.30	183	936



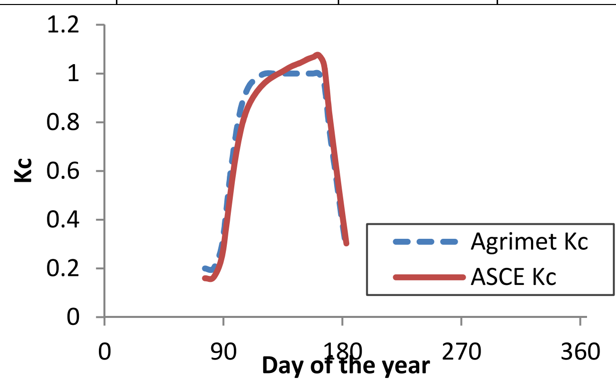
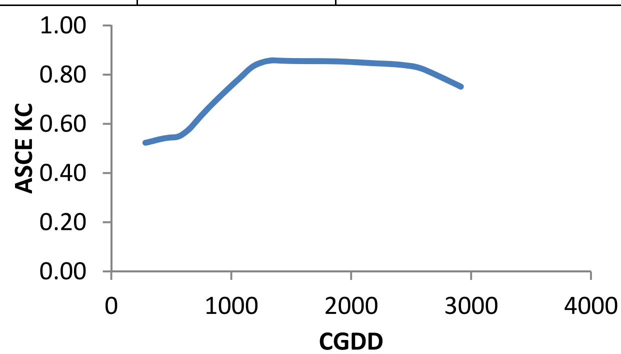


Figure 4.12. Right: canola crop coefficients based on CGDD. Left: comparison between canola crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.13. Old and converted crop coefficients for carrots during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Carrot full irrigation					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.70	0.75	0.52	91	284
10	0.70	0.76	0.53	98	338
20	0.70	0.77	0.54	105	405
30	0.70	0.78	0.54	112	481
40	0.70	0.78	0.55	119	563
50	0.73	0.79	0.58	126	650
60	0.79	0.80	0.63	132	743
70	0.85	0.80	0.68	139	845
80	0.91	0.81	0.73	146	954
90	0.97	0.81	0.79	153	1070
100	1.03	0.82	0.84	160	1189
110	1.05	0.82	0.86	168	1328
120	1.05	0.81	0.86	177	1478
130	1.05	0.81	0.86	185	1638
140	1.05	0.81	0.85	193	1825
150	1.05	0.81	0.85	202	1999
160	1.05	0.81	0.85	210	2185
170	1.05	0.80	0.84	218	2389
180	1.04	0.80	0.83	226	2568
190	1.00	0.80	0.79	235	2735
200	0.95	0.79	0.75	243	2914



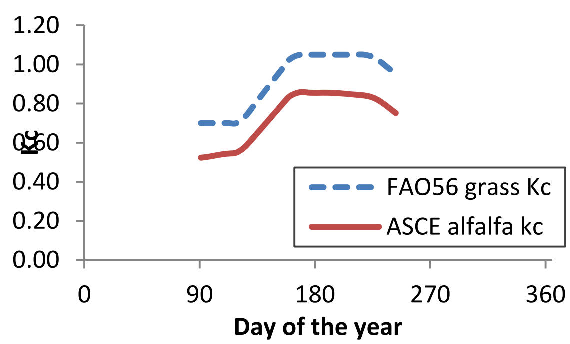


Figure 17. Right: carrot crop coefficients based on CGDD. Left: comparison between carrot crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.14. Old and converted crop coefficients for cattails, and bulrushes (killing frost) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Cattails, Bulrushes, killing frost					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.30	0.79	0.24	121	601
10	0.30	0.79	0.24	125	650
20	0.30	0.79	0.24	129	703
30	0.39	0.80	0.31	133	757
40	0.50	0.80	0.40	137	816
50	0.62	0.80	0.50	141	874
60	0.74	0.81	0.59	145	938
70	0.85	0.81	0.69	149	1002
80	0.97	0.81	0.79	153	1070
90	1.08	0.81	0.88	157	1139
100	1.20	0.82	0.98	161	1206
110	1.20	0.82	0.98	171	1364
120	1.20	0.81	0.98	181	1559
130	1.20	0.81	0.98	191	1760
140	1.20	0.81	0.97	201	1976
150	1.20	0.81	0.97	211	2208
160	1.20	0.80	0.96	220	2433
170	1.20	0.80	0.96	230	2653
180	1.20	0.79	0.95	240	2855
190	0.75	0.78	0.59	250	3047
200	0.30	0.77	0.23	260	3218

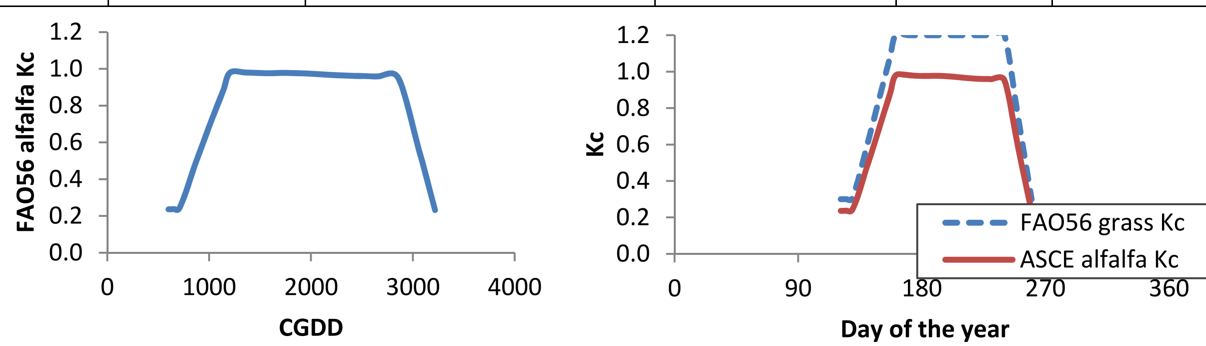


Figure 18. Right: cattails, and bulrushes (killing frost) crop coefficients based on CGDD. Left: comparison between cattails, and bulrushes crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.15. Old and converted crop coefficients for cattails, and bulrushes (no frost) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Cattails, Bulrushes, no frost					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.60	0.79	0.47	121	601
10	0.60	0.79	0.47	125	650
20	0.60	0.79	0.48	129	703
30	0.66	0.80	0.52	133	757
40	0.74	0.80	0.59	137	816
50	0.81	0.80	0.65	141	874
60	0.89	0.81	0.72	145	938
70	0.97	0.81	0.78	149	1002
80	1.05	0.81	0.85	153	1070
90	1.12	0.81	0.91	157	1139
100	1.20	0.82	0.98	161	1206
110	1.20	0.82	0.98	171	1364
120	1.20	0.81	0.98	181	1559
130	1.20	0.81	0.98	191	1760
140	1.20	0.81	0.97	201	1976
150	1.20	0.81	0.97	211	2208
160	1.20	0.80	0.96	220	2433
170	1.20	0.80	0.96	230	2653
180	1.20	0.79	0.95	240	2855
190	0.90	0.78	0.70	250	3047
200	0.60	0.77	0.46	260	3218

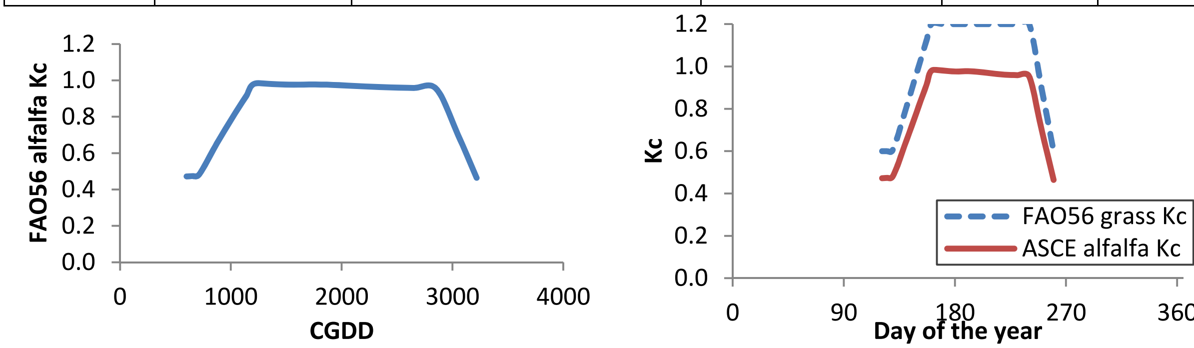
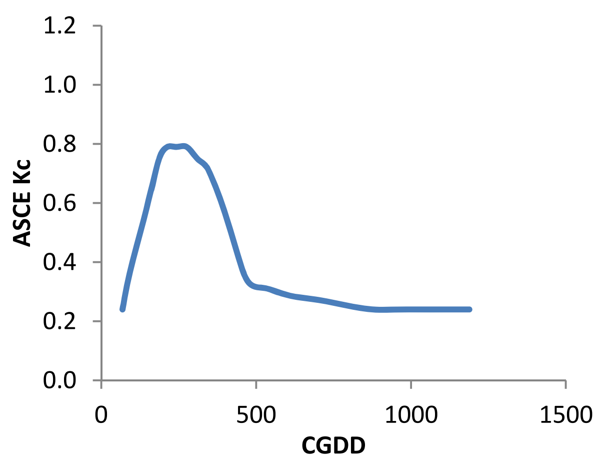


Figure 19. Right: cattails, and bulrushes (no frost) crop coefficients based on CGDD. Left: comparison between cattails, and bulrushes (no frost) crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.16. Crop coefficients for cheatgrass during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Cheatgrass			
% growth stage	Kc Derived By Allen Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
		DOY	Tb=0
0	0.24	60	69
10	0.32	64	82
20	0.42	68	103
30	0.52	71	132
40	0.64	75	160
50	0.76	79	190
60	0.79	83	213
70	0.79	87	243
80	0.79	90	276
90	0.75	94	310
100	0.71	98	347
110	0.55	104	405
120	0.34	110	470
130	0.31	117	538
140	0.29	123	613
150	0.27	129	703
160	0.26	135	786
170	0.24	141	874
180	0.24	148	971
190	0.24	154	1070
200	0.24	160	1189



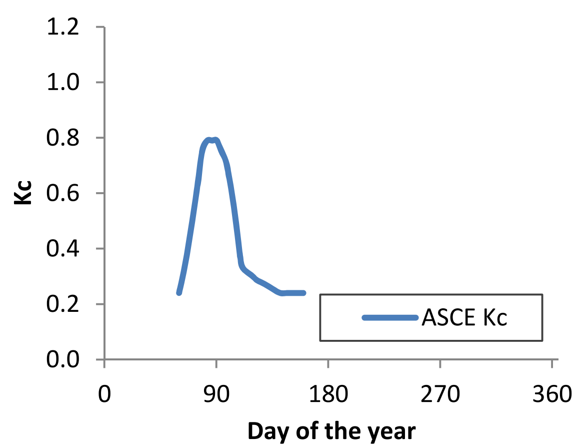
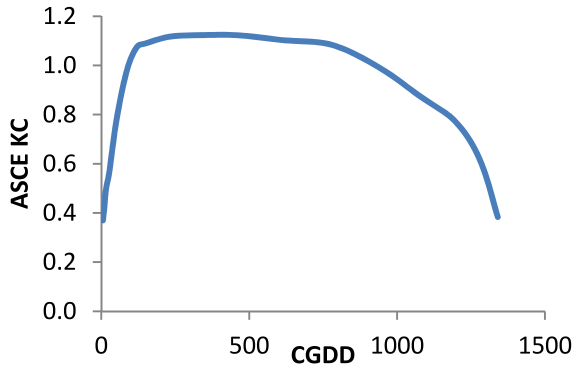


Figure 4.16. Right: cheatgrass crop coefficients based on CGDD. Left: cheatgrass crop coefficients based on days of the year

Table 4.17. Old and converted crop coefficients for cherries with a cover crop on the orchard floor during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Cherry winter cover					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.4	0.92	0.37	110	6
10	0.45	0.94	0.42	114	10
20	0.52	0.95	0.49	118	16
30	0.58	0.96	0.56	122	26
40	0.66	0.98	0.65	126	36
50	0.76	0.99	0.75	130	48
60	0.85	1.00	0.85	133	63
70	0.94	1.02	0.95	137	81
80	1	1.03	1.03	141	100
90	1.04	1.04	1.08	145	124
100	1.04	1.05	1.09	149	148
110	1.04	1.07	1.12	162	231
120	1.04	1.08	1.12	175	335
130	1.04	1.08	1.12	188	464
140	1.04	1.06	1.10	201	612
150	1.04	1.04	1.08	214	782
160	0.97	1.02	0.99	226	943
170	0.88	0.99	0.87	239	1080
180	0.8	0.96	0.77	252	1198
190	0.66	0.93	0.61	265	1281
200	0.43	0.89	0.38	278	1340



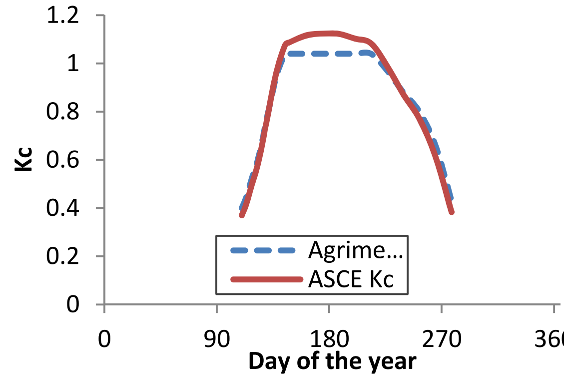
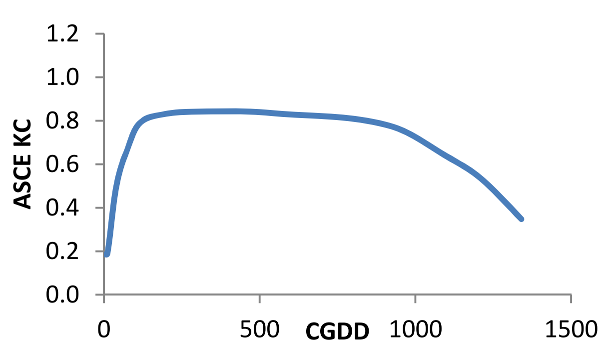


Figure 4.17. Right: Cherry (winter cover) crop coefficients based on CGDD. Left: comparison between Cherry (winter cover) crop coefficients based on Kimberly 1982 and ASCE standardized Penman-Monteith equation

Table 4.18. Old and converted crop coefficients for cherries without a cover crop during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Cherry no cover					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.2	0.92	0.18	110	6
10	0.2	0.94	0.19	114	10
20	0.25	0.95	0.24	118	16
30	0.37	0.96	0.36	122	26
40	0.48	0.98	0.47	126	36
50	0.56	0.99	0.56	130	48
60	0.62	1.00	0.62	133	63
70	0.68	1.02	0.69	137	81
80	0.74	1.03	0.76	141	100
90	0.77	1.04	0.80	145	124
100	0.78	1.05	0.82	149	148
110	0.78	1.07	0.84	162	231
120	0.78	1.08	0.84	175	335
130	0.78	1.08	0.84	188	464
140	0.78	1.06	0.83	201	612
150	0.78	1.04	0.81	214	782
160	0.75	1.02	0.76	226	943
170	0.66	0.99	0.65	239	1080
180	0.57	0.96	0.55	252	1198
190	0.47	0.93	0.44	265	1281
200	0.39	0.89	0.35	278	1340



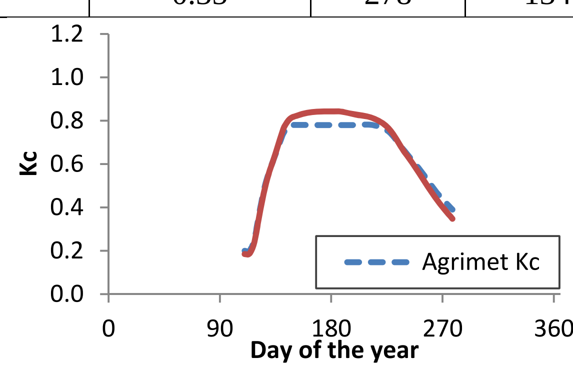
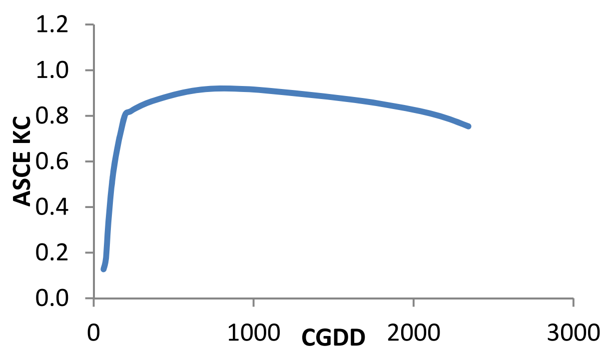


Figure 4.18. Right: Cherry (no cover) crop coefficients based on CGDD. Left: comparison between Cherry (no cover) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.19. Old and converted crop coefficients for clover during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Clover					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				CGDD	Tb=5
0	0.15	0.85	0.13	91	62
10	0.2	0.87	0.17	95	77
20	0.4	0.88	0.35	100	94
30	0.58	0.90	0.52	104	118
40	0.69	0.92	0.63	109	141
50	0.79	0.94	0.74	113	173
60	0.85	0.95	0.81	117	198
70	0.85	0.96	0.82	122	229
80	0.85	0.98	0.83	126	266
90	0.85	0.99	0.85	131	299
100	0.85	1.01	0.86	135	344
110	0.85	1.05	0.89	150	490
120	0.85	1.08	0.92	164	670
130	0.85	1.08	0.92	179	862
140	0.85	1.07	0.91	193	1093
150	0.85	1.05	0.89	208	1336
160	0.85	1.03	0.87	222	1602
170	0.85	1.00	0.85	237	1828
180	0.85	0.96	0.82	251	2043
190	0.85	0.93	0.79	266	2203
200	0.85	0.89	0.75	280	2343



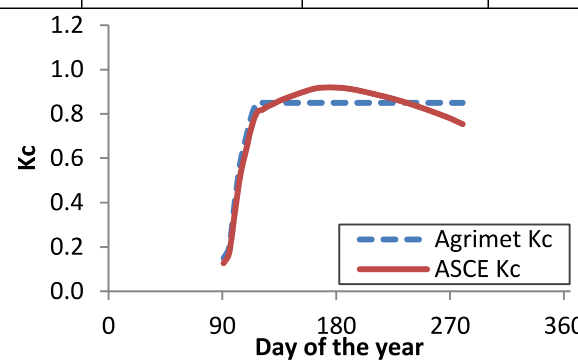
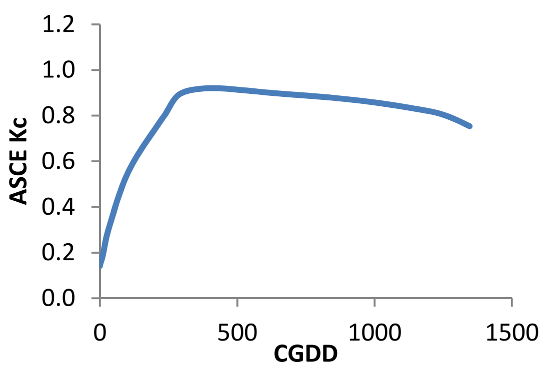


Figure 4.19. Right: Clover crop coefficients based on CGDD. Left: comparison between Clover crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.20. Old and converted crop coefficients for concord grapes during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Concord Grape					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.16	0.88	0.14	100	0
10	0.17	0.91	0.15	107	2
20	0.2	0.94	0.19	114	10
30	0.28	0.96	0.27	121	24
40	0.35	0.98	0.34	128	42
50	0.44	1.01	0.44	135	67
60	0.53	1.03	0.54	141	100
70	0.61	1.04	0.64	148	142
80	0.68	1.06	0.72	155	191
90	0.75	1.08	0.81	162	238
100	0.83	1.08	0.90	169	292
110	0.85	1.08	0.92	180	395
120	0.85	1.07	0.91	191	507
130	0.85	1.06	0.90	202	638
140	0.85	1.04	0.89	213	782
150	0.85	1.02	0.87	225	919
160	0.85	1.00	0.85	236	1041
170	0.85	0.98	0.83	247	1148
180	0.85	0.95	0.81	258	1234
190	0.85	0.92	0.78	269	1297
200	0.85	0.89	0.75	280	1346



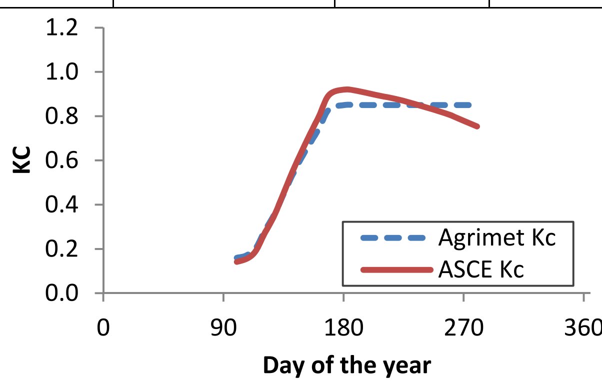
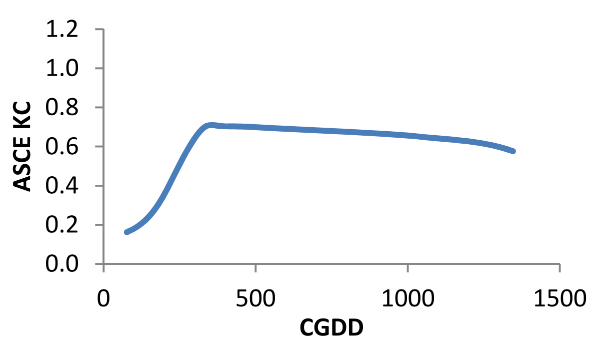


Figure 4.20. Right: Concord grape crop coefficients based on CGDD. Left: comparison between Concord grape crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.21. Old and converted crop coefficients for cucumbers during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Cucumber					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.16	1.01	0.16	136	76
10	0.18	1.03	0.19	142	105
20	0.22	1.04	0.23	149	142
30	0.31	1.06	0.33	155	191
40	0.42	1.07	0.45	162	231
50	0.56	1.08	0.60	168	284
60	0.65	1.08	0.70	174	335
70	0.65	1.08	0.70	181	395
80	0.65	1.08	0.70	187	464
90	0.65	1.07	0.70	194	530
100	0.65	1.06	0.69	200	612
110	0.65	1.05	0.68	208	717
120	0.65	1.04	0.67	216	819
130	0.65	1.02	0.67	224	919
140	0.65	1.01	0.65	232	1010
150	0.65	0.99	0.64	240	1091
160	0.65	0.97	0.63	248	1166
170	0.65	0.96	0.62	256	1227
180	0.65	0.93	0.61	264	1276
190	0.65	0.91	0.59	272	1318
200	0.65	0.89	0.58	280	1346



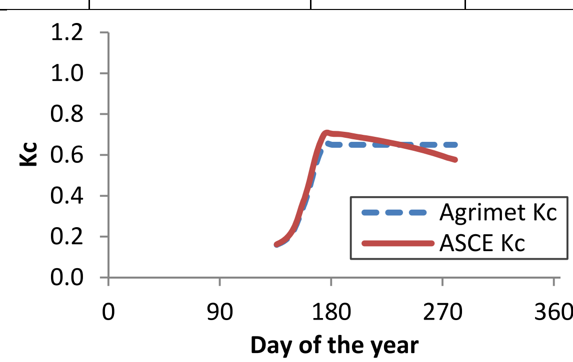
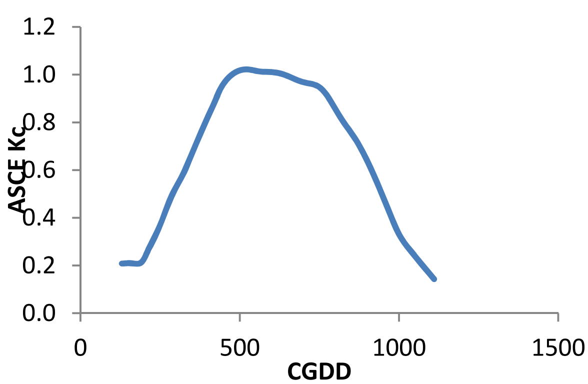


Figure 4.21. Right: Cucumber crop coefficients based on CGDD. Left: comparison between cucumber crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.22. Old and converted crop coefficients for dry beans during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Dry Bean					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.2	1.04	0.21	146	130
10	0.2	1.05	0.21	151	154
20	0.2	1.06	0.21	155	191
30	0.26	1.07	0.28	160	217
40	0.35	1.08	0.38	164	252
50	0.45	1.08	0.49	169	284
60	0.55	1.08	0.59	173	326
70	0.66	1.08	0.71	178	364
80	0.8	1.08	0.87	182	415
90	0.9	1.08	0.97	187	454
100	0.95	1.07	1.02	191	507
110	0.95	1.07	1.01	196	565
120	0.95	1.06	1.01	201	625
130	0.925	1.05	0.97	206	690
140	0.9	1.04	0.94	211	757
150	0.785	1.04	0.81	217	819
160	0.67	1.03	0.69	222	882
170	0.5	1.02	0.51	227	943
180	0.33	1.01	0.33	232	999
190	0.24	1.00	0.24	237	1050
200	0.145	0.98	0.14	242	1110



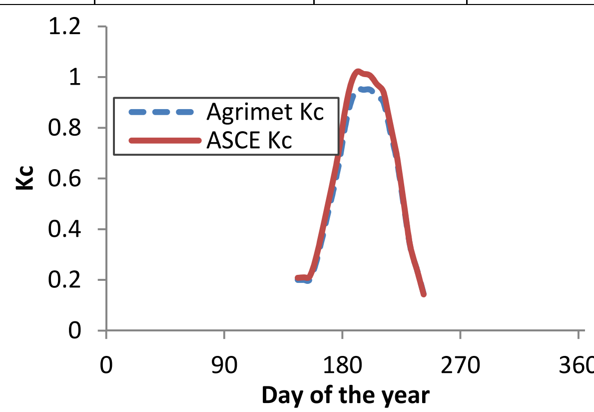
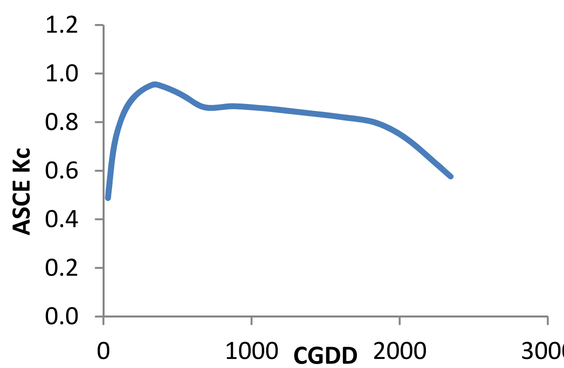


Figure 4.22. Right: Dry Bean crop coefficients based on CGDD. Left: comparison between dry bean crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.23. Old and converted crop coefficients for grass hay (mean) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Grass Hay (mean)					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.6	0.81	0.49	80	31
10	0.69	0.83	0.57	86	44
20	0.78	0.85	0.66	91	62
30	0.85	0.87	0.74	97	86
40	0.88	0.89	0.79	103	107
50	0.92	0.92	0.84	109	141
60	0.94	0.94	0.88	114	179
70	0.95	0.96	0.91	120	213
80	0.95	0.98	0.93	126	258
90	0.95	1.00	0.95	131	307
100	0.94	1.02	0.95	137	363
110	0.87	1.05	0.92	151	514
120	0.8	1.08	0.86	166	683
130	0.8	1.08	0.87	180	877
140	0.8	1.07	0.86	194	1110
150	0.8	1.05	0.84	209	1354
160	0.8	1.03	0.82	223	1602
170	0.8	1.00	0.80	237	1842
180	0.76	0.96	0.73	251	2043
190	0.7	0.93	0.65	266	2203
200	0.65	0.89	0.58	280	2343



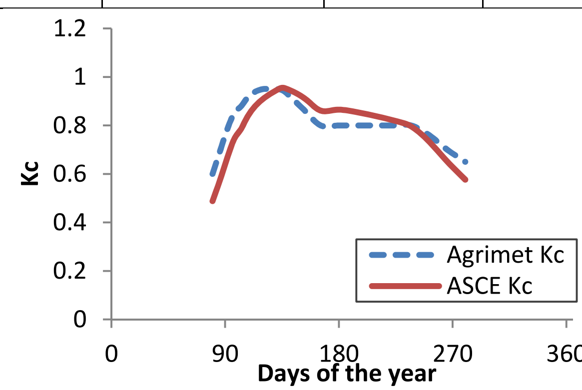


Figure 4.23. Right: Grass hay (mean) crop coefficients based on CGDD. Left: comparison between grass hay (mean) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.24. Old and converted crop coefficients for grass hay (peak) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Grass Hay (peak)					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.6	0.81	0.49	80	31
10	0.69	0.83	0.57	86	44
20	0.78	0.85	0.66	91	62
30	0.85	0.87	0.74	97	86
40	0.88	0.89	0.79	103	107
50	0.92	0.92	0.84	109	141
60	0.95	0.94	0.89	114	179
70	0.96	0.96	0.92	120	213
80	0.96	0.98	0.94	126	258
90	0.96	1.00	0.96	131	307
100	0.96	1.02	0.97	137	363
110	0.95	1.05	1.00	151	514
120	0.93	1.08	1.00	166	683
130	0.92	1.08	1.00	180	877
140	0.9	1.07	0.96	194	1110
150	0.89	1.05	0.93	209	1354
160	0.87	1.03	0.89	223	1602
170	0.86	1.00	0.86	237	1842
180	0.84	0.96	0.81	251	2043
190	0.83	0.93	0.77	266	2203
200	0.81	0.89	0.72	280	2343

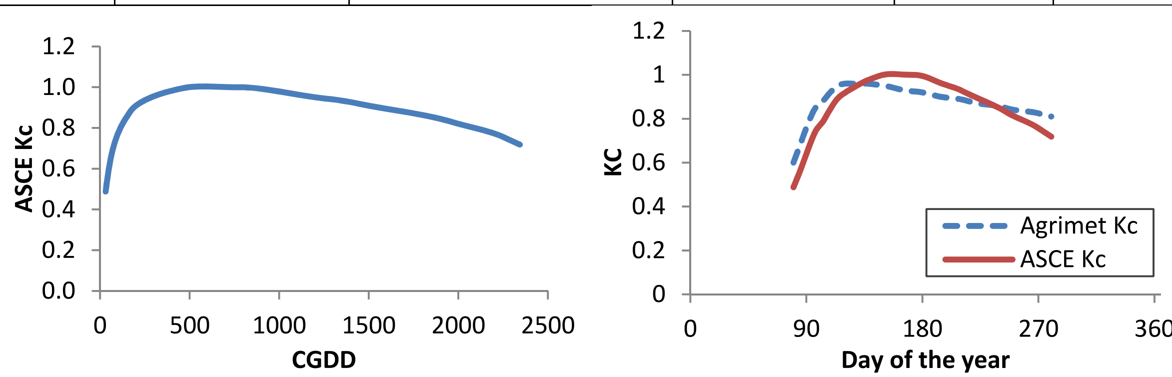


Figure 4.24. Right: Grass hay (peak) crop coefficients based on CGDD. Left: comparison between grass hay (peak) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.25. Old and converted crop coefficients for field corn during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Field Corn					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.2	0.99	0.20	129	204
10	0.2	1.01	0.20	136	244
20	0.2	1.03	0.21	143	288
30	0.2	1.05	0.21	151	336
40	0.23	1.07	0.25	158	387
50	0.32	1.08	0.34	165	446
60	0.42	1.08	0.45	172	502
70	0.55	1.08	0.59	179	570
80	0.7	1.08	0.76	187	640
90	0.85	1.07	0.91	194	716
100	0.95	1.06	1.01	201	808
110	0.955	1.05	1.00	207	868
120	0.959	1.04	1.00	213	940
130	0.953	1.03	0.99	218	1011
140	0.947	1.02	0.97	224	1081
150	0.941	1.01	0.95	230	1149
160	0.924	1.00	0.93	236	1202
170	0.9	0.99	0.89	242	1261
180	0.87	0.98	0.85	247	1318
190	0.838	0.96	0.81	253	1367
200	0.802	0.95	0.76	259	1414

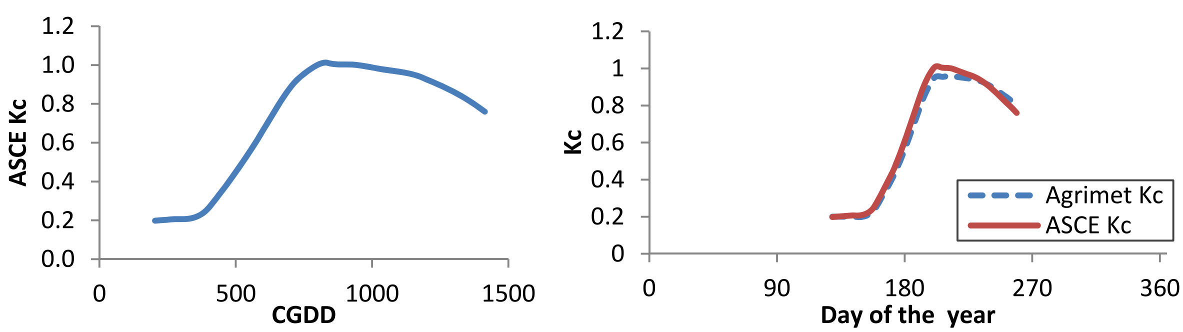
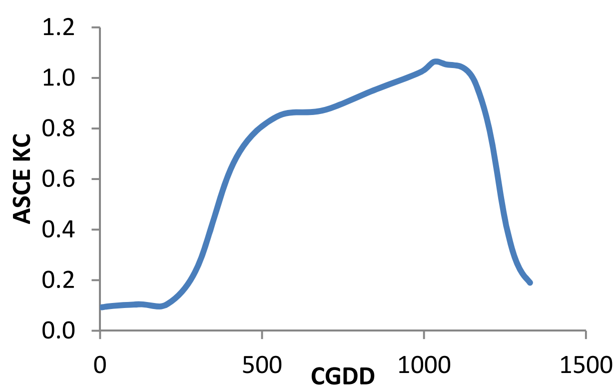


Figure 4.25. Right: Field corn crop coefficients based on CGDD. Left: comparison between field corn crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.26. Old and converted crop coefficients for hops during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Hops					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.1	0.92	0.09	110	6
10	0.1	0.97	0.10	122	29
20	0.1	1.01	0.10	134	67
30	0.1	1.04	0.10	146	130
40	0.1	1.07	0.11	158	210
50	0.23	1.08	0.25	170	299
60	0.62	1.08	0.67	182	415
70	0.79	1.07	0.84	194	542
80	0.83	1.05	0.87	206	690
90	0.92	1.03	0.95	218	844
100	1.01	1.01	1.02	230	988
110	1.06	1.00	1.06	234	1031
120	1.06	0.99	1.05	239	1070
130	1.06	0.98	1.04	243	1120
140	1.01	0.98	0.98	248	1157
150	0.85	0.96	0.82	252	1198
160	0.64	0.96	0.61	256	1227
170	0.44	0.94	0.42	261	1254
180	0.31	0.93	0.29	265	1281
190	0.25	0.92	0.23	270	1302
200	0.21	0.90	0.19	274	1327



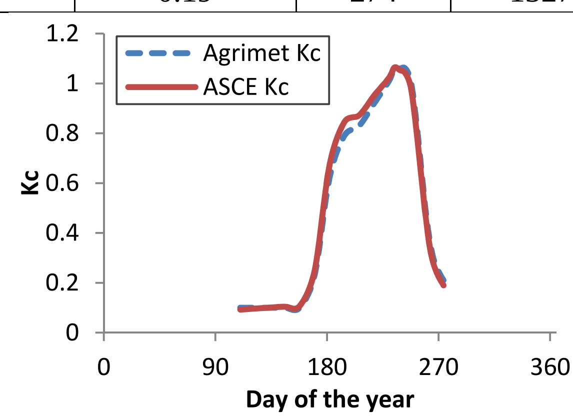
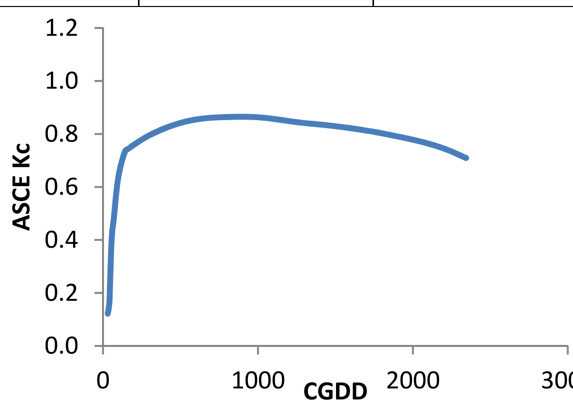


Figure 4.26. Right: Hops crop coefficients based on CGDD. Left: comparison between hops crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.27. Old and converted crop coefficients for lawn grass during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Lawn					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.15	0.81	0.12	80	31
10	0.2	0.82	0.16	85	41
20	0.47	0.84	0.40	89	55
30	0.58	0.86	0.50	94	73
40	0.69	0.88	0.61	99	90
50	0.75	0.90	0.67	104	112
60	0.8	0.92	0.73	108	141
70	0.8	0.93	0.74	113	166
80	0.8	0.95	0.76	118	198
90	0.8	0.97	0.77	122	236
100	0.8	0.98	0.79	127	274
110	0.8	1.03	0.82	142	413
120	0.8	1.07	0.85	158	586
130	0.8	1.08	0.86	173	774
140	0.8	1.08	0.86	188	1012
150	0.8	1.05	0.84	204	1263
160	0.8	1.03	0.83	219	1532
170	0.8	1.00	0.80	234	1798
180	0.8	0.97	0.78	249	2017
190	0.8	0.93	0.75	265	2193
200	0.8	0.89	0.71	280	2343



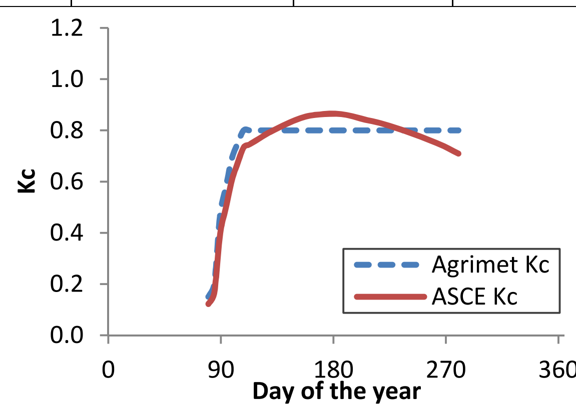


Figure 4.27. Right: Lawn grass crop coefficients based on CGDD. Left: comparison between lawn grass crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.28. Old and converted crop coefficients for lentil during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Lentil					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.2	0.90	0.18	105	415
10	0.22	0.92	0.20	111	470
20	0.26	0.94	0.25	116	538
30	0.31	0.96	0.30	122	601
40	0.42	0.98	0.41	127	676
50	0.55	1.00	0.55	133	743
60	0.68	1.02	0.69	138	830
70	0.8	1.03	0.83	144	906
80	0.9	1.05	0.94	149	1002
90	0.95	1.06	1.01	155	1087
100	0.95	1.07	1.02	160	1189
110	0.95	1.08	1.02	166	1275
120	0.95	1.08	1.02	171	1382
130	0.95	1.08	1.03	177	1478
140	0.95	1.08	1.03	182	1599
150	0.9	1.08	0.97	188	1699
160	0.82	1.07	0.88	193	1825
170	0.72	1.06	0.77	199	1932
180	0.6	1.05	0.63	204	2069
190	0.46	1.05	0.48	210	2185
200	0.3	1.04	0.31	215	2321

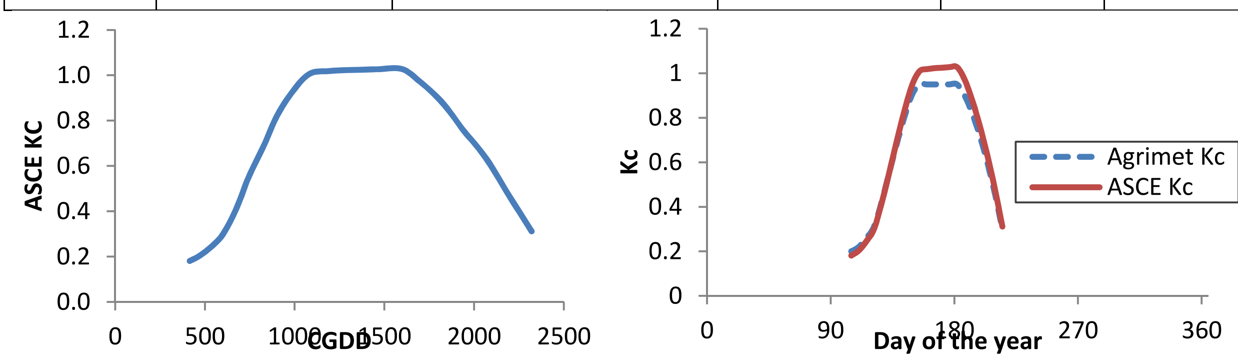


Figure 4.28. Right: Lentil crop coefficients based on CGDD. Left: comparison between lentil crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.29. Old and converted crop coefficients for melon during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Melon					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.16	1.01	0.16	136	76
10	0.18	1.03	0.19	142	105
20	0.22	1.04	0.23	149	142
30	0.31	1.06	0.33	155	191
40	0.42	1.07	0.45	162	231
50	0.56	1.08	0.60	168	284
60	0.65	1.08	0.70	174	335
70	0.65	1.08	0.70	181	395
80	0.65	1.08	0.70	187	464
90	0.65	1.07	0.70	194	530
100	0.65	1.06	0.69	200	612
110	0.65	1.05	0.68	208	717
120	0.65	1.04	0.67	216	819
130	0.65	1.02	0.67	224	919
140	0.65	1.01	0.65	232	1010
150	0.65	0.99	0.64	240	1091
160	0.65	0.97	0.63	248	1166
170	0.65	0.96	0.62	256	1227
180	0.65	0.93	0.61	264	1276
190	0.65	0.91	0.59	272	1318
200	0.65	0.89	0.58	280	1346

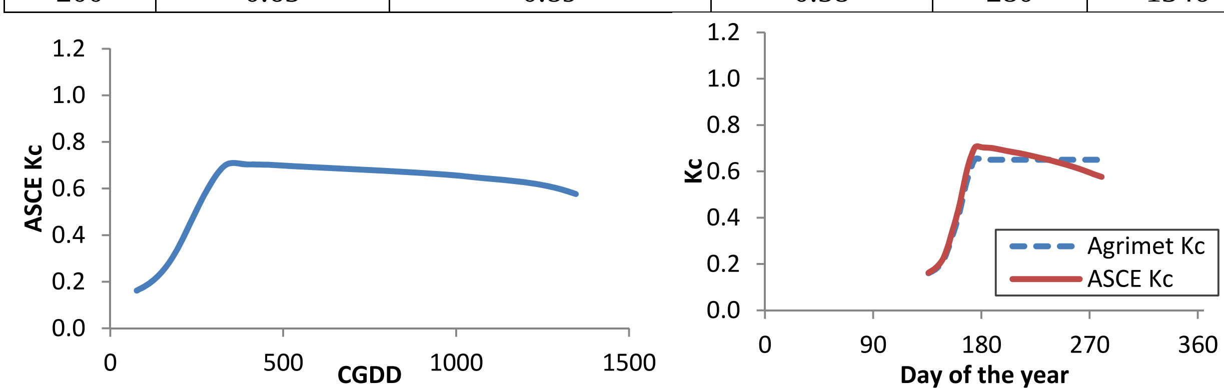


Figure 4.29. Right: Melon crop coefficients based on CGDD. Left: comparison between melon crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.30. Old and converted crop coefficients for mint during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Mint					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.16	0.96	0.15	119	213
10	0.17	0.97	0.16	124	243
20	0.22	0.99	0.22	128	282
30	0.31	1.00	0.31	133	316
40	0.42	1.02	0.43	137	363
50	0.54	1.03	0.56	142	413
60	0.66	1.04	0.69	147	457
70	0.76	1.05	0.80	151	514
80	0.84	1.06	0.89	156	563
90	0.89	1.07	0.95	160	622
100	0.92	1.08	0.99	165	683
110	0.95	1.08	1.03	173	774
120	0.95	1.08	1.03	181	892
130	0.95	1.08	1.02	188	1012
140	0.5	1.07	0.53	196	1143
150	0.75	1.05	0.79	204	1282
160	0.8	1.04	0.84	212	1409
170	0.8	1.03	0.82	220	1549
180	0.8	1.02	0.81	227	1688
190	0.8	1.00	0.80	235	1813
200	0.8	0.98	0.79	243	1932

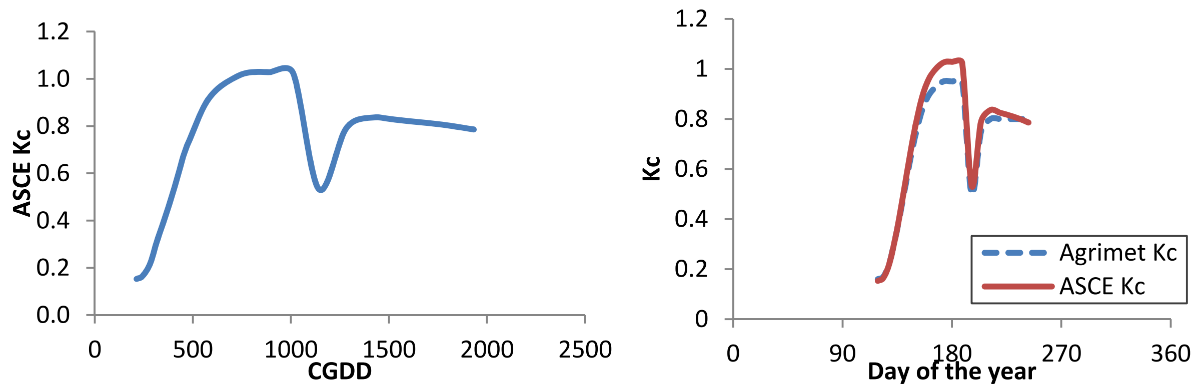
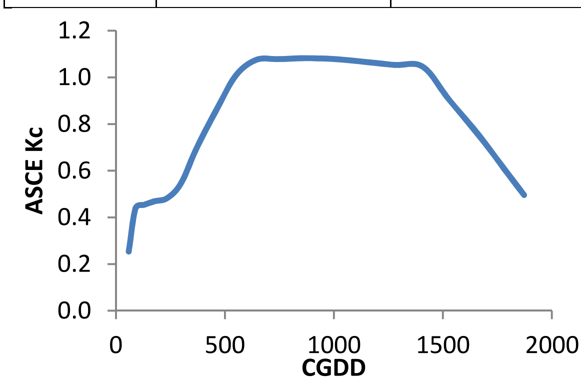


Figure 4.30. Right: Mint crop coefficients based on CGDD. Left: comparison between mint crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.31. Old and converted crop coefficients for onions during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Onion					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.3	0.84	0.25	90	59
10	0.5	0.88	0.44	98	90
20	0.5	0.91	0.45	106	130
30	0.5	0.94	0.47	114	179
40	0.5	0.97	0.48	122	236
50	0.55	0.99	0.55	130	299
60	0.69	1.02	0.70	138	373
70	0.82	1.04	0.85	146	457
80	0.95	1.06	1.01	154	550
90	1	1.08	1.08	162	645
100	1	1.08	1.08	170	747
110	1	1.08	1.08	177	831
120	1	1.08	1.08	184	936
130	1	1.08	1.08	191	1043
140	1	1.06	1.06	198	1159
150	1	1.05	1.05	205	1282
160	1	1.04	1.04	211	1409
170	0.87	1.03	0.90	218	1532
180	0.75	1.02	0.77	225	1653
190	0.62	1.01	0.62	232	1768
200	0.5	0.99	0.50	239	1872



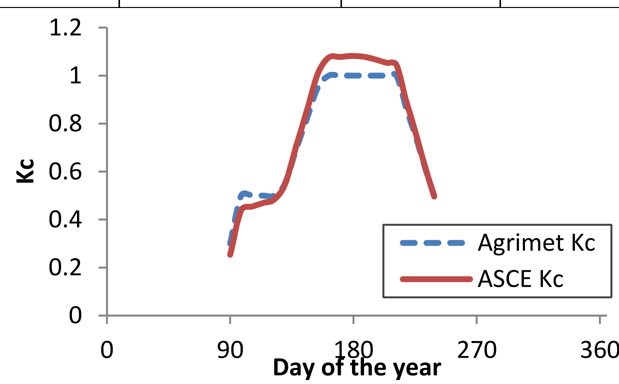


Figure 4.31. Right: Onion crop coefficients based on CGDD. Left: comparison between onion crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.32. Old and converted crop coefficients for pasture grass during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Pasture (low management)					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.25	0.81	0.20	80	31
10	0.3	0.82	0.25	85	41
20	0.36	0.84	0.30	89	55
30	0.43	0.86	0.37	94	73
40	0.5	0.88	0.44	99	90
50	0.6	0.90	0.54	104	112
60	0.63	0.92	0.58	108	141
70	0.66	0.93	0.61	113	166
80	0.68	0.95	0.65	118	198
90	0.68	0.97	0.66	122	236
100	0.68	0.98	0.67	127	274
110	0.68	1.03	0.70	142	413
120	0.68	1.07	0.73	158	586
130	0.68	1.08	0.73	173	774
140	0.68	1.08	0.73	188	1012
150	0.68	1.05	0.72	204	1263
160	0.68	1.03	0.70	219	1532
170	0.68	1.00	0.68	234	1798
180	0.65	0.97	0.63	249	2017
190	0.6	0.93	0.56	265	2193
200	0.4	0.89	0.35	280	2343

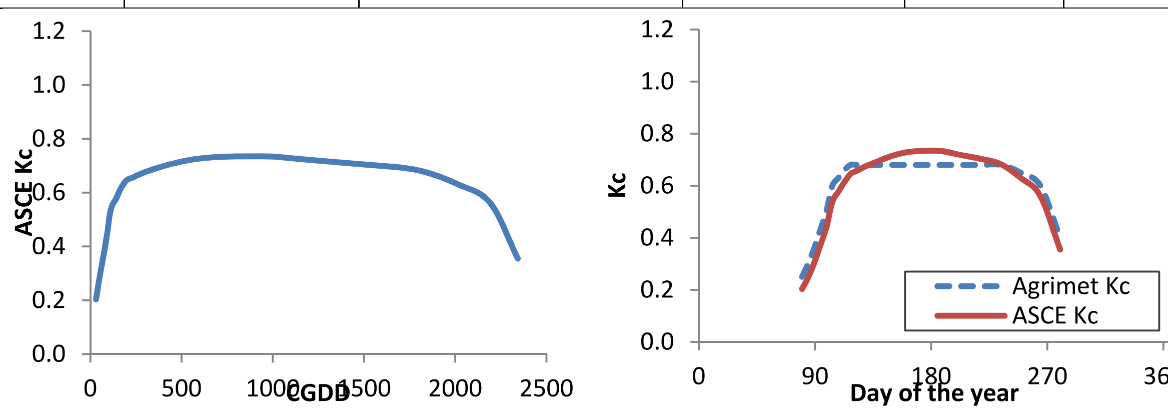


Figure 4.32. Right: Pasture grass crop coefficients based on CGDD. Left: comparison between pasture grass crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.33. Old and converted crop coefficients for peaches during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Peach					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.4	0.92	0.37	110	6
10	0.45	0.94	0.42	114	10
20	0.52	0.95	0.49	118	16
30	0.58	0.96	0.56	122	26
40	0.66	0.98	0.65	126	36
50	0.76	0.99	0.75	130	48
60	0.85	1.00	0.85	133	63
70	0.94	1.02	0.95	137	81
80	1	1.03	1.03	141	100
90	1.04	1.04	1.08	145	124
100	1.04	1.05	1.09	149	148
110	1.04	1.07	1.12	162	231
120	1.04	1.08	1.12	175	335
130	1.04	1.08	1.12	188	464
140	1.04	1.06	1.10	201	612
150	1.04	1.04	1.08	214	782
160	0.97	1.02	0.99	226	943
170	0.88	0.99	0.87	239	1080
180	0.8	0.96	0.77	252	1198
190	0.66	0.93	0.61	265	1281
200	0.43	0.89	0.38	278	1340

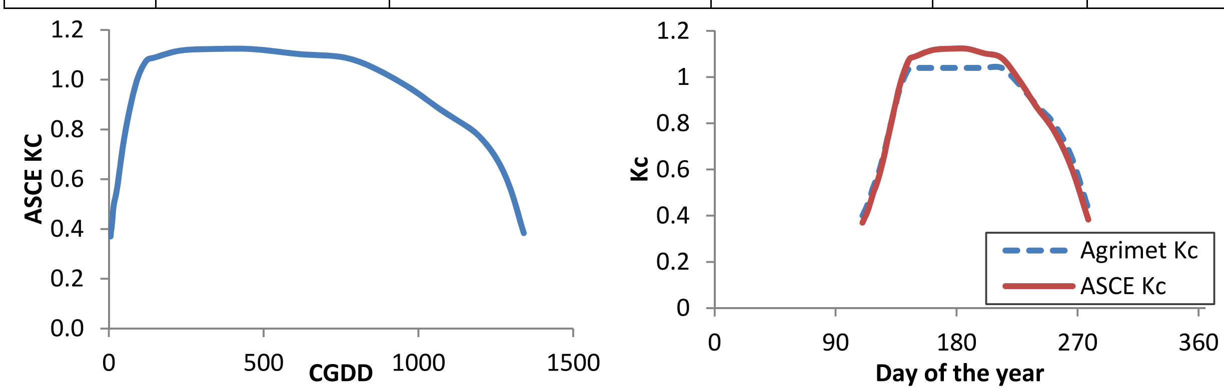


Figure 4.33. Right: Peach crop coefficients based on CGDD. Left: comparison between peach crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.34. Old and converted crop coefficients for pears during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Pear					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.2	0.92	0.18	110	6
10	0.2	0.94	0.19	114	10
20	0.23	0.95	0.22	118	16
30	0.31	0.96	0.30	122	26
40	0.42	0.98	0.41	126	36
50	0.53	0.99	0.53	130	48
60	0.66	1.00	0.66	133	63
70	0.77	1.02	0.78	137	81
80	0.84	1.03	0.86	141	100
90	0.89	1.04	0.92	145	124
100	0.95	1.05	0.99	149	148
110	1.03	1.07	1.11	162	231
120	1.07	1.08	1.16	175	335
130	1.08	1.08	1.17	188	464
140	1.08	1.06	1.15	201	612
150	1.07	1.04	1.11	214	782
160	1.04	1.02	1.06	226	943
170	1	0.99	0.99	239	1080
180	0.79	0.96	0.76	252	1198
190	0.56	0.93	0.52	265	1281
200	0.36	0.89	0.32	278	1340

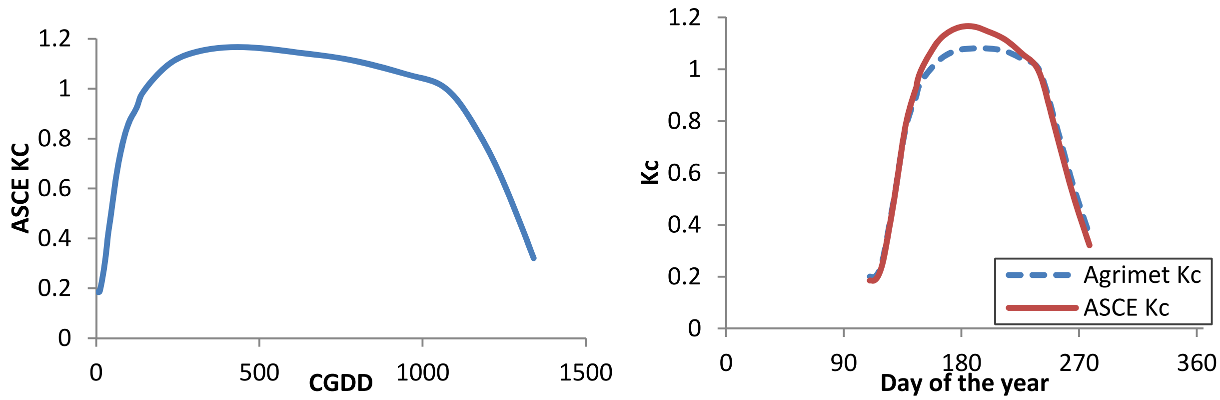
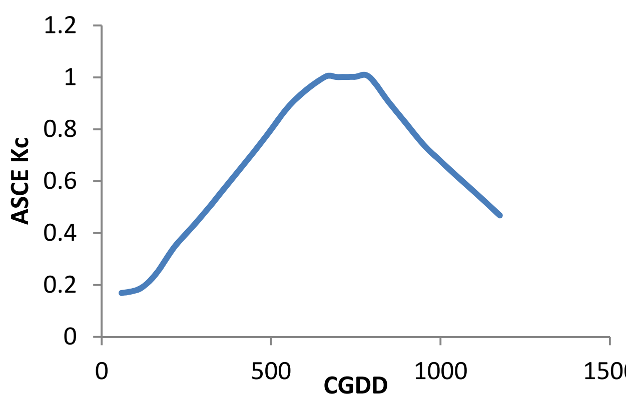


Figure 4.34. Right: Pear crop coefficients based on CGDD. Left: comparison between pear crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.35. Old and converted crop coefficients for peas during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Peas					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.2	0.84	0.17	90	59
10	0.2	0.87	0.17	97	86
20	0.21	0.90	0.19	105	118
30	0.26	0.93	0.24	112	159
40	0.36	0.96	0.34	119	213
50	0.43	0.98	0.42	127	266
60	0.51	1.00	0.51	134	325
70	0.62	1.03	0.64	141	402
80	0.73	1.04	0.76	148	479
90	0.85	1.06	0.90	156	563
100	0.93	1.08	1.00	163	657
110	0.93	1.08	1.00	167	695
120	0.93	1.08	1.00	170	747
130	0.93	1.08	1.00	174	788
140	0.838	1.08	0.91	177	846
150	0.769	1.08	0.83	181	892
160	0.683	1.08	0.74	184	951
170	0.632	1.08	0.68	188	996
180	0.564	1.07	0.61	191	1059
190	0.512	1.07	0.55	195	1110
200	0.44	1.06	0.47	198	1175



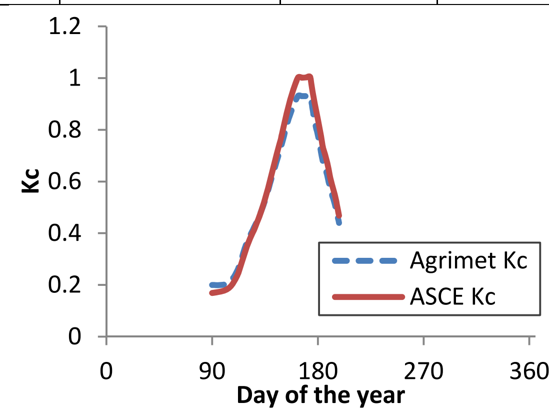
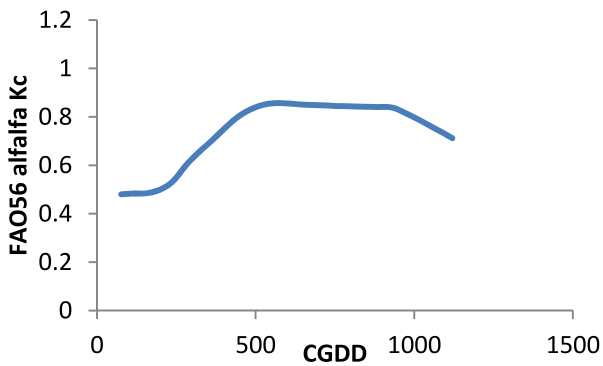


Figure 4.35. Right: Pea crop coefficients based on CGDD. Left: comparison between pea crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.36. Old and converted crop coefficients for peppers during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Pepper					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.60	0.80	0.48	136	76
10	0.60	0.81	0.48	144	117
20	0.60	0.81	0.49	153	168
30	0.64	0.82	0.52	161	231
40	0.75	0.82	0.62	170	292
50	0.88	0.81	0.72	178	374
60	0.99	0.81	0.81	186	454
70	1.05	0.81	0.85	195	542
80	1.05	0.81	0.85	203	651
90	1.05	0.80	0.85	212	757
100	1.05	0.80	0.84	220	869
110	1.05	0.80	0.84	222	894
120	1.05	0.80	0.84	225	919
130	1.04	0.80	0.83	227	943
140	1.02	0.80	0.81	229	977
150	1.00	0.80	0.80	232	999
160	0.98	0.80	0.78	234	1021
170	0.96	0.80	0.76	236	1050
180	0.94	0.79	0.75	238	1070
190	0.93	0.79	0.73	241	1091
200	0.90	0.79	0.71	243	1120



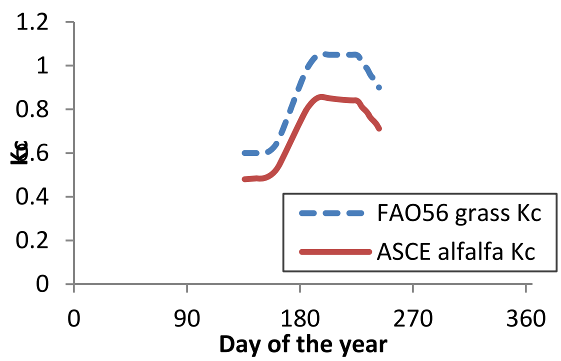


Figure 4.36. Right: Pepper crop coefficients based on CGDD. Left: comparison between pepper crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.37. Old and converted crop coefficients for peppermint during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Peppermint					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.16	0.83	0.13	86	46
10	0.17	0.86	0.15	93	69
20	0.22	0.88	0.19	100	98
30	0.31	0.91	0.28	107	136
40	0.42	0.94	0.39	114	179
50	0.54	0.96	0.52	121	229
60	0.66	0.99	0.65	128	282
70	0.76	1.01	0.77	135	344
80	0.84	1.03	0.87	142	413
90	0.89	1.05	0.93	149	490
100	0.92	1.07	0.98	156	575
110	0.95	1.08	1.02	168	721
120	0.95	1.08	1.03	181	892
130	0.95	1.07	1.02	193	1093
140	0.95	1.05	1.00	206	1300
150	0.95	1.03	0.98	218	1532
160	0.95	1.01	0.96	230	1736
170	0.95	0.98	0.94	243	1918
180	0.95	0.96	0.91	255	2092
190	0.95	0.92	0.88	268	2224
200	0.95	0.89	0.84	280	2343

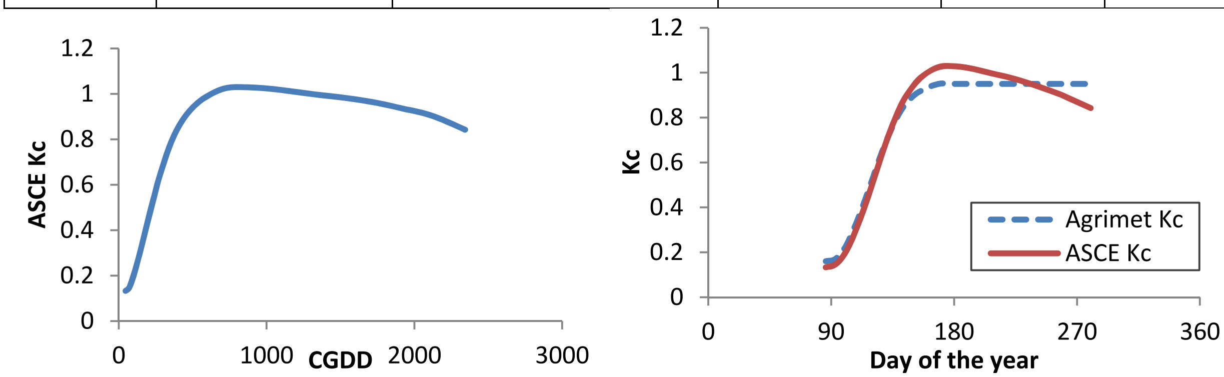


Figure 4.37. Right: Peppermint crop coefficients based on CGDD. Left: comparison between peppermint crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.38. Old and converted crop coefficients for plums during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Plum					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.2	0.92	0.18	110	6
10	0.2	0.94	0.19	114	10
20	0.23	0.95	0.22	118	16
30	0.31	0.96	0.30	122	26
40	0.42	0.98	0.41	126	36
50	0.53	0.99	0.53	130	48
60	0.66	1.00	0.66	133	63
70	0.77	1.02	0.78	137	81
80	0.84	1.03	0.86	141	100
90	0.89	1.04	0.92	145	124
100	0.95	1.05	0.99	149	148
110	0.95	1.07	1.02	162	231
120	0.96	1.08	1.04	175	335
130	0.98	1.08	1.06	188	464
140	1	1.06	1.06	201	612
150	1	1.04	1.04	214	782
160	1	1.02	1.02	226	943
170	1	0.99	0.99	239	1080
180	0.78	0.96	0.75	252	1198
190	0.6	0.93	0.56	265	1281
200	0.39	0.89	0.35	278	1340

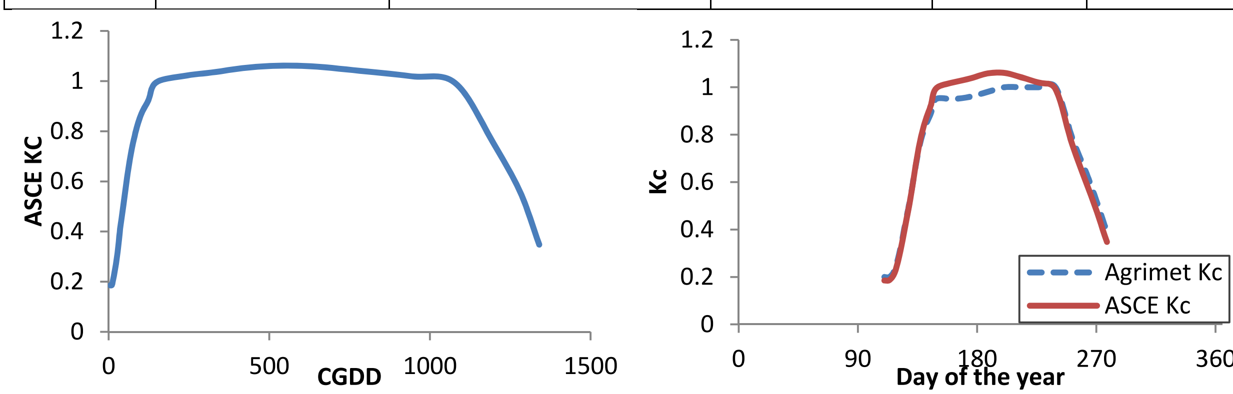


Figure 4.38. Right: Plum crop coefficients based on CGDD. Left: comparison between plum crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.39. Old and converted crop coefficients for poplar trees (first year) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Poplar First Year					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.15	0.99	0.15	130	52
10	0.18	1.00	0.18	132	59
20	0.2	1.01	0.20	134	67
30	0.23	1.01	0.23	136	76
40	0.25	1.02	0.25	138	85
50	0.28	1.02	0.29	140	95
60	0.3	1.03	0.31	142	105
70	0.33	1.04	0.34	144	117
80	0.35	1.04	0.36	146	130
90	0.38	1.04	0.40	148	142
100	0.4	1.05	0.42	150	154
110	0.43	1.08	0.46	163	245
120	0.46	1.08	0.50	176	353
130	0.49	1.08	0.53	189	485
140	0.52	1.06	0.55	202	638
150	0.55	1.04	0.57	215	807
160	0.58	1.02	0.59	228	966
170	0.61	0.99	0.60	241	1101
180	0.64	0.96	0.61	254	1213
190	0.67	0.92	0.62	267	1292
200	0.7	0.89	0.62	280	1346

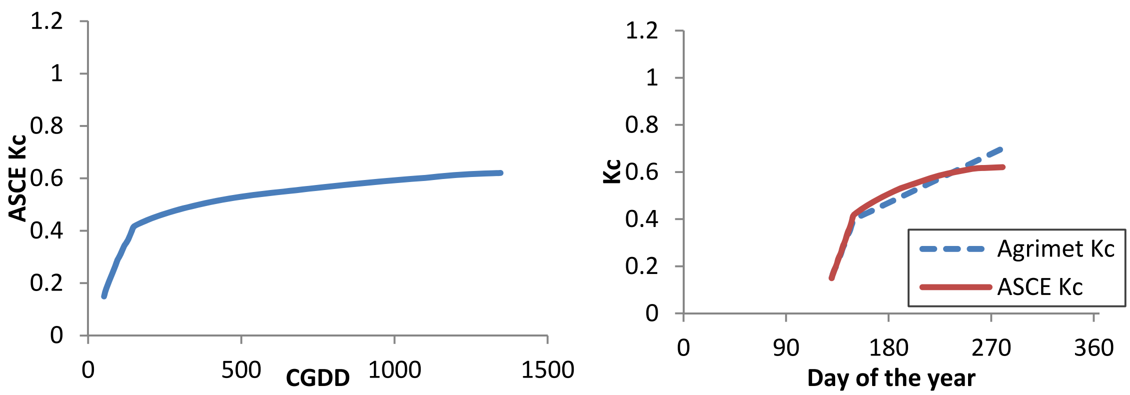
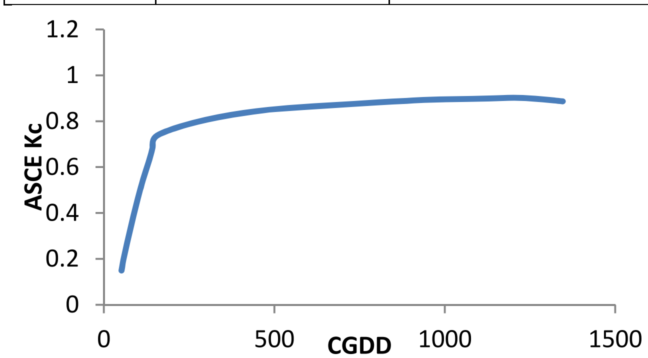


Figure 4.39. Right: Poplar (first year) crop coefficients based on CGDD. Left: comparison between poplar (first year) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.40. Old and converted crop coefficients for poplar trees (second year) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Poplar Second Year					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.15	0.99	0.15	130	52
10	0.21	1.00	0.21	132	59
20	0.26	1.01	0.26	134	67
30	0.32	1.01	0.32	136	76
40	0.37	1.02	0.38	138	85
50	0.43	1.02	0.44	140	95
60	0.48	1.03	0.49	142	105
70	0.54	1.04	0.56	144	117
80	0.59	1.04	0.61	146	130
90	0.65	1.04	0.68	148	142
100	0.7	1.05	0.74	150	154
110	0.73	1.08	0.79	163	245
120	0.76	1.08	0.82	176	353
130	0.79	1.08	0.85	189	485
140	0.82	1.06	0.87	202	638
150	0.85	1.04	0.88	215	807
160	0.88	1.02	0.89	228	966
170	0.91	0.99	0.90	241	1101
180	0.94	0.96	0.90	254	1213
190	0.97	0.92	0.89	267	1292
200	1	0.89	0.89	280	1346



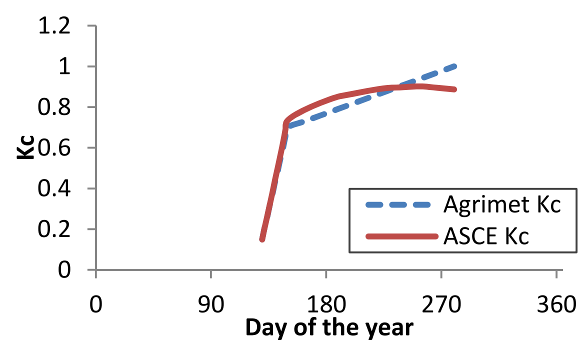
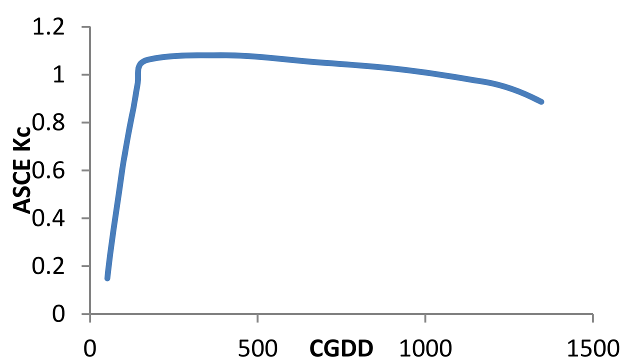


Figure 4.40. Right: Poplar (second year) crop coefficients based on CGDD. Left: comparison between poplar (second year) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.41. Old and converted crop coefficients for poplar trees (third year) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Poplar Third and Subsequent Years					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.15	0.99	0.15	130	52
10	0.24	1.00	0.24	132	59
20	0.32	1.01	0.32	134	67
30	0.41	1.01	0.42	136	76
40	0.49	1.02	0.50	138	85
50	0.58	1.02	0.59	140	95
60	0.66	1.03	0.68	142	105
70	0.75	1.04	0.78	144	117
80	0.83	1.04	0.86	146	130
90	0.92	1.04	0.96	148	142
100	1	1.05	1.05	150	154
110	1	1.08	1.08	163	245
120	1	1.08	1.08	176	353
130	1	1.08	1.08	189	485
140	1	1.06	1.06	202	638
150	1	1.04	1.04	215	807
160	1	1.02	1.02	228	966
170	1	0.99	0.99	241	1101
180	1	0.96	0.96	254	1213
190	1	0.92	0.92	267	1292
200	1	0.89	0.89	280	1346



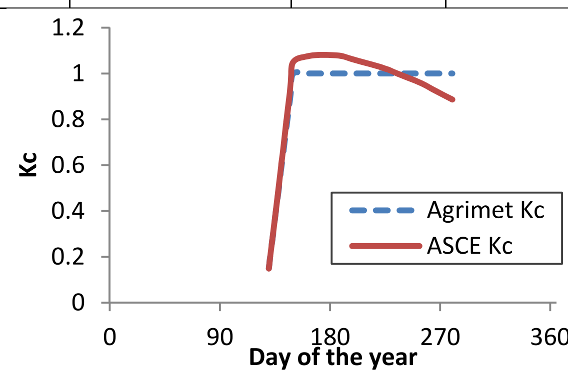


Figure 4.41. Right: Poplar (third year) crop coefficients based on CGDD. Left: comparison between poplar (third year) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.42. Old and converted crop coefficients for potatoes during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Potato					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.2	0.99	0.20	128	282
10	0.2	1.00	0.20	134	325
20	0.2	1.02	0.20	140	383
30	0.22	1.04	0.23	145	446
40	0.31	1.05	0.33	151	514
50	0.41	1.07	0.44	157	586
60	0.51	1.08	0.55	163	645
70	0.62	1.08	0.67	169	721
80	0.7	1.08	0.76	174	802
90	0.76	1.08	0.82	180	892
100	0.78	1.08	0.84	186	982
110	0.78	1.07	0.84	193	1076
120	0.774	1.06	0.82	199	1192
130	0.76	1.05	0.80	206	1318
140	0.748	1.04	0.78	213	1426
150	0.731	1.03	0.75	220	1549
160	0.71	1.02	0.72	226	1671
170	0.686	1.01	0.69	233	1768
180	0.658	0.99	0.65	240	1872
190	0.63	0.98	0.62	246	1975
200	0.602	0.96	0.58	253	2068

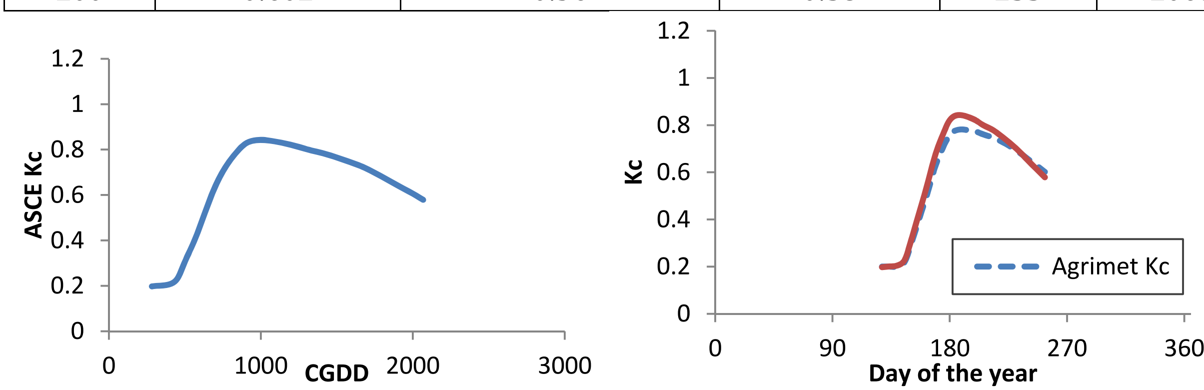
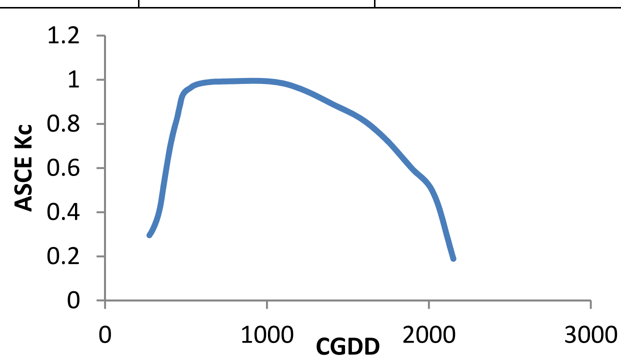


Figure 4.42. Right: Potato crop coefficients based on CGDD. Left: comparison between potato crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.43. Old and converted crop coefficients for potatoes (shepody) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Potato (shepody)					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.3	0.98	0.30	127	274
10	0.33	0.99	0.33	131	299
20	0.4	1.01	0.40	134	335
30	0.52	1.02	0.53	138	363
40	0.68	1.03	0.70	141	402
50	0.8	1.04	0.83	145	446
60	0.89	1.04	0.93	149	479
70	0.91	1.06	0.96	152	526
80	0.92	1.06	0.98	156	563
90	0.92	1.07	0.99	159	610
100	0.92	1.08	0.99	163	657
110	0.92	1.08	0.99	173	774
120	0.92	1.08	1.00	182	922
130	0.92	1.07	0.99	192	1076
140	0.9	1.06	0.95	202	1227
150	0.85	1.04	0.89	212	1409
160	0.8	1.03	0.82	221	1584
170	0.72	1.01	0.73	231	1736
180	0.61	0.99	0.60	241	1888
190	0.5	0.97	0.48	250	2030
200	0.2	0.94	0.19	260	2151



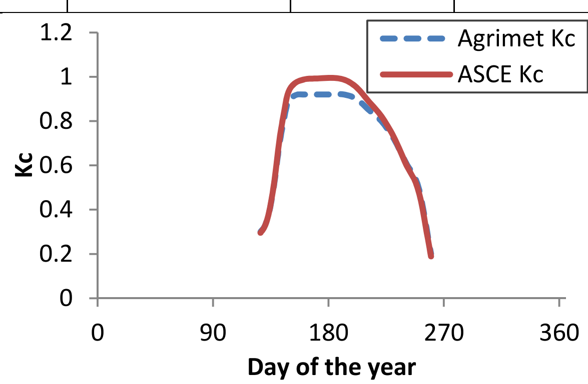
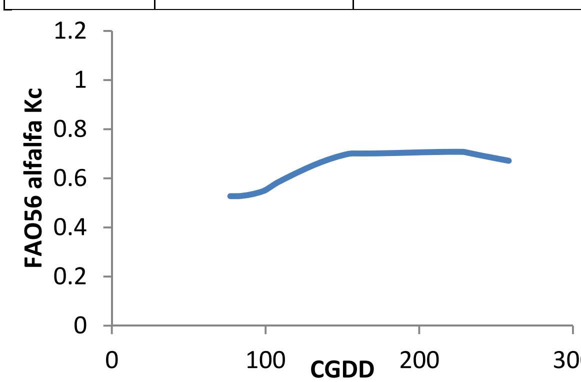


Figure 4.43. Right: Potato (shepody) crop coefficients based on CGDD. Left: comparison between Potato (shepody) crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.44. Old and converted crop coefficients for radishes during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Radish					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.7	0.75	0.53	95	77
10	0.7	0.76	0.53	98	86
20	0.72	0.76	0.55	100	98
30	0.76	0.76	0.58	103	107
40	0.82	0.77	0.63	105	123
50	0.86	0.77	0.66	108	136
60	0.9	0.78	0.70	110	153
70	0.9	0.78	0.70	113	166
80	0.9	0.78	0.70	115	185
90	0.9	0.78	0.71	118	198
100	0.9	0.79	0.71	120	221
110	0.9	0.79	0.71	121	221
120	0.9	0.79	0.71	121	229
130	0.9	0.79	0.71	122	229
140	0.88	0.79	0.70	122	236
150	0.88	0.79	0.70	123	236
160	0.8	0.79	0.69	123	243
170	0.8	0.79	0.69	124	243
180	0.86	0.79	0.68	124	251
190	0.86	0.79	0.68	125	251
200	0.85	0.79	0.67	125	258



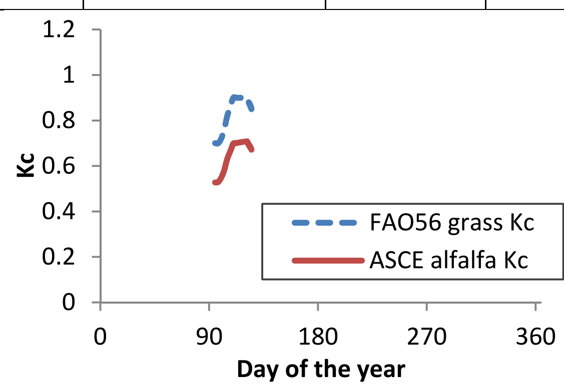
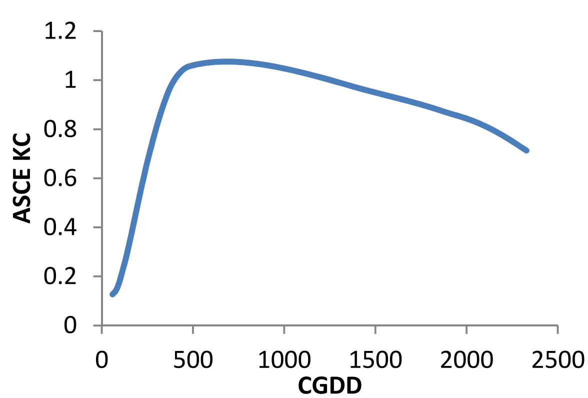


Figure 4.44. Right: Radish crop coefficients based on CGDD. Left: comparison between radish crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.45. Old and converted crop coefficients for raspberries during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Raspberry					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.15	0.84	0.13	90	59
10	0.17	0.87	0.15	96	81
20	0.23	0.89	0.21	102	107
30	0.33	0.92	0.30	108	141
40	0.46	0.94	0.43	114	179
50	0.6	0.96	0.58	120	221
60	0.73	0.98	0.72	126	266
70	0.85	1.00	0.85	132	316
80	0.95	1.02	0.97	138	373
90	1	1.04	1.04	144	435
100	1.01	1.05	1.06	150	502
110	1	1.08	1.08	163	645
120	0.99	1.08	1.07	176	816
130	0.97	1.08	1.05	188	1012
140	0.95	1.06	1.01	201	1227
150	0.92	1.04	0.96	214	1462
160	0.9	1.02	0.92	227	1671
170	0.88	0.99	0.87	240	1872
180	0.86	0.96	0.83	252	2056
190	0.83	0.93	0.77	265	2203
200	0.8	0.89	0.71	278	2328



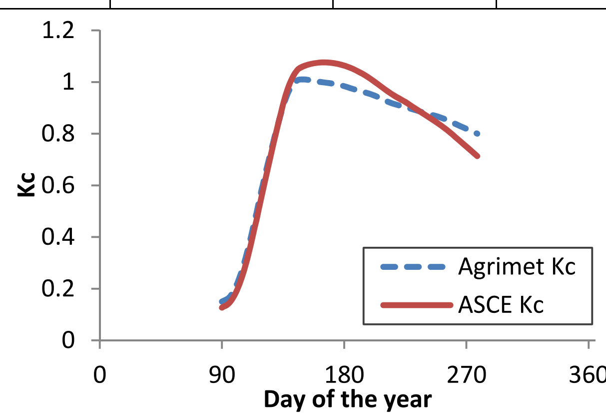
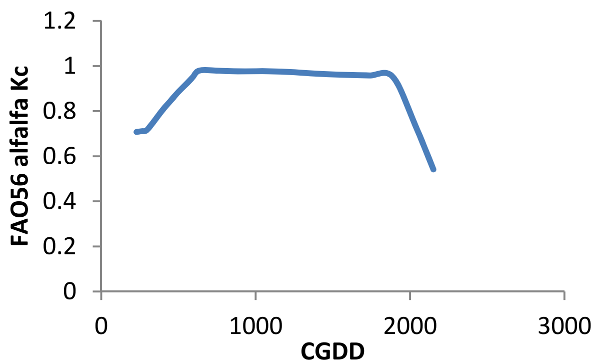


Figure 4.45. Right: Raspberry crop coefficients based on CGDD. Left: comparison between raspberry crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.46. Old and converted crop coefficients for a reed swamp with moist soil in eastern central WA based on day of the year and cumulative growing degree days.

Reed Swamp, moist soil					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.90	0.79	0.71	121	229
10	0.90	0.79	0.71	125	258
20	0.90	0.79	0.71	129	291
30	0.93	0.80	0.74	133	325
40	0.97	0.80	0.77	137	363
50	1.01	0.80	0.81	141	402
60	1.05	0.81	0.84	145	446
70	1.08	0.81	0.88	149	490
80	1.12	0.81	0.91	153	537
90	1.16	0.81	0.94	157	586
100	1.20	0.82	0.98	161	633
110	1.20	0.82	0.98	171	747
120	1.20	0.81	0.98	181	892
130	1.20	0.81	0.98	191	1043
140	1.20	0.81	0.97	201	1209
150	1.20	0.81	0.97	211	1391
160	1.20	0.80	0.96	220	1566
170	1.20	0.80	0.96	230	1736
180	1.20	0.79	0.95	240	1888
190	0.95	0.78	0.74	250	2030
200	0.70	0.77	0.54	260	2151



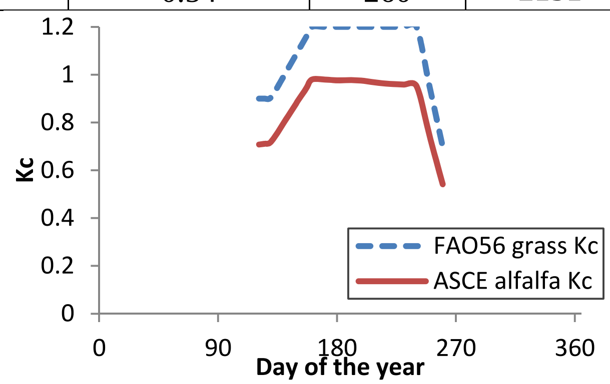


Figure 4.46. Right: Reed swamp with moist soil crop coefficients based on CGDD. Left: comparison between reed swamp with moist crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.47. Old and converted crop coefficients for a short reed swamp with standing water in eastern central WA based on day of the year and cumulative growing degree days.

Reed Swamp, standing water					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	1.00	0.79	0.79	121	229
10	1.00	0.79	0.79	125	258
20	1.00	0.79	0.79	129	291
30	1.02	0.80	0.81	133	325
40	1.05	0.80	0.84	137	363
50	1.07	0.80	0.86	141	402
60	1.10	0.81	0.89	145	446
70	1.12	0.81	0.91	149	490
80	1.15	0.81	0.93	153	537
90	1.17	0.81	0.96	157	586
100	1.20	0.82	0.98	161	633
110	1.20	0.82	0.98	171	747
120	1.20	0.81	0.98	181	892
130	1.20	0.82	0.98	191	1043
140	1.20	0.81	0.97	201	1209
150	1.20	0.81	0.97	211	1391
160	1.20	0.80	0.96	220	1566
170	1.20	0.80	0.96	230	1736
180	1.20	0.79	0.95	240	1888
190	1.10	0.78	0.86	250	2030
200	1.00	0.77	0.77	260	2151

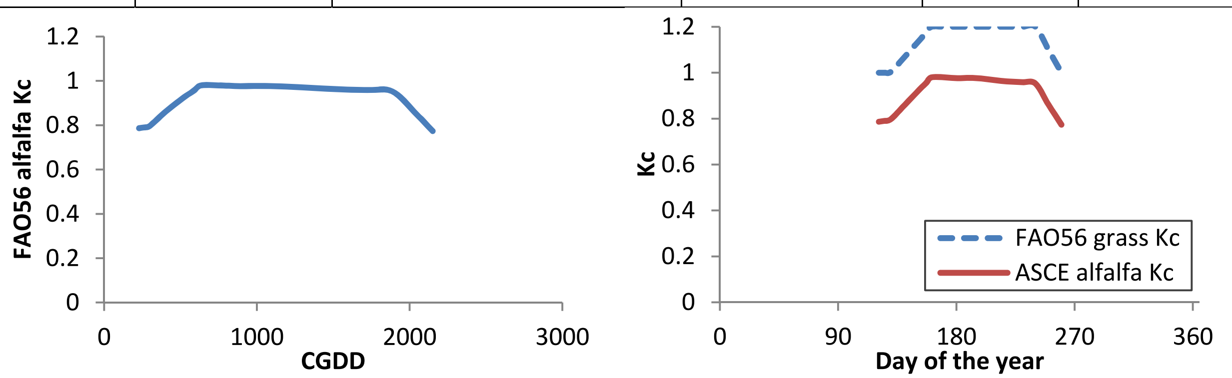


Figure 4.47. Right: Crop coefficients for a reed swamp with standing water crop based on CGDD. Left: comparison between these crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.48. Crop coefficients for sagebrush during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Sagebrush			
% growth stage	Kc Derived By Allen Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
		DOY	Tb=0
0	0.34	92	293
10	0.36	95	310
20	0.38	98	338
30	0.41	100	366
40	0.44	103	395
50	0.46	106	427
60	0.48	109	448
70	0.50	112	481
80	0.51	114	516
90	0.52	117	550
100	0.52	120	588
110	0.54	134	757
120	0.54	148	971
130	0.54	161	1206
140	0.52	175	1458
150	0.50	189	1739
160	0.49	203	2022
170	0.49	217	2344
180	0.48	230	2653
190	0.45	244	2934
200	0.34	258	3186

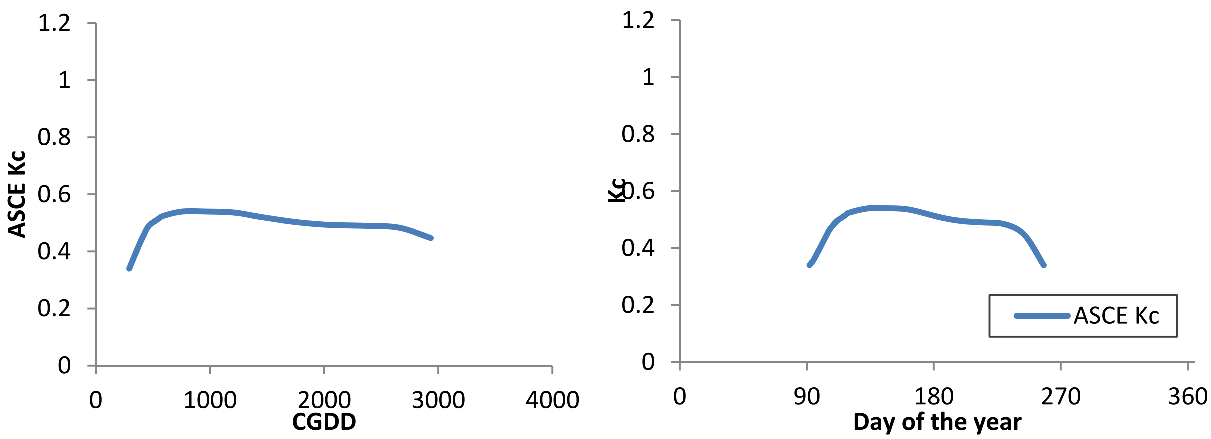


Figure 4.48. Right: Sagebrush crop coefficients based on CGDD. Left: Sagebrush crop coefficients based on days of the year

Table 4.49. Old and converted crop coefficients for safflower during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Safflower					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.2	0.84	0.17	90	59
10	0.2	0.87	0.17	98	86
20	0.3	0.90	0.27	105	123
30	0.6	0.93	0.56	113	166
40	0.83	0.96	0.80	120	221
50	0.94	0.98	0.93	128	274
60	0.98	1.01	0.99	135	344
70	1	1.03	1.03	143	413
80	1	1.05	1.05	150	502
90	1	1.07	1.07	158	586
100	1	1.08	1.08	165	683
110	1	1.08	1.08	171	747
120	1	1.08	1.08	176	831
130	1	1.08	1.08	182	907
140	1	1.08	1.08	187	996
150	1	1.07	1.07	193	1076
160	0.94	1.06	1.00	198	1175
170	0.8	1.05	0.84	204	1263
180	0.62	1.05	0.65	209	1373
190	0.43	1.04	0.45	215	1462
200	0.2	1.03	0.21	220	1566

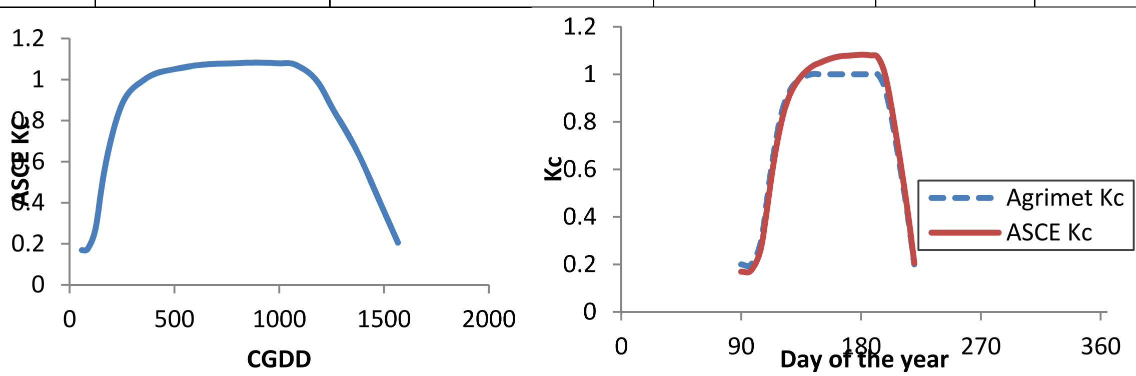
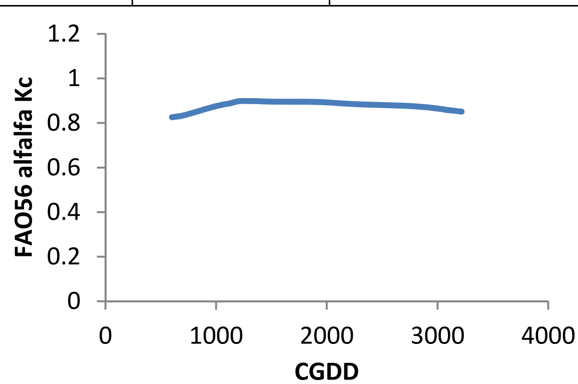


Figure 4.49. Right: Safflower crop coefficients based on CGDD. Left: comparison between Safflower crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.50. Old and converted crop coefficients for Short Vegetation (no frost) during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Short Vegetation, no frost					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	1.05	0.79	0.83	121	601
10	1.05	0.79	0.83	125	650
20	1.05	0.79	0.83	129	703
30	1.05	0.80	0.84	133	757
40	1.06	0.80	0.85	137	816
50	1.07	0.80	0.86	141	874
60	1.07	0.81	0.87	145	938
70	1.08	0.81	0.88	149	1002
80	1.09	0.81	0.88	153	1070
90	1.09	0.81	0.89	157	1139
100	1.10	0.82	0.90	161	1206
110	1.10	0.82	0.90	171	1364
120	1.10	0.81	0.89	181	1559
130	1.10	0.81	0.90	191	1760
140	1.10	0.81	0.89	201	1976
150	1.10	0.81	0.89	211	2208
160	1.10	0.80	0.88	220	2433
170	1.10	0.80	0.88	230	2653
180	1.10	0.79	0.87	240	2855
190	1.10	0.78	0.86	250	3047
200	1.10	0.77	0.85	260	3218



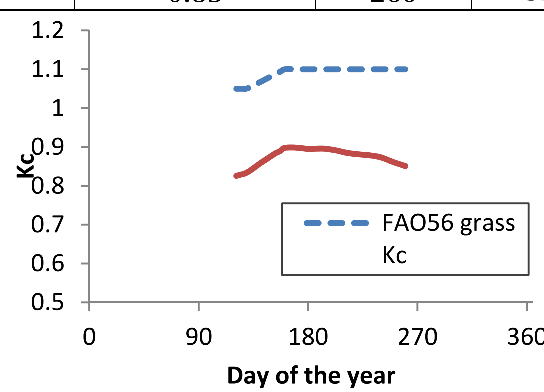
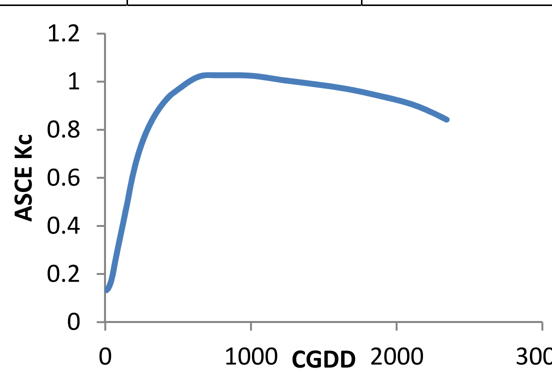


Figure 4.50. Right: Short Vegetation (no frost) crop coefficients based on CGDD. Left: comparison between Short Vegetation (no frost) crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.51. Old and converted crop coefficients for spearmint during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Spearmint					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.17	0.78	0.13	71	9
10	0.18	0.81	0.15	79	25
20	0.22	0.83	0.18	87	46
30	0.31	0.86	0.27	94	73
40	0.41	0.89	0.37	102	107
50	0.54	0.92	0.50	110	153
60	0.67	0.95	0.64	118	198
70	0.77	0.98	0.75	126	258
80	0.84	1.00	0.84	133	325
90	0.89	1.03	0.92	141	402
100	0.92	1.05	0.96	149	490
110	0.95	1.08	1.02	162	645
120	0.95	1.08	1.03	175	816
130	0.95	1.08	1.02	188	1012
140	0.95	1.06	1.01	201	1227
150	0.95	1.04	0.99	215	1462
160	0.95	1.02	0.97	228	1688
170	0.95	0.99	0.94	241	1888
180	0.95	0.96	0.91	254	2068
190	0.95	0.93	0.88	267	2213
200	0.95	0.89	0.84	280	2343



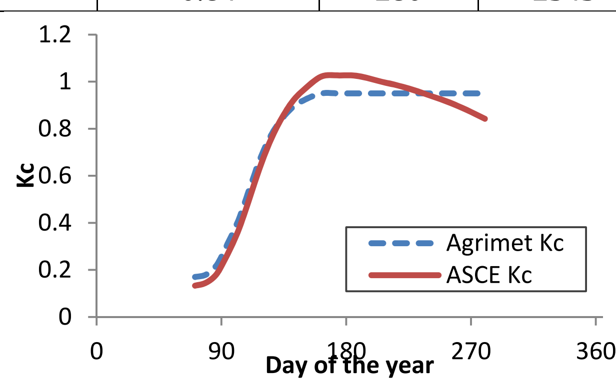


Figure 4.51. Right: Spearmint crop coefficients based on CGDD. Left: comparison between spearmint crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.52. Old and converted crop coefficients for spinach during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Spinach					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.70	0.75	0.52	88	259
10	0.70	0.75	0.52	91	284
20	0.70	0.75	0.53	94	310
30	0.70	0.76	0.53	98	338
40	0.70	0.76	0.53	101	366
50	0.70	0.77	0.54	104	405
60	0.70	0.77	0.54	107	438
70	0.70	0.78	0.54	110	470
80	0.70	0.78	0.55	114	505
90	0.70	0.78	0.55	117	538
100	0.70	0.79	0.55	120	588
110	0.75	0.79	0.59	130	703
120	0.83	0.80	0.66	139	845
130	0.90	0.81	0.73	149	986
140	0.98	0.81	0.79	158	1155
150	1.00	0.82	0.82	168	1311
160	1.00	0.81	0.81	177	1498
170	1.00	0.81	0.81	187	1679
180	1.00	0.81	0.81	196	1890
190	1.00	0.81	0.81	206	2092
200	0.95	0.80	0.76	215	2321

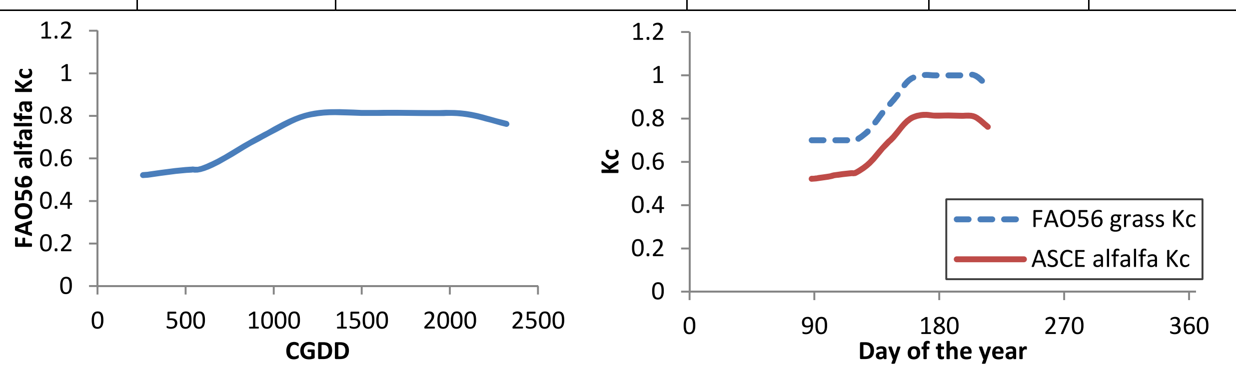


Figure 4.52. Right: Spinach crop coefficients based on CGDD. Left: comparison between spinach crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.53. Old and converted crop coefficients for spring grain during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Spring Grain					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.2	0.85	0.17	92	66
10	0.2	0.88	0.18	100	94
20	0.21	0.91	0.19	107	136
30	0.26	0.94	0.24	115	179
40	0.39	0.97	0.38	122	236
50	0.55	0.99	0.55	130	299
60	0.66	1.02	0.67	138	363
70	0.78	1.04	0.81	145	446
80	0.92	1.06	0.97	153	526
90	1	1.07	1.07	160	622
100	1	1.08	1.08	168	721
110	1	1.08	1.08	173	774
120	1	1.08	1.08	177	846
130	1	1.08	1.08	182	907
140	1	1.08	1.08	186	982
150	1	1.08	1.08	191	1043
160	1	1.07	1.07	195	1126
170	0.99	1.06	1.05	200	1192
180	0.94	1.05	0.99	204	1282
190	0.9	1.05	0.94	209	1354
200	0.7	1.04	0.73	213	1444

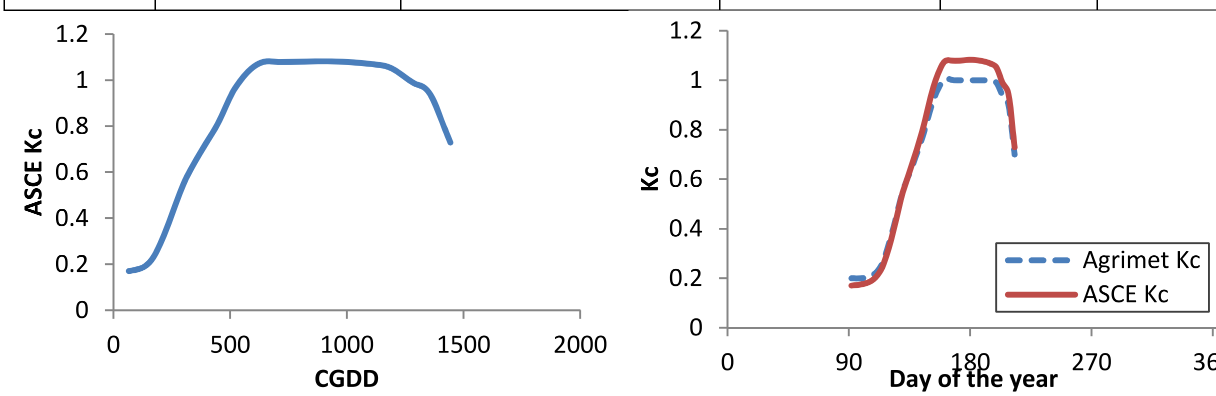
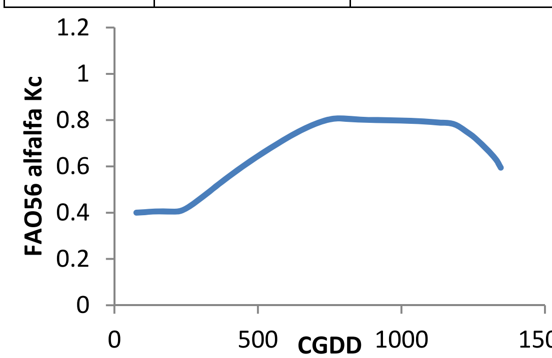


Figure 4.53. Right: Spring grain crop coefficients based on CGDD. Left: comparison between spring grain crop coefficients based on Kimberly and ASCE standardized Penman-Monteith equations

Table 4.54. Old and converted crop coefficients for squash during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Squash					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.50	0.80	0.40	136	76
10	0.50	0.81	0.40	144	117
20	0.50	0.81	0.41	153	168
30	0.50	0.82	0.41	161	231
40	0.56	0.82	0.45	170	292
50	0.66	0.81	0.53	178	374
60	0.74	0.81	0.61	186	454
70	0.83	0.81	0.68	195	542
80	0.93	0.81	0.76	203	651
90	1.00	0.80	0.80	212	757
100	1.00	0.80	0.80	220	869
110	1.00	0.80	0.80	226	943
120	1.00	0.80	0.80	232	1010
130	1.00	0.79	0.79	238	1070
140	1.00	0.79	0.79	244	1130
150	1.00	0.78	0.78	250	1183
160	0.97	0.78	0.75	256	1227
170	0.92	0.77	0.71	262	1266
180	0.88	0.76	0.67	268	1297
190	0.84	0.75	0.63	274	1327
200	0.80	0.74	0.59	280	1346



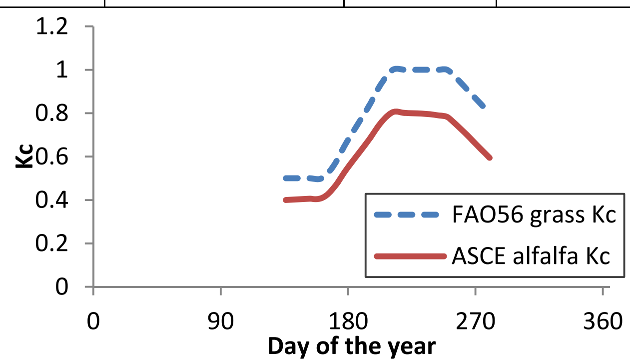
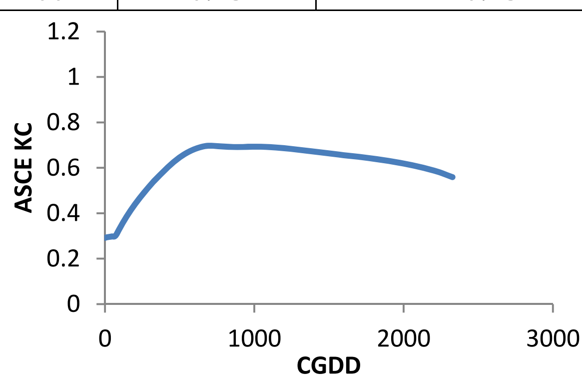


Figure 4.54. Right: Squash crop coefficients based on CGDD. Left: comparison between squash crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.55. Old and converted crop coefficients for strawberries during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Strawberry					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.40	0.73	0.29	65	0
10	0.40	0.73	0.29	72	12
20	0.40	0.74	0.30	79	28
30	0.40	0.74	0.30	86	46
40	0.40	0.75	0.30	93	69
50	0.44	0.76	0.33	100	98
60	0.49	0.77	0.38	107	136
70	0.54	0.78	0.42	114	179
80	0.59	0.79	0.46	121	229
90	0.64	0.79	0.51	128	282
100	0.69	0.80	0.55	135	344
110	0.79	0.81	0.64	149	490
120	0.85	0.82	0.69	164	657
130	0.85	0.81	0.69	178	846
140	0.85	0.81	0.69	192	1076
150	0.84	0.81	0.68	207	1318
160	0.82	0.80	0.66	221	1566
170	0.80	0.80	0.64	235	1813
180	0.79	0.78	0.62	249	2017
190	0.77	0.77	0.59	264	2183
200	0.75	0.75	0.56	278	2328



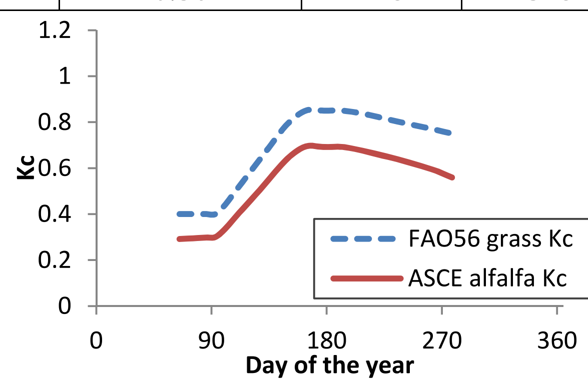


Figure 4.55. Right: Strawberry crop coefficients based on CGDD. Left: comparison between strawberry crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.56. Old and converted crop coefficients for sugar beets during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Sugar Beet					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	0.26	0.95	0.25	117	550
10	0.26	0.97	0.25	125	638
20	0.26	1.00	0.26	133	743
30	0.26	1.02	0.27	140	860
40	0.26	1.04	0.27	148	986
50	0.27	1.07	0.29	156	1122
60	0.29	1.08	0.31	164	1240
70	0.38	1.08	0.41	172	1382
80	0.5	1.08	0.54	179	1539
90	0.75	1.08	0.81	187	1699
100	1	1.07	1.07	195	1868
110	1	1.05	1.05	203	2045
120	1	1.04	1.04	211	2231
130	1	1.03	1.03	219	2411
140	0.998	1.02	1.02	227	2590
150	0.99	1.00	0.99	236	2755
160	0.95	0.98	0.93	244	2914
170	0.904	0.96	0.87	252	3065
180	0.86	0.95	0.82	260	3202
190	0.82	0.92	0.76	268	3326
200	0.775	0.90	0.70	276	3459

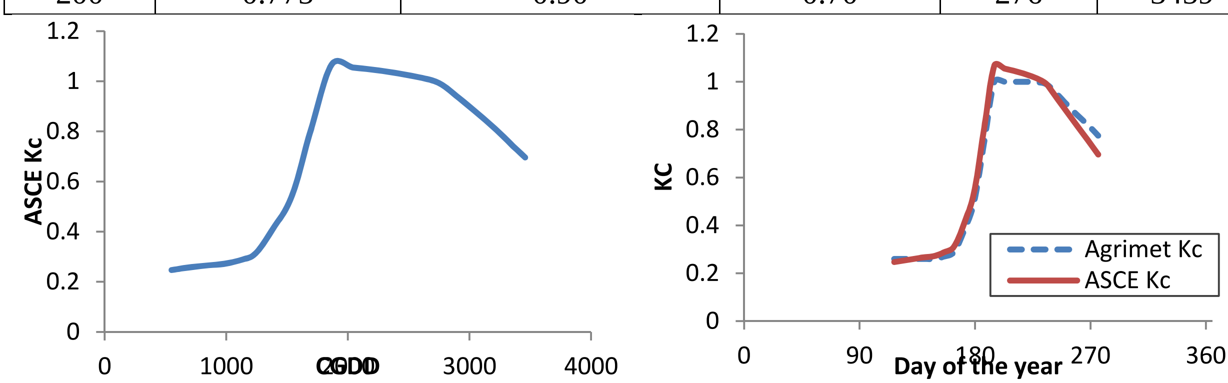


Figure 4.56. Right: Sugar beet crop coefficients based on CGDD. Left: comparison between sugar beet crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.57. Old and converted crop coefficients for sweet corn during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Sweet Corn					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.2	0.99	0.20	130	209
10	0.2	1.02	0.20	137	250
20	0.2	1.04	0.21	145	295
30	0.2	1.05	0.21	152	343
40	0.23	1.07	0.25	159	401
50	0.32	1.08	0.34	167	453
60	0.42	1.08	0.45	174	512
70	0.55	1.08	0.60	181	591
80	0.7	1.08	0.75	188	660
90	0.85	1.07	0.91	196	739
100	0.95	1.05	1.00	203	832
110	0.947	1.05	1.00	207	868
120	0.943	1.05	0.99	210	916
130	0.939	1.04	0.98	214	964
140	0.936	1.04	0.97	218	999
150	0.932	1.03	0.96	222	1046
160	0.926	1.02	0.95	225	1093
170	0.923	1.02	0.94	229	1127
180	0.919	1.01	0.93	233	1171
190	0.887	1.00	0.89	236	1211
200	0.871	0.99	0.86	240	1251

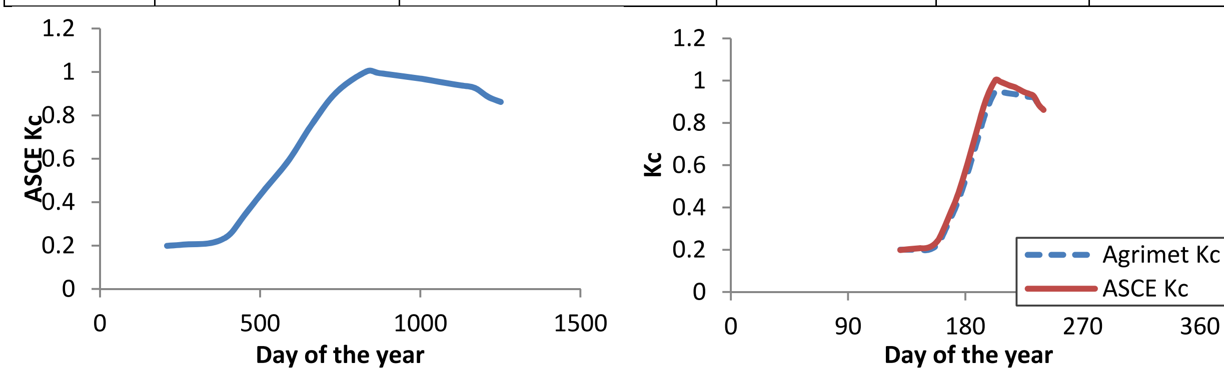
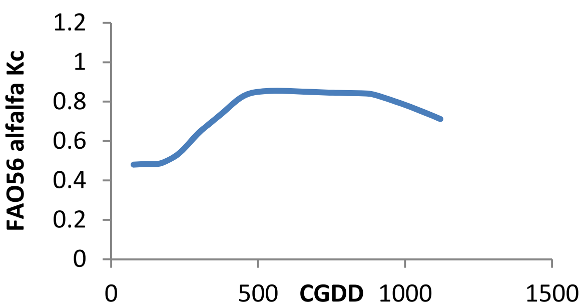


Figure 4.57. Right: Sweet corn crop coefficients based on CGDD. Left: comparison between sweet corn crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.58. Old and converted crop coefficients for tomatoes during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Tomato					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.60	0.80	0.48	136	76
10	0.60	0.81	0.48	144	117
20	0.60	0.81	0.49	153	168
30	0.66	0.82	0.54	161	231
40	0.77	0.82	0.63	170	292
50	0.90	0.81	0.74	178	374
60	1.02	0.81	0.83	186	454
70	1.05	0.81	0.85	195	542
80	1.05	0.81	0.85	203	651
90	1.05	0.80	0.85	212	757
100	1.05	0.80	0.84	220	869
110	1.04	0.80	0.84	222	894
120	1.03	0.80	0.82	225	919
130	1.02	0.80	0.81	227	943
140	1.00	0.80	0.80	229	977
150	0.98	0.80	0.78	232	999
160	0.97	0.80	0.77	234	1021
170	0.95	0.80	0.75	236	1050
180	0.93	0.79	0.74	238	1070
190	0.92	0.79	0.73	241	1091
200	0.90	0.79	0.71	243	1120



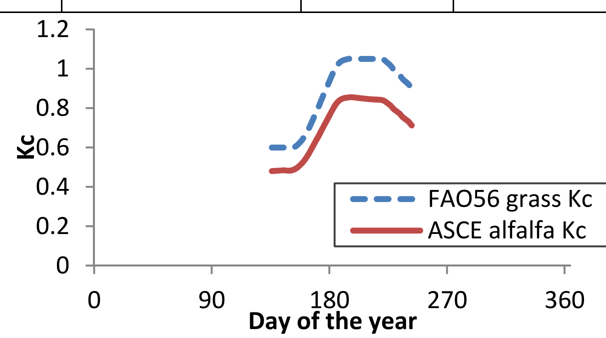


Figure 4.58. Right: Tomato crop coefficients based on CGDD. Left: comparison between tomato crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equations

Table 4.59. Old and converted crop coefficients for wine grapes during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

Wine Grape					
% of growth stage	Kc From Agrimet Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=10
0	0.16	0.91	0.15	106	2
10	0.18	0.94	0.17	113	10
20	0.22	0.96	0.21	120	24
30	0.31	0.98	0.31	127	42
40	0.42	1.01	0.42	134	67
50	0.56	1.03	0.58	142	100
60	0.65	1.04	0.68	149	142
70	0.65	1.06	0.69	156	191
80	0.65	1.08	0.70	163	238
90	0.65	1.08	0.70	170	292
100	0.65	1.08	0.70	177	364
110	0.65	1.08	0.70	187	464
120	0.65	1.06	0.69	198	576
130	0.65	1.05	0.68	208	703
140	0.65	1.03	0.67	218	844
150	0.65	1.02	0.66	229	966
160	0.65	0.99	0.65	239	1070
170	0.65	0.97	0.63	249	1174
180	0.65	0.95	0.62	259	1248
190	0.65	0.92	0.60	270	1302
200	0.65	0.89	0.58	280	1346

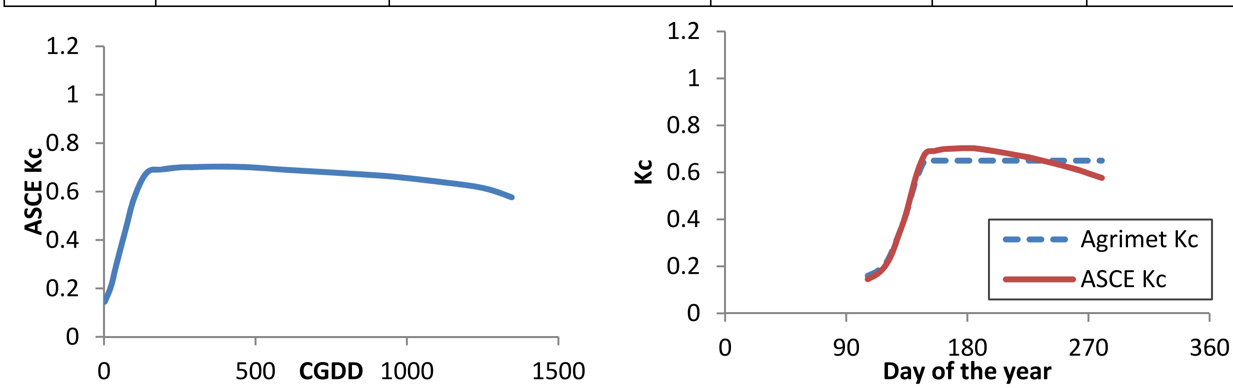


Figure 4.59. Right: Wine grape crop coefficients based on CGDD. Left: comparison between wine grape crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.60. Old and converted crop coefficients for winter grain during its growing period in eastern central WA based on day of the year and cumulative growing degree days.

winter grain					
% of growth stage	Kc Derived By Wright Based On Kimberly	Coefficient Used To Convert Kc Based On Kimberly To ASCE	Converted Kc Based On ASCE	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=5
0	0.3	0.77	0.23	66	1
10	0.3	0.79	0.24	75	16
20	0.3	0.82	0.25	84	39
30	0.5	0.85	0.43	93	66
40	0.75	0.89	0.67	102	103
50	0.9	0.92	0.83	111	153
60	0.98	0.96	0.94	119	213
70	1	0.99	0.99	128	282
80	1	1.02	1.02	137	363
90	1	1.04	1.04	146	457
100	1	1.06	1.06	155	563
110	1	1.07	1.07	159	610
120	1	1.08	1.08	163	657
130	1	1.08	1.08	167	708
140	1	1.08	1.08	171	760
150	1	1.08	1.08	176	816
160	1	1.08	1.08	180	877
170	1	1.08	1.08	184	936
180	0.99	1.08	1.07	188	996
190	0.97	1.07	1.04	192	1059
200	0.91	1.07	0.97	196	1143

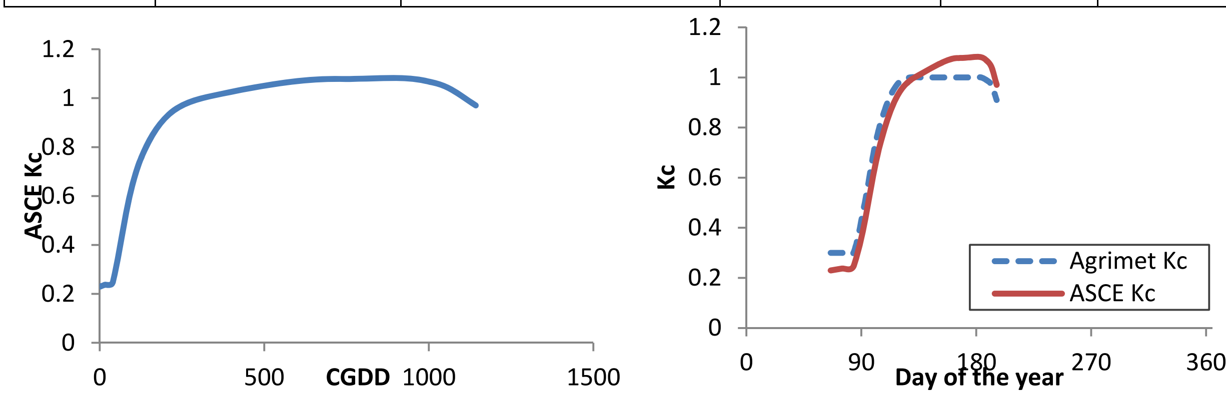
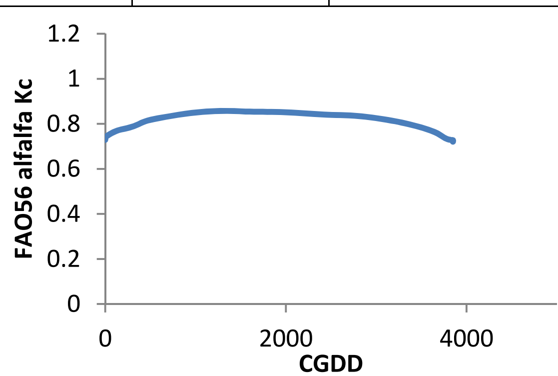


Figure 4.60. Right: Winter grain crop coefficients based on CGDD. Left: comparison between winter grain crop coefficients based on the Kimberly 1982 and the ASCE standardized Penman-Monteith equations.

Table 4.61. Old and converted crop coefficients for open water that is less than 2 meter depth in eastern central WA based on day of the year and cumulative growing degree days.

Open Water<2					
% of growth stage	Kc From FAO56 Based On Grass	Coefficient Used To Convert Kc Based On FAO56 Grass To ASCE Alfalfa	Converted Kc Based On ASCE Alfalfa	Average Planting Dates & CGDD In Eastern central WA	
				DOY	Tb=0
0	1.05	0.70	0.73	1	0
10	1.05	0.69	0.73	19	0
20	1.05	0.70	0.74	37	4
30	1.05	0.72	0.75	56	51
40	1.05	0.74	0.77	74	146
50	1.05	0.75	0.79	92	293
60	1.05	0.78	0.81	110	470
70	1.05	0.79	0.83	128	689
80	1.05	0.81	0.85	147	954
90	1.05	0.82	0.86	165	1257
100	1.05	0.81	0.85	183	1599
110	1.05	0.81	0.85	201	1999
120	1.05	0.80	0.84	219	2411
130	1.05	0.80	0.84	238	2795
140	1.05	0.78	0.82	256	3135
150	1.05	0.76	0.79	274	3417
160	1.05	0.73	0.76	292	3643
170	1.05	0.70	0.74	310	3771
180	1.05	0.69	0.73	329	3842
190	1.05	0.69	0.72	347	3850
200	1.05	0.69	0.73	365	3850



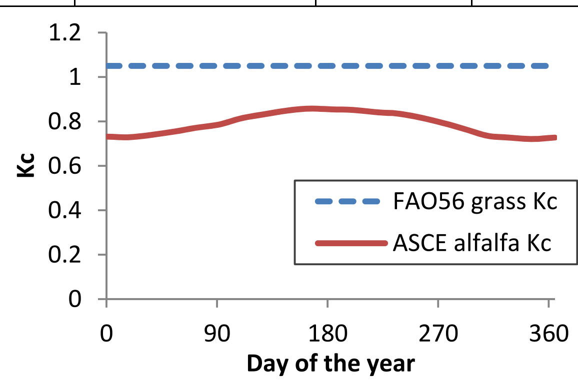
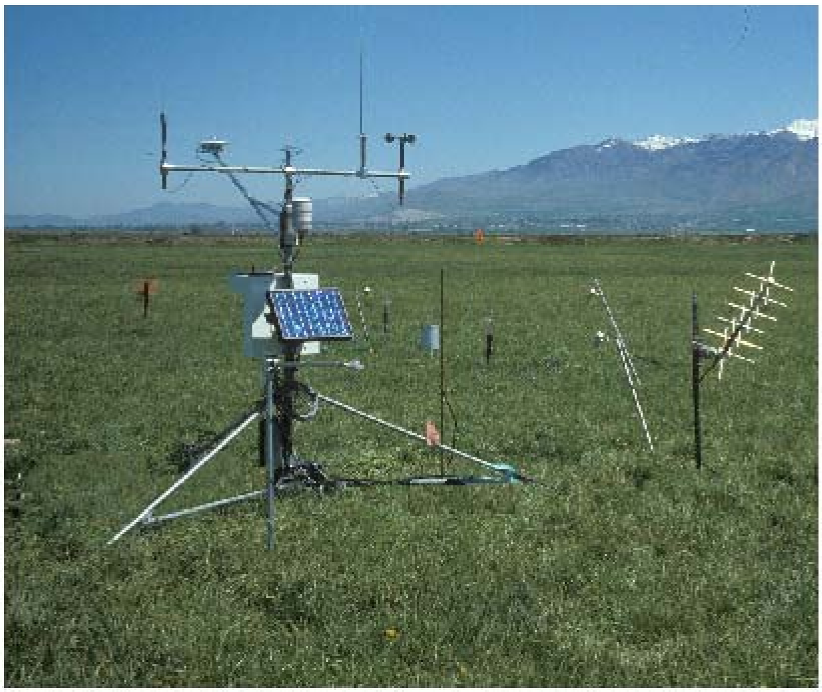


Figure 4.61. Right: Open water (<2m) crop coefficients based on CGDD. Left: comparison between open water (<2m) crop coefficients based on FAO56 for Grass and Alfalfa ASCE standardized Penman-Monteith equation

Appendix 5

THE ASCE STANDARDIZED REFERENCE EVAPOTRANSPIRATION EQUATION



Task Committee on Standardization of Reference Evapotranspiration

Environmental and Water Resources Institute
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January, 2005
Final Report

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