FARM IRRIGATION FACT SHEETS

SET 5: SCHEDULING BASICS

Evapotranspiration, Weather Stations, Recent Extremes, Water Needs for Specific Crops

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LIVING LANDS AGROECOLOGY

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Living Lands Agroecology, 2023

Scheduling 101

Scheduling doesn't help unless you first ensure the irrigation system **applies water evenly** at a **known application rate**.

HOW MUCH WATER?

Use weather-based estimation.

To schedule irrigation, we need to guess how much water the crops need based on the ***weather***, the ***type of irrigation***, and the ***crop's growth stage***.

The weather-based approach described below budgets irrigation to specific crops.

We should ***also check the soil*** after we irrigate to see if we applied too much or too little, but it's good to get it roughly right in the first place.

1. EVAPOTRANSPIRATION (ET_o)

Weather stations report "ET_o" for an ideal "reference" grass.

Reference evapotranspiration, ***ET_o,*** is the amount of water used in one day — given the weather — by a vigorous, healthy grass that's about 12" tall in a deep, well-watered soil.

ET_o (e.g. from ***Farmwest.com***) is usually estimated from four weather variables: ***temperature, wind speed, solar radiation,*** and ***humidity.***

2. CROP COEFFICIENT (K_c & ET_c)

Crop type, stage of growth, and health all influence water needs.

To adjust *ET_o* for a particular crop, we multiply it by a ***crop coefficient, K_c,*** that we pick from a table or graph, or our own experience with the crop.

The ***crop evapotranspiration, ET_c***, is the amount of water we expect the crop uses in one day, given the weather conditions.

$$ET_c = K_c \times ET_o$$

3. EFFECTIVE RAINFALL (P_{eff})

Only some rain "effectively" makes it to the roots.

If it rained a certain depth in a day, ***P***, the "effective precipitation", ***P_{eff},*** is the water that actually makes it to the roots.

The first 5mm that falls isn't counted, and the rest that falls is only about 75% effective.

$$P_{eff} = (P - 5mm) \times 75\%$$

4. MOISTURE DEFICIT (MD)

The net loss of water in the soil.

The crop's moisture deficit, ***MD_{crop}***, is the depth of water we need to replace in the soil. It's the water used by the crop, ***ET_c***, minus effective rainfall, ***P_{eff}.***

$$MD_{crop} = ET_c - P_{eff}$$

Each day's moisture deficit adds up until you irrigate and, ideally, eliminate the deficit.

5. IRRIGATION DEPTH

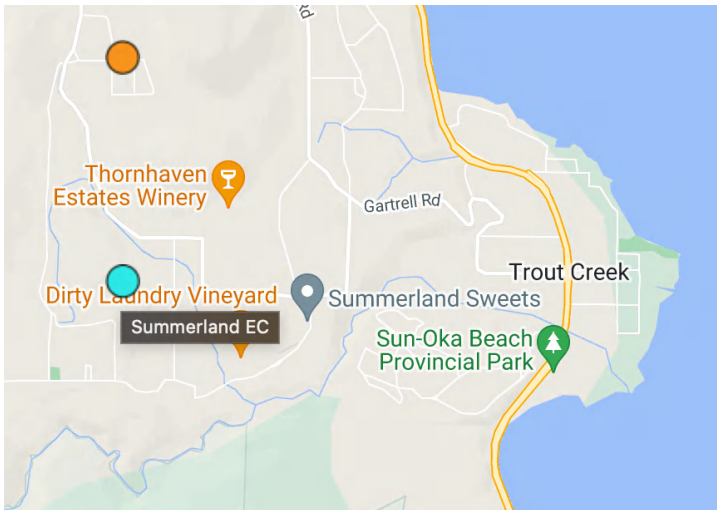
Apply extra water to account for irrigation inefficiencies.

Not all the water you apply makes it to the plants' roots. The system's ***efficiency*** is perhaps only 70% (sprinkler), 80% (microsprinkler), or 90% (drip).

To replace the crop's moisture deficit since you last irrigated, ***MD_{crop}***, the volume we actually apply has to be greater. It's a simple division:

$$\text{Depth to Irrigate} = MD_{crop} / \text{Efficiency}$$

Weather Stations



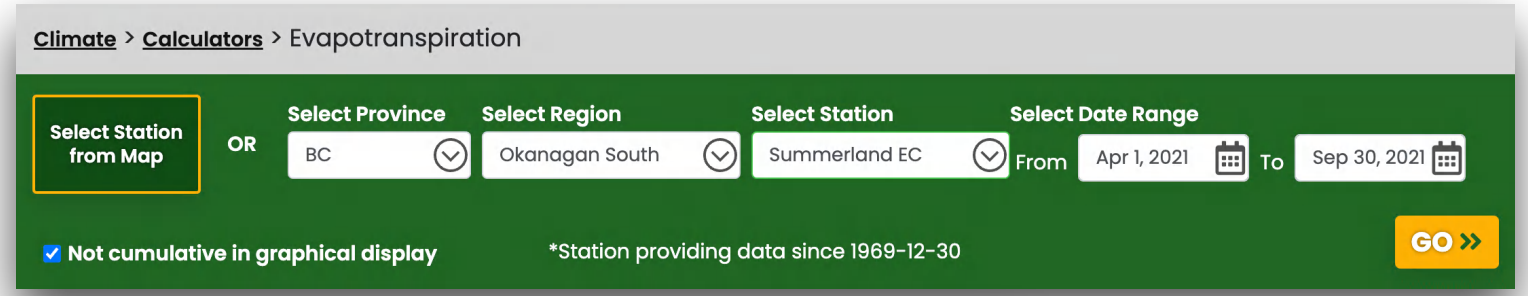
SUMMERLAND EXAMPLE

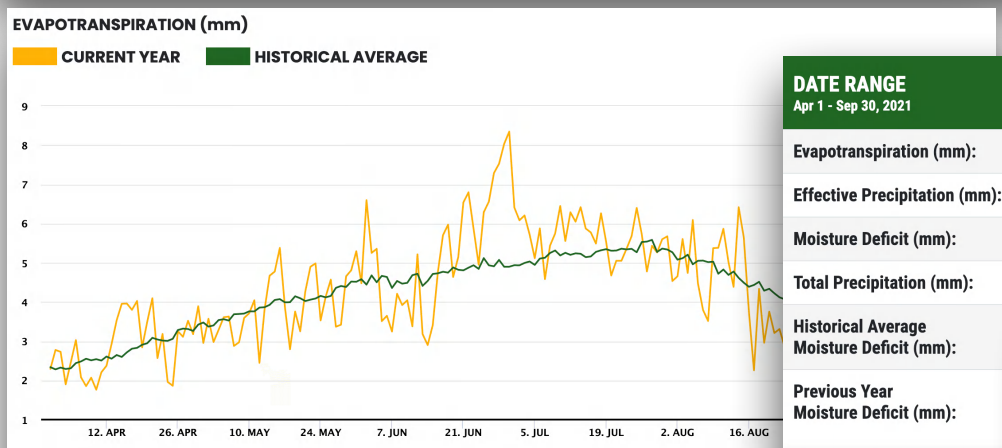
Let's go through the steps…

First, go to the ***Evapotranspiration Calculator*** at ***Farmwest.com***. Choose a region (Okanagan), a weather station (Summerland EC), a date range (Apr 1 to Sept 30) and hit ***"Go"***.

"Click to See Daily Data" gives you the details.

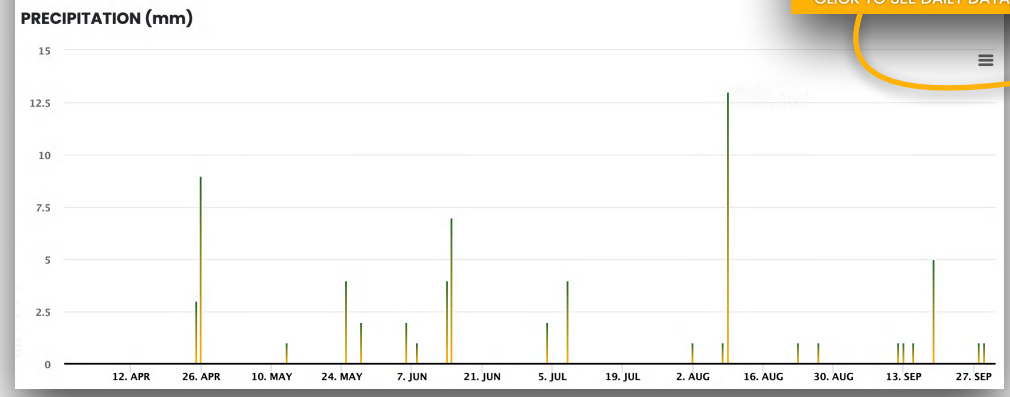
The data shown below is for **2021, the hottest, driest year from 2018 to 2022**. Next, we'll look at how all 5 years stack up…





DATE RANGE Apr 1 - Sep 30, 2021	TOTAL	DAILY AVERAGE
Evapotranspiration (mm):	750	4.1
Effective Precipitation (mm):	11	0.1
Moisture Deficit (mm):	740	4
Total Precipitation (mm):	66	0.4
Historical Average Moisture Deficit (mm):		
Previous Year Moisture Deficit (mm):		

CLICK TO SEE DAILY DATA



Date	TMax	TMin	ET	Prec	MD
2021-04-01	16.5000	8.5000	2.2947	0.0000	2.2947
2021-04-02	16.5000	2.6000	2.7760	0.0000	2.7760
2021-04-03	17.0000	4.8000	2.7289	0.0000	2.7289
2021-04-04	11.4000	4.4000	1.8994	0.0000	1.8994
2021-04-05	12.7000	-0.6000	2.4592	0.0000	2.4592
2021-04-06	16.8000	0.9000	3.0252	0.0000	3.0252
2021-04-07	12.9000	5.6000	2.0800	0.0000	2.0800
2021-04-08	9.6000	2.4000	1.8539	0.0000	1.8539
2021-04-09	9.9000	0.3000	2.0687	0.0000	2.0687
2021-04-10	8.1000	1.1000	1.7626	0.0000	1.7626
2021-04-11	9.6000	-2.1000	2.2066	0.0000	2.2066
2021-04-12	11.5000	0.1000	2.3724	0.0000	2.3724
2021-04-13	14.9000	0.1000	2.9279	0.0000	2.9279
2021-04-14	19.2000	2.5000	3.5337	0.0000	3.5337
2021-04-15	21.8000	3.7000	3.9547	0.0000	3.9547
2021-04-16	21.9000	4.3000	3.9596	0.0000	3.9596
2021-04-17	21.1000	4.8000	3.7994	0.0000	3.7994
2021-04-18	23.7000	8.6000	4.0240	0.0000	4.0240
2021-04-19	15.7000	4.9000	2.8435	0.0000	2.8435
2021-04-20	18.0000	2.0000	3.4980	0.0000	3.4980
2021-04-21	21.6000	3.5000	4.0946	0.0000	4.0946

Evapotranspiration (ET_o)

WEEKLY AVERAGES

2018 to 2022 ET_o and rainfall in "water depth per day"

The chart has ***reference evapotranspiration (ET_o)*** and ***effective precipitation*** for the five seasons from 2018 to 2022 as ***weekly averages*** measured in ***millimetres per day.***

Why weekly? Most crops can handle an extreme on a day or two if it's balanced over the week.

If you irrigate crops that demand daily adjustments to extremes, use daily evapotranspiration and not weekly averages.

Max Daily ET_o (yellow): Highest recorded ET_o on a single day of that week, between 2018 and 2022.

Max Weekly ET_o (orange): Highest weekly average ET_o between 2018 to 2022.

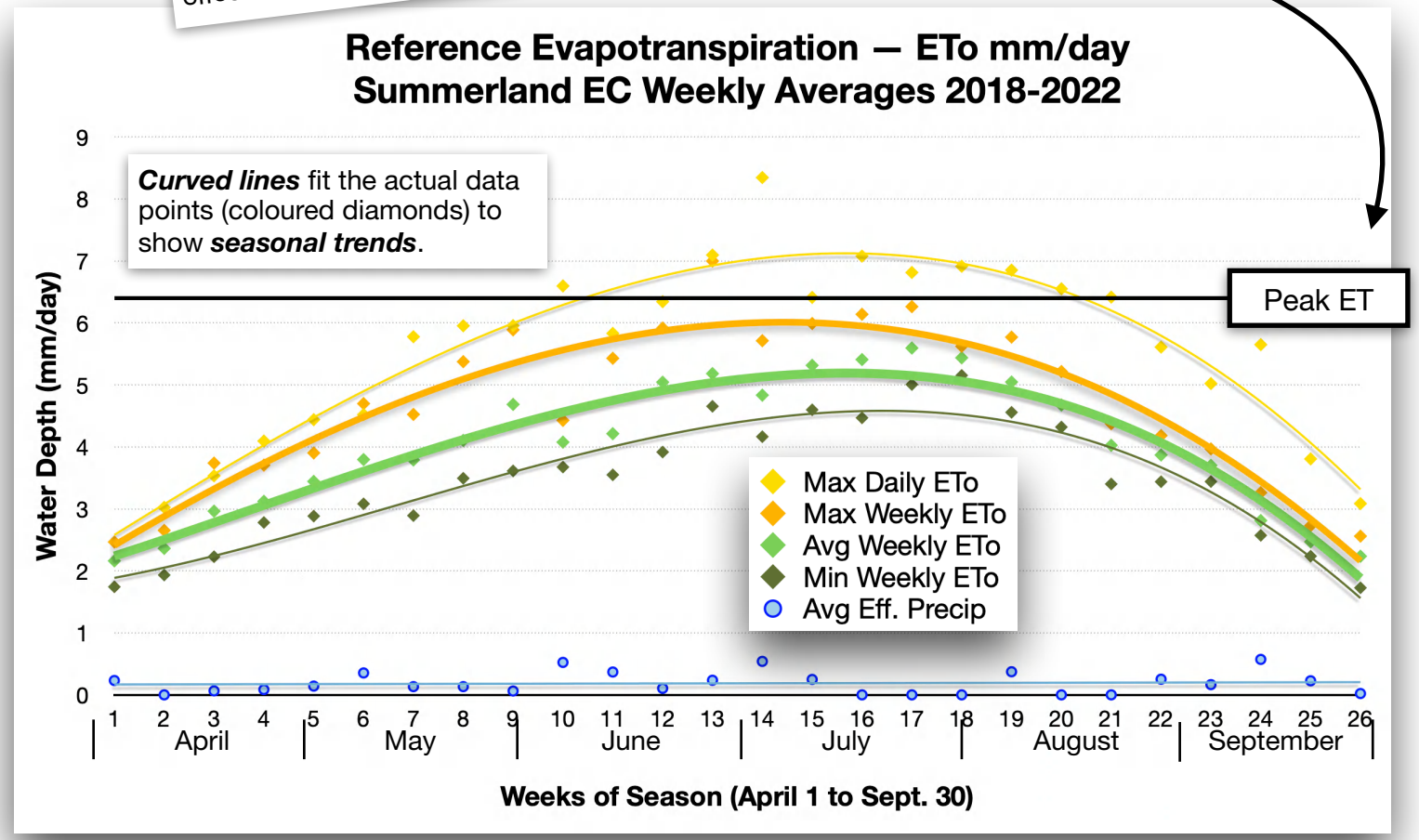
Avg Weekly ET_o (light green): Average of all ET_o in that week for all years, 2018 to 2022.

Min Weekly ET_o (dark green): Lowest weekly average ET_o between 2018 to 2022.

Avg Eff Precip (blue): Weekly average effective precipitation for all years, 2018 to 2022.

The chart is in ***millimetres of water per day*** for both reference evapotranspiration (ET_o) and effective precipitation (rainfall).

"Peak ET" is the amount used by the Province to assign water license limits. It's ***6.4 mm/day in Summerland***. Find it online for any property at the ***"BC Agriculture Water Calculator."***



Next, we'll ***compare hot and cool seasons*** against the seasonal trends for 2018-2022 "Max Weekly *ETo*" ***(orange)***,"Average Weekly *ETo*" ***(light green)***, and "Average Effective Precipitation" ***(blue).***

Hot and Cool Seasons

EXTREME SEASONS

Hot/Dry (2021) & Cool/Wet (2019)

***2021** (red)* was the hottest and driest year — highest "moisture deficit" — from 2018 to 2022.

***2019** (blue)* had the lowest moisture deficit, owing to rainfall and cooler-than-usual conditions.

The weekly average values for 2019 and 2021 are shown below, in ***millimetres of water per day,*** for reference evapotranspiration (ET_o, solid line) and effective precipitation (dotted line).

With data from 2018 to 2022, we've included the ***trends for average week** (green)* and ***maximum week** (orange)*.**

***Max Weekly ET_o** (orange trend line)*: trend for highest weekly ET_o, from 2018 to 2022.

***Avg Weekly ET_o** (green trend line)*: trend for average weekly ET_o, from 2018 to 2022.

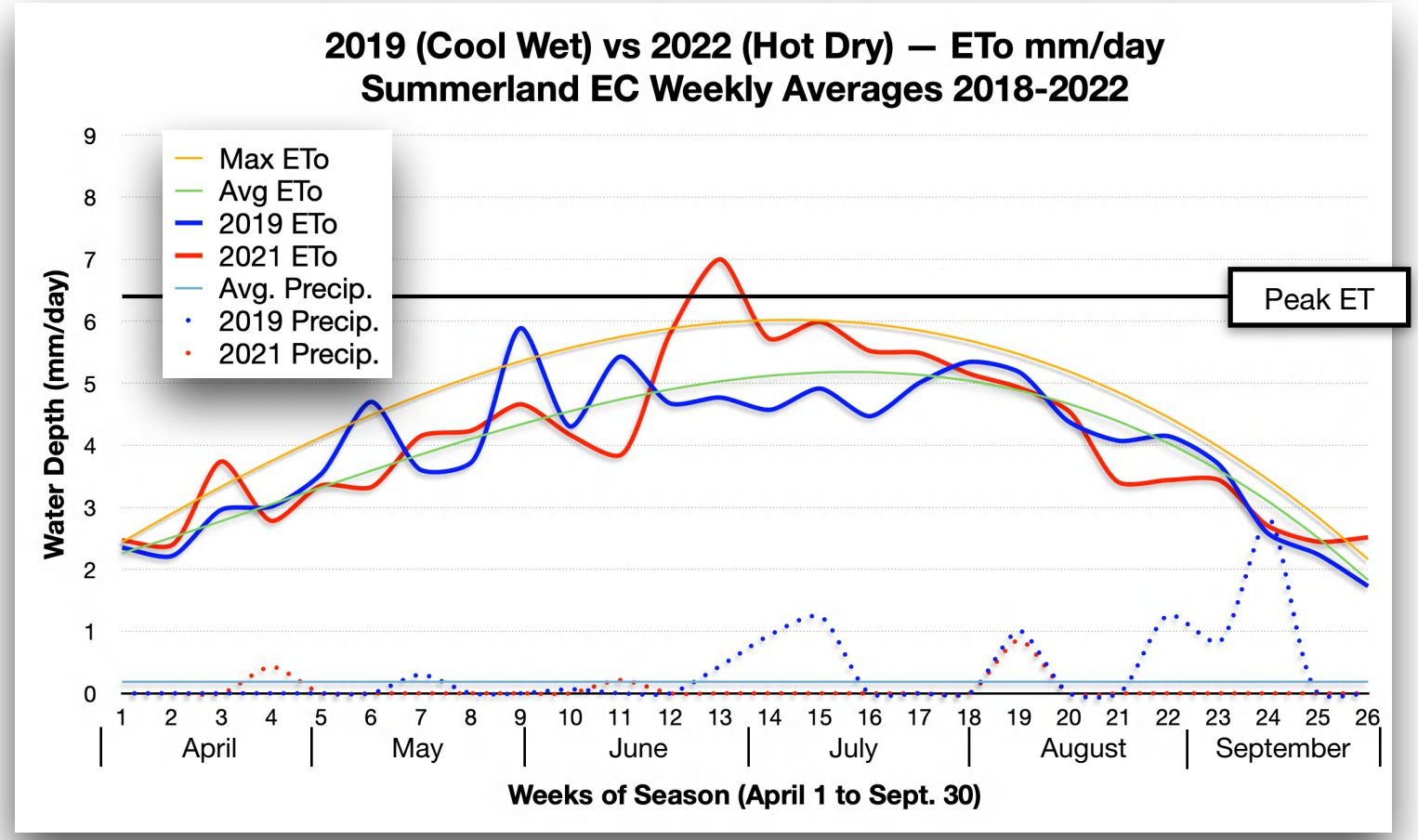
***2019 ET_o** (blue line)*: 2019 ET_o weekly averages.

***2021 ET_o** (red line)*: 2021 ET_o weekly averages.

***Avg Eff Precip.** (light blue)*: Average of 0.2mm of daily effective precipitation from 2018 to 2022.

***2019 Precip.** (blue dots)*: 2019 effective precipitation, weekly averages.

***2021 ET_o** (red dots)*: 2021 effective precipitation, weekly averages.



Next we'll choose ***"crop coefficients"*** to adjust the reference evapotranspiration to see how 2019, 2022, and the 2018-2022 trends translate into ***irrigation amounts for specific crops***…

Crop Water Needs (ET_c)

ADJUST REFERENCE ET_o

Crop age, stage, health and soil all affect the plant's thirst.

The "reference" evapotranspiration, ***ET_o***, is for a vigorous, 12-inch tall grass growing in loose, rich soil with ample water.

We use "crop coefficients", ***K_c***, to adjust these values to meet our crop's specific conditions.

To calculate ***crop evapotranspiration, ET_c***, multiply the reference *ET_o* by the coefficient *K_c*.

$$ET_c = K_c \times ET_o$$

CHOOSING COEFFICIENTS

Experience plays a role.

There are several sources for crop coefficients, not least ***your own experience*** as you observe crops' water requirements (ET_c) and compare them to reference ET_o from weather stations.

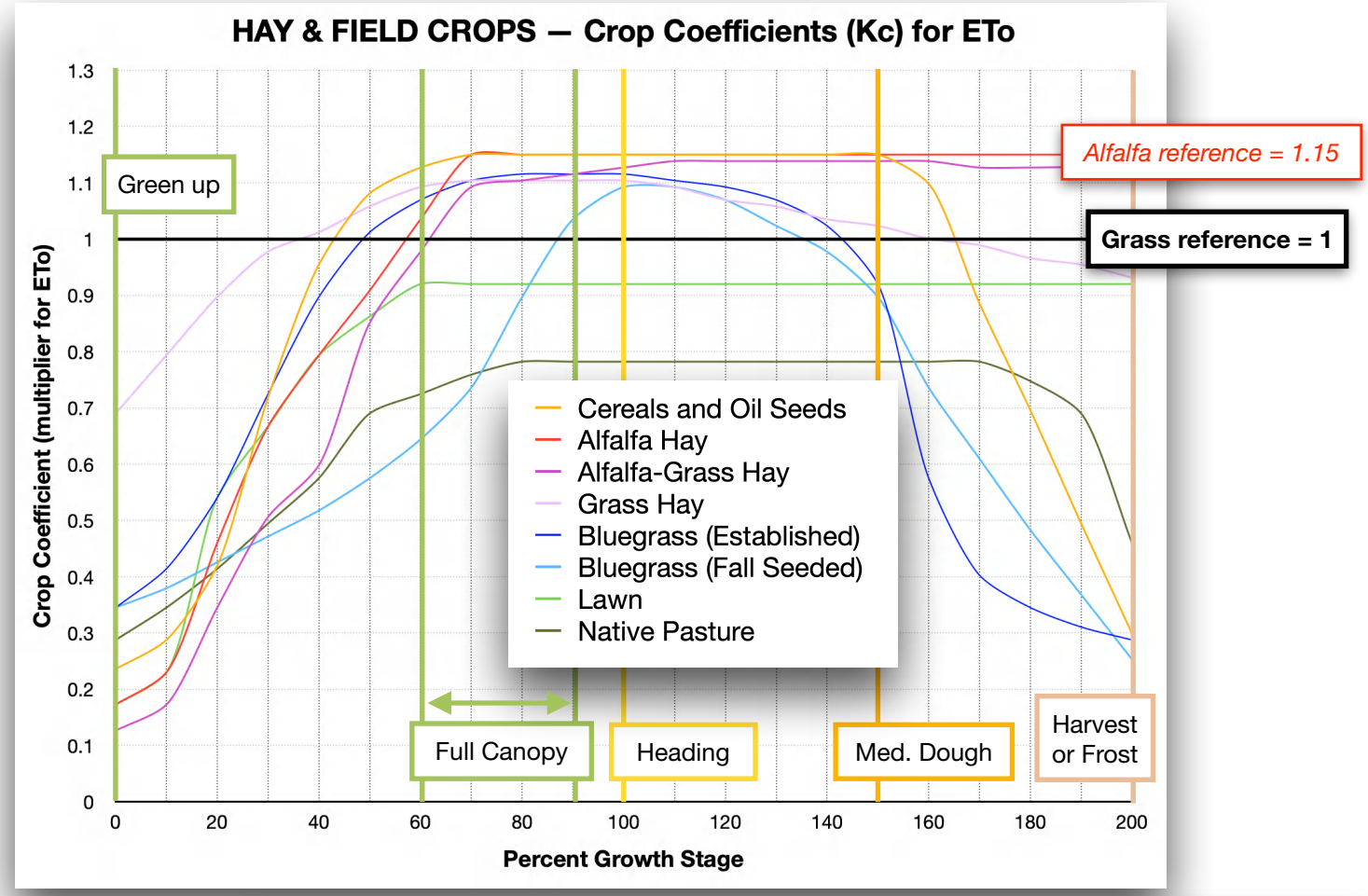
Here, we've reproduced the crop coefficients for ***AgriMet (USDA) in Washington and Oregon***.

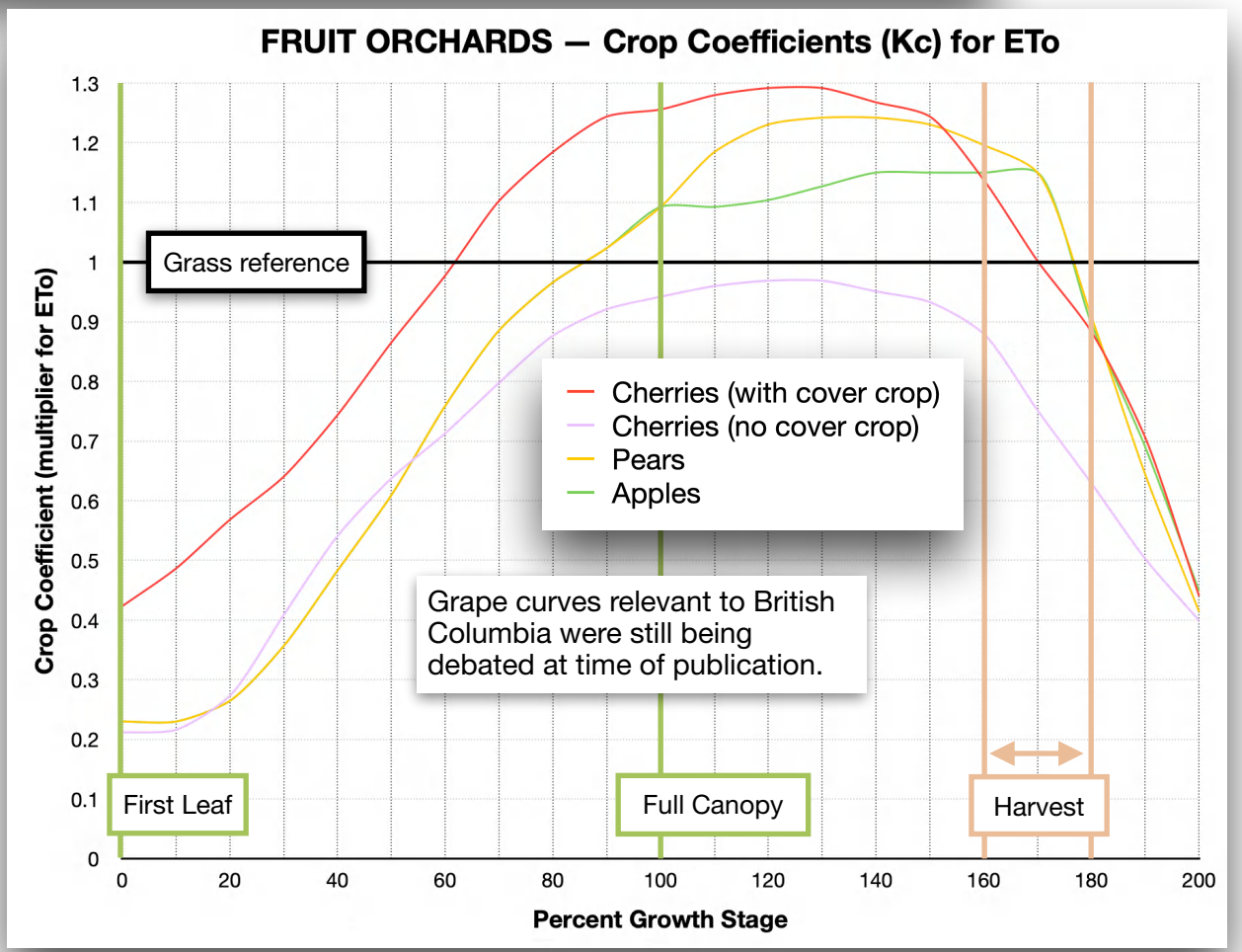
"Percent Growth Stage" is used to vary the coefficients from 0% (first leaf) to 100% (full canopy) to 200% (killing frost).

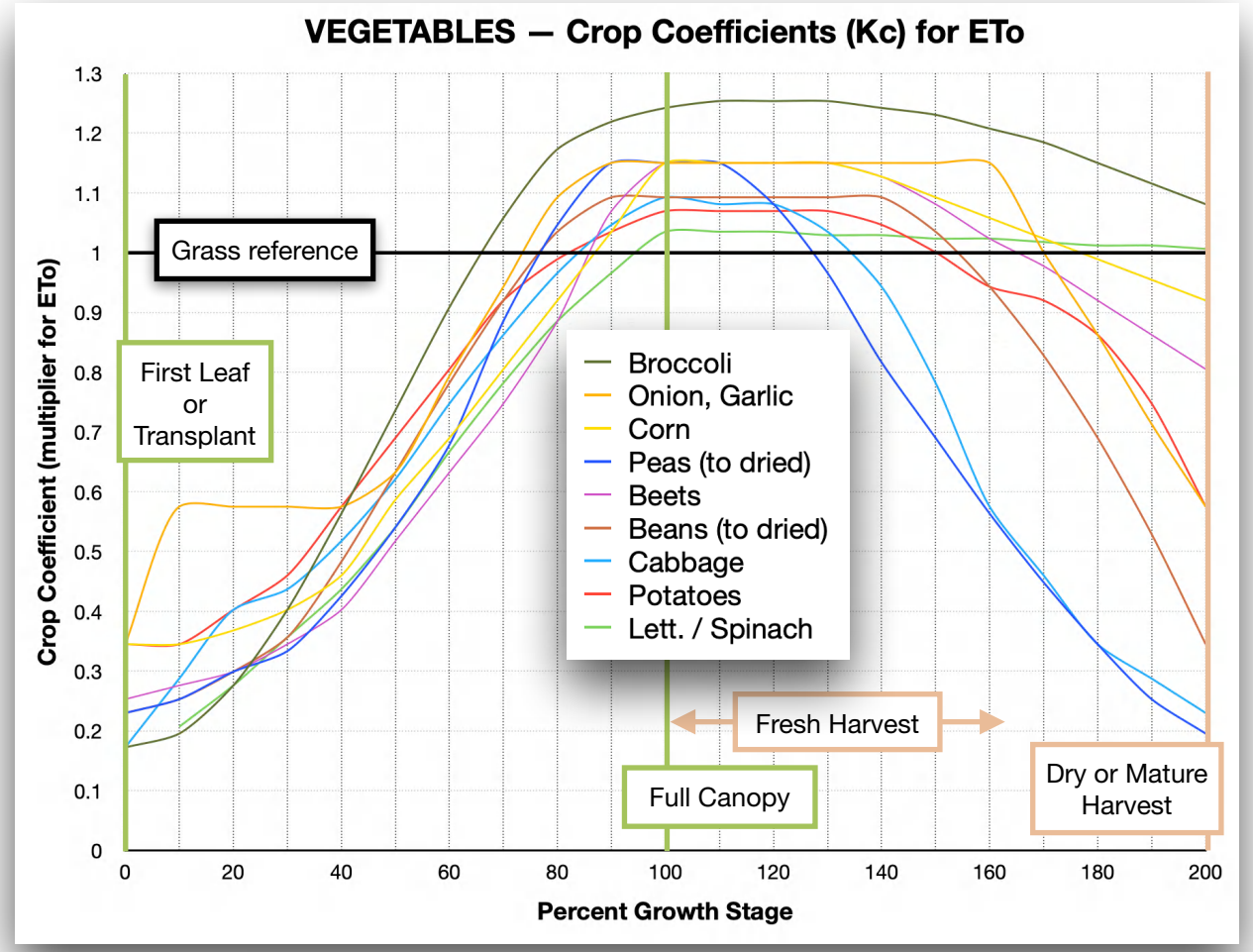
Percent Growth Stages for AgriMet (NRCS-USDA) Crop Coefficients

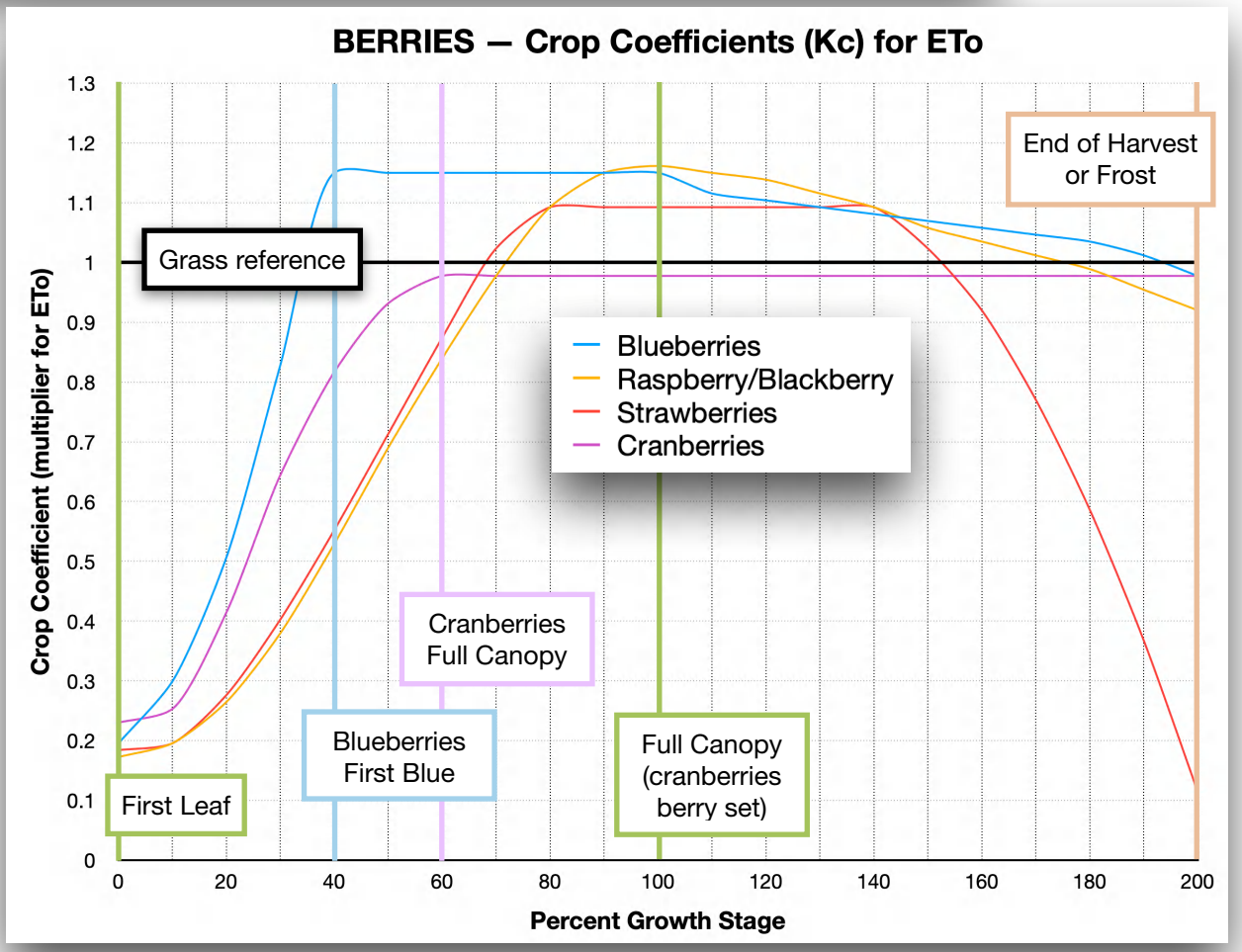
% Growth Stage	*HAY & FIELD CROPS*	*FRUIT ORCHARDS*	*BERRIES/GRAPES*	*VEGETABLES*	*HERBS, SEEDS, PERENNIALS, TREES*
0	**Green Up, Emergence, Break Dormancy**	**First Leaf**	**First Leaf Break Dormancy**	**First Leaf, Emergence, Transplant**	**Break Dormancy** *Asparagus: 2' Tall*
10					
20	*Pasture: Last -4°C*				
30					
40			*Blueberry: First Blue*	*Alliums: Emergence*	
50					
60	*Grass/Alfalfa: Full Canopy Pasture/Lawn: 4-6"*		*Cranberry: Full Canopy*		
70	*Cereals & Oils: Full Canopy*				
80	*Pasture: Full Canopy*				
90					
100	**Heading Begins** *Cereals & Oils: Heading 50%*	**Full Canopy**	**Full Canopy/Bloom** *Blueberry: Full Blue Cranberry: Berry Set*	**Full Canopy/Bloom** *Corn: Tasseling Alliums: 50% 12-leaf*	**Full Canopy** *Hops: Top of trellis*
110					
120					
130					
140				*Beans: Lower leaves yellow*	
150	*Cereals: Medium Dough*				
160		**Harvest**		*Alliums: Last irrigation*	*Hops/Mint: Harvest*
170					
180					
190					
200	**Killing Frost (-4°C), Harvest**	**3-4 Weeks after Harvest**	**Killing Frost, End of Harvest**	**Killing Frost, Dead Stems, Harvest**	**Killing Frost, Dormant, Harvest** *Hops: Dead Vines*

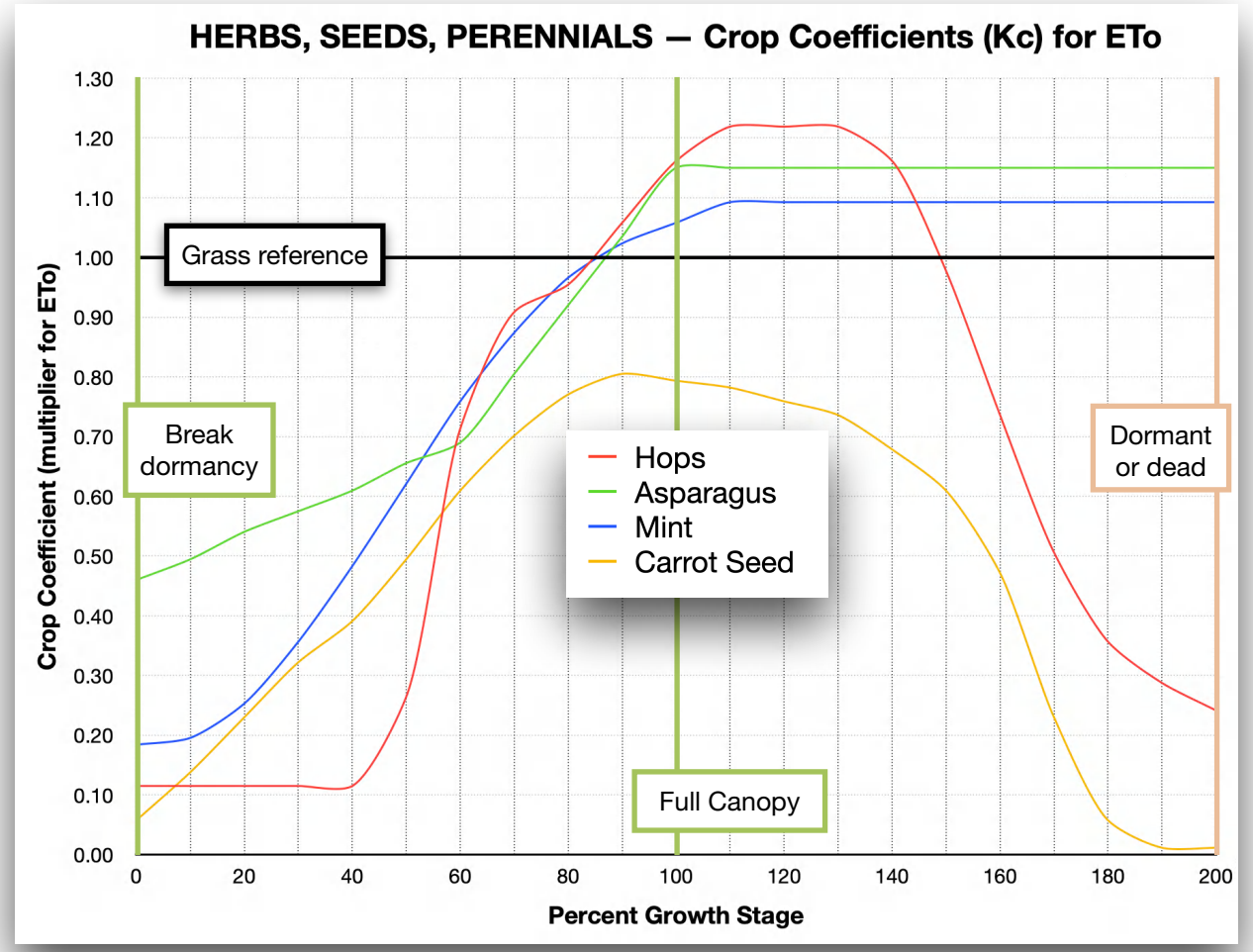
Remember: Better roughly right than exactly wrong!

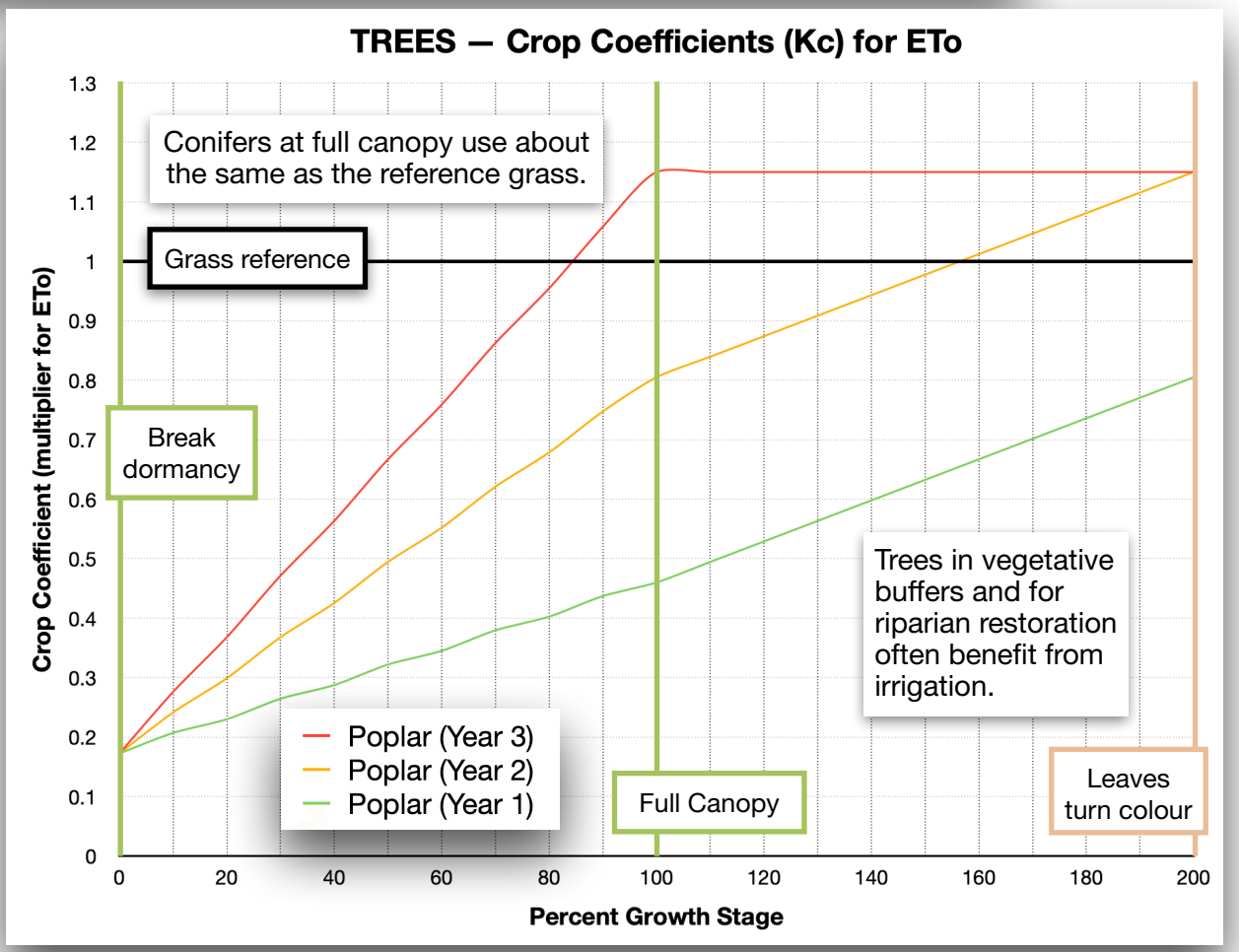

HAY & FIELD CROPS — Crop Coefficients (Kc) for ETo
Crop Coefficient (multiplier for ETo)
Percent Growth Stage
Green up
Alfalfa reference = 1.15
Grass reference = 1
Cereals and Oil Seeds
Alfalfa Hay
Alfalfa-Grass Hay
Grass Hay
Bluegrass (Established)
Bluegrass (Fall Seeded)
Lawn
Native Pasture
Full Canopy
Heading
Med. Dough
Harvest or Frost


FRUIT ORCHARDS — Crop Coefficients (Kc) for ETo
Crop Coefficient (multiplier for ETo)
Percent Growth Stage
Grass reference
Cherries (with cover crop)
Cherries (no cover crop)
Pears
Apples
Grape curves relevant to British Columbia were still being debated at time of publication.
First Leaf
Full Canopy
Harvest


VEGETABLES — Crop Coefficients (Kc) for ETo
Crop Coefficient (multiplier for ETo)
Percent Growth Stage
Grass reference
First Leaf or Transplant
Full Canopy
Fresh Harvest
Dry or Mature Harvest
Broccoli
Onion, Garlic
Corn
Peas (to dried)
Beets
Beans (to dried)
Cabbage
Potatoes
Lett. / Spinach


BERRIES — Crop Coefficients (Kc) for ETo
Crop Coefficient (multiplier for ETo)
Percent Growth Stage
Grass reference
End of Harvest or Frost
First Leaf
Blueberries First Blue
Cranberries Full Canopy
Full Canopy (cranberries berry set)
Blueberries
Raspberry/Blackberry
Strawberries
Cranberries


HERBS, SEEDS, PERENNIALS — Crop Coefficients (Kc) for ETo
Crop Coefficient (multiplier for ETo)
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Grass reference
Break dormancy
Hops
Asparagus
Mint
Carrot Seed
Full Canopy
Dormant or dead
0
20
40
60
80
100
120
140
160
180
200
Percent Growth Stage


TREES — Crop Coefficients (Kc) for ETo
Crop Coefficient (multiplier for ETo)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Conifers at full canopy use about the same as the reference grass.
Grass reference
Break dormancy
Trees in vegetative buffers and for riparian restoration often benefit from irrigation.
Poplar (Year 3)
Poplar (Year 2)
Poplar (Year 1)
Full Canopy
Leaves turn colour
0
20
40
60
80
100
120
140
160
180
200
Percent Growth Stage

Pear Orchard Example

MOISTURE DEFICIT (MD_{crop})

Water for a Pear Orchard Season

Crop coefficients, K_c, for pears *(bottom graph)* were used to adjust the weekly average ***reference evapotranspiration ET_o*** for four scenarios: 2019 "cool/wet year" ***(blue)***, 2021 "hot/dry year" ***(red)***, and the trends for an "average year" ***(green)*** and a "maximum year" ***(orange)*** from 2018 to 2022.

Effective precipitation was subtracted from the crop's evapotranspiration to give the ***crop moisture deficit*** *(top graph).*

2019 Moisture Deficit for pears (blue): MD_{crop} = ET_o x K_c minus 2019 effective precipitation.

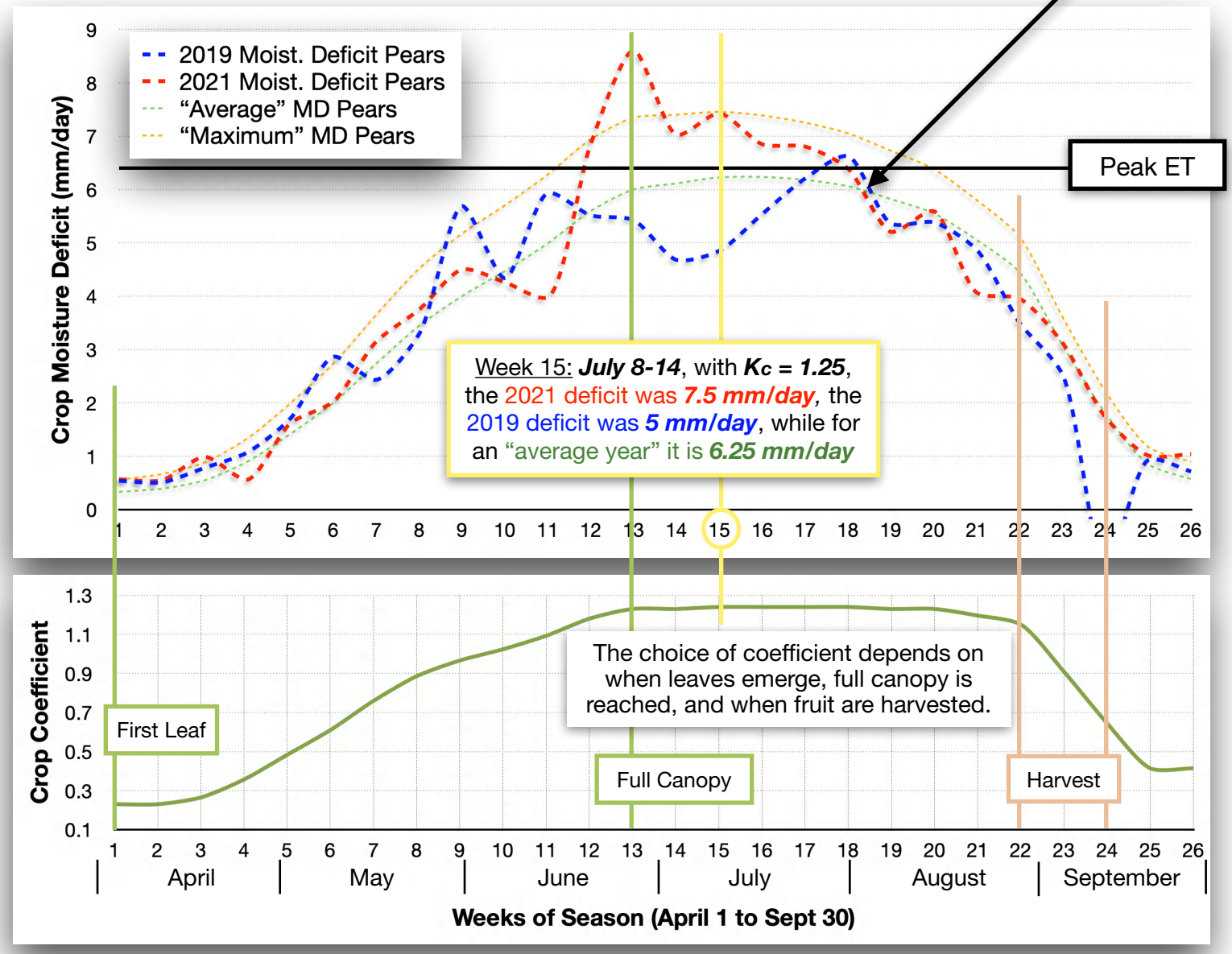
2021 Moisture Deficit for pears (red): MD_{crop} = ET_o x K_c minus 2021 effective precipitation.

Maximum MD_{crop} for pears (orange): Highest weekly ET_o minus average precipitation 2018-2022.

Average MD_{crop} for pears (green): Average weekly ET_o minus average precipitation 2018-2022.

Add water for *inefficiencies!*

E.g. With ***microsprinklers (80% efficient)*** if the moisture deficit is 6mm/day, ***apply 7.5 mm/day.***



Grass Hay Example

MOISTURE DEFICIT (MD_{crop})

Water for Three Cuts of Hay

Crop coefficients, K_c, for grass hay *(bottom)* were used to adjust the ***weekly average reference evapotranspiration ET_o*** for four scenarios: 2019 "cool/wet year" ***(blue)***, 2021 "hot/dry year" ***(red)***, and the trends for an "average year" ***(green)*** and a "maximum year" ***(orange)*** from 2018 to 2022.

Effective precipitation was subtracted from the crop's evapotranspiration to give the ***crop moisture deficit (top graph).***

2019 Moisture Deficit for grass (blue): MD_{crop} = ET_o x K_c minus 2019 effective precipitation.

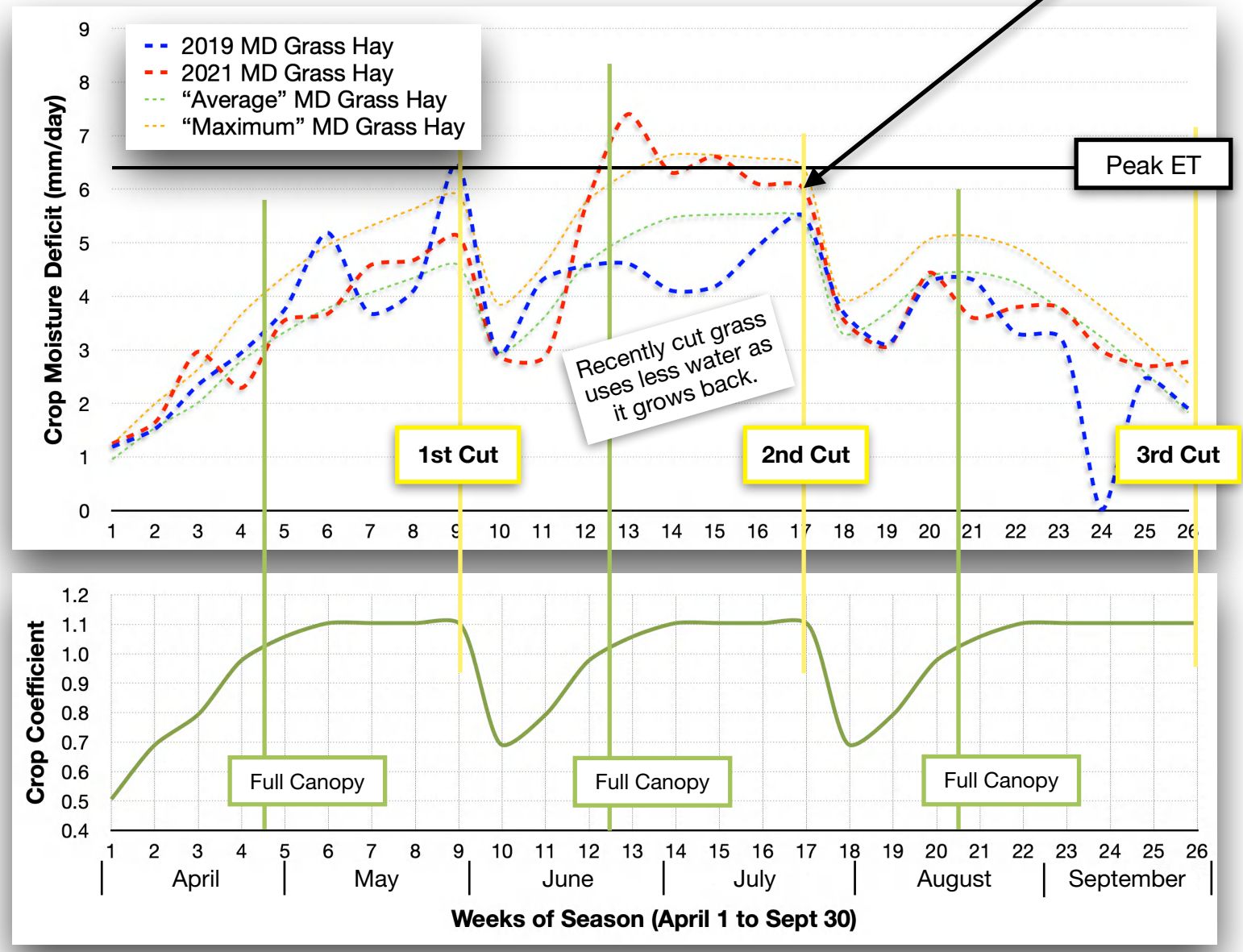
2021 Moisture Deficit for grass (red): MD_{crop} = ET_o x K_c minus 2021 effective precipitation.

Maximum MD_{crop} for grass (orange): Highest weekly ET_o minus average precipitation 2018-2022.

Average MD_{crop} for grass (green): Average weekly ET_o minus average precipitation 2018-2022.

Add water for *inefficiencies!*

E.g. With ***sprinklers (70% efficient)*** if the crop's moisture deficit is 6mm/day, ***apply 8.5 mm/day.***



Schedule Adjustments

PEAK SCHEDULE

Schedule for "Peak" Conditions

Calculate the ***time each irrigation zone must run*** to meet the crop's requirements in "peak" season, when it's ***very hot and dry*** and the crop is growing well at ***full canopy***. The sprinkler approach below is slightly different for drip, but the principle is the same for all irrigation systems:

1) Identify ***Peak ETo (mm/day)*** for your area — e.g. from bcwatercalculator.ca
2) Choose a ***Peak Crop Coefficient (Kc)*** for the crop growing in the zone.
3) Calculate ***Peak Crop ETc = Kc x ETo***
4) Adjust ETc by the ***application efficiency*** — e.g. for regular sprinklers, about 70 to 75% — to get the ***Peak Application (mm/day)***
5) Use the ***application rate (mm/hour)*** to calculate ***"Peak Schedule" (hour/day)***.

Example: Beets with Sprinklers

BC Agriculture Water Calculator

1) Peak ETo = **6.1 mm/day**

2) Peak Kc (full canopy) = 1.15

3) Peak ETc = 1.15 x 6.1
= **7 mm/day**

4) App. Efficiency = 70%
Peak App. = 7 ÷ 70%
= **10 mm/day**

5) App. Rate = **5 mm/hour**
Peak Sch. = 10 ÷ 5
= **2 hours/day**

... So schedule the beet zone for 2 hours/day.

farmwest.com

DATE RANGE May 19 - May 26, 2022	TOTAL	DAILY AVERAGE
Evapotranspiration (mm):	32	4
Effective Precipitation (mm):	0.7	0.1

Average over previous week

1) Avg. ETo = **4 mm/day**
Avg. Peff = **0.1 mm/day**

2) Kc (80% canopy) = 0.9

3) ETc = 0.9 x 4
= **3.6 mm/day**

4) MDcrop = 3.6 - 0.1
= **3.5 mm/day**

5) "Adjust" = MDcrop ÷ Peak ETc
= 3.5 ÷ 7
= **50%**

... So dial in 50% and it will run the beets for only **1 hour**.

REGULAR ADJUSTMENTS

Adjust for Actual Conditions

A ***percentage***, often called ***"seasonal adjust"*** is calculated regularly (e.g. once per week) from a weather report. For irrigation that cycles around over many days (e.g. wheelmoves), the question is how long to wait between cycles, but the principle — to adjust to conditions — is the same:

1) From a weather service — e.g. farmwest.com — get the ***average ETo*** and ***effective precipitation (Peff)*** since you last irrigated.
2) Choose a ***crop coefficient (Kc)*** based on the crop's current condition and growth stage.
3) Calculate ***crop water use, ETc = Kc x ETo***
4) Subtract effective precipitation to get the crop's ***moisture deficit, MDcrop = ETc - Peff***
5) Compare the moisture deficit to ***Peak ETc*** to get the **"seasonal adjust"** percentage.