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SPRINKLER IRRIGATION SCHEDULING USING A WATER BUDGET METHOD

Using a water budget to schedule sprinkler irrigation systems is similar to balancing a chequebook. The plant's soil water storage reservoir can be considered as a bank. This reservoir can hold a limited amount of water that is useful for the crop. Adding too much water to the soil reservoir will mean water loss due to deep percolation (DP) and/or runoff. The crop evapotranspiration (ET_c), or the crop water use, is the crop's daily water withdrawal. Irrigation (IRR) and effective precipitation (EP) are deposits. This water budget method works well with a computer spreadsheet that allows the daily reference ET (ET_o), precipitation and irrigation amounts to be accounted for irrigation scheduling. Figure 1 below shows the schematics of the water budget method for scheduling sprinkler irrigation.

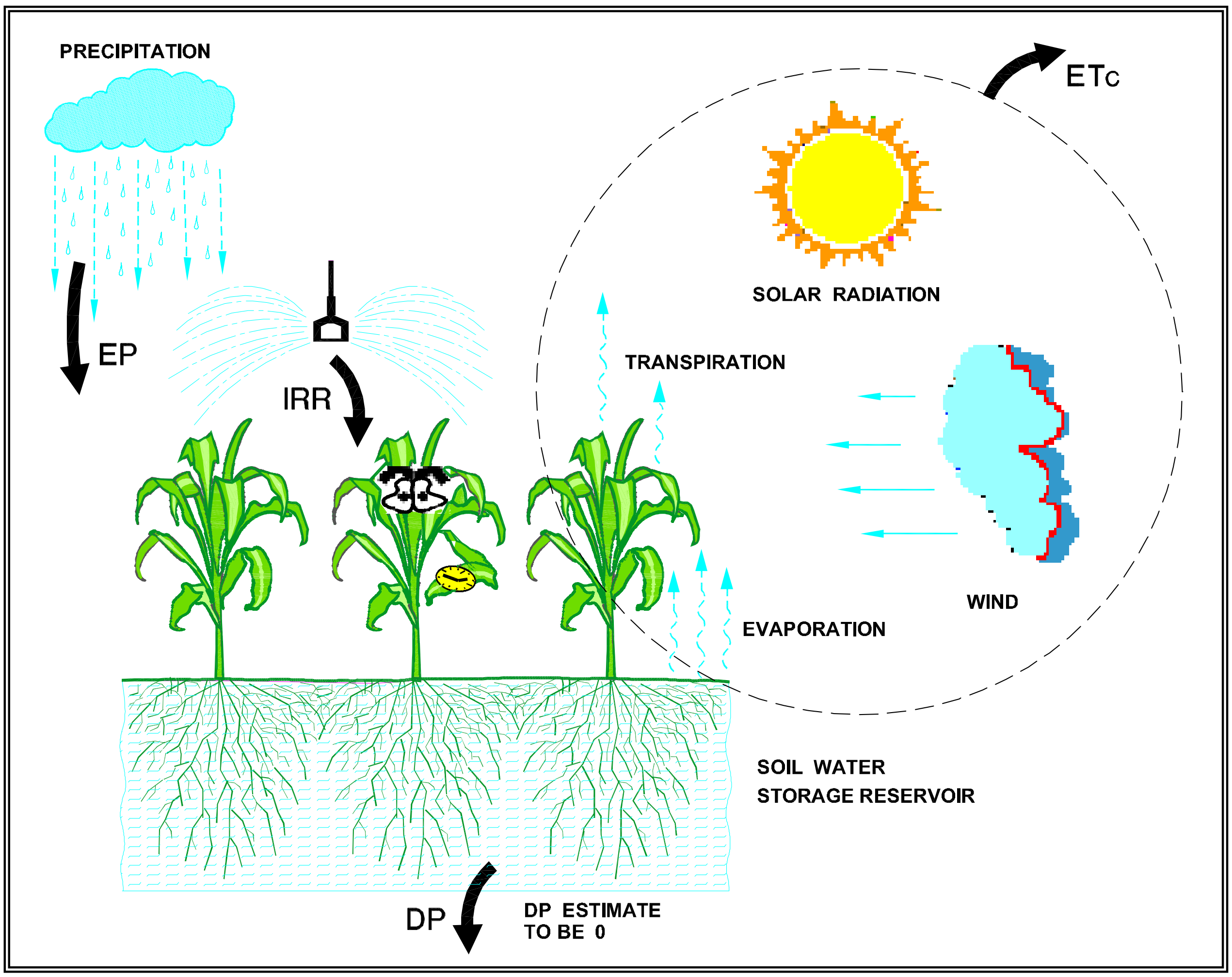

Figure 1 Crop Water Balance

WATER BALANCE EQUATION

Equation 1 can be used to calculate a water balance:

$$CSWC = PSWC + EP + IRR - ET_c - DP \qquad \textbf{[Equation 1]}$$

where CSWC = current soil water content (today) [mm]
PSWC = previous soil water content (yesterday) [mm]
EP = effective precipitation since yesterday [mm]
IRR = irrigation since yesterday [mm]
ET_c = crop evapotranspiration [mm]
DP = deep percolation, water lost beyond the root zone [mm]

The water budget equation does not provide a factor for runoff as good irrigation management practices should eliminate runoff. Deep percolation (DP) is also assumed to be zero in most cases as it is difficult to measure and should be minimal if good irrigation practices are followed. If leaching is desired in some instances, then the amount of irrigation applied would need to exceed the soil water storage capacity.

To set up an effective irrigation scheduling program, use the following steps:

STEP 1 DETERMINE SOIL WATER CONTENT – CSWC AND PSWC

The first step is to determine how much water is in the soil or 'bank'. See Factsheet 619.000-1 Soil Water Storage Capacity and Available Soil Moisture.

What If the Crop Root Zone Changes over the Season ?

It will be necessary to adjust the soil water holding capacity for annual crops that develop larger root systems as the growing season progresses. For example, an annual crop in May might have a 0.15-m rooting depth and would have a smaller reservoir of water to draw upon than later in the season when the rooting depth is 0.40 m.

How Much Water is in the Soil at the Start of the Water Budget ?

Measuring the existing soil moisture can be difficult. It is therefore easier to start the water budget after a thorough irrigation or rainfall that fills the entire root zone. The water budget would then start with a full storage value equal to the Soil Water Storage (SWS).

If the soil is not full, the actual soil moisture may be determined using tensiometers or other soil moisture monitoring devices. See Factsheet 577.100-2 Irrigation Scheduling With Tensiometers.

ACTION

- At the top of the worksheet, enter the **Soil Water Storage (SWS) Capacity** and the **Maximum Allowable Deficit (MAD)**.
- In the table that follows, enter the current amount of soil moisture in the **Previous Soil Water Storage (PSWC)** column.

STEP 2 DETERMINE EFFECTIVE PRECIPITATION (EP)

Precipitation data can be collected with an on-site rain gauge or obtained from climate stations. Daily climate data in real-time can be obtained from www.farmwest.com for various climate stations throughout British Columbia.

Determining Effective Precipitation

Dry Climate

In dry climate during the irrigation season, rainfall of less than 5 mm does not add any moisture to the soil reservoir as most of it is evaporated before entering the soil. Therefore, if rainfall is less than 5 mm, the effective precipitation (EP) is zero. If rainfall is over 5 mm, only 75% of it will be considered as EP. Refer to Equation 2.

$$EP = (RAIN - 5) \times 0.75 \qquad \textbf{[Equation 2]}$$

where EP = effective precipitation [mm]
RAIN = rainfall [mm]

Wet Climate

In wetter climates or periods of the year when there are many days of rainfall in succession, the summation of the total amount of rainfall can be added without using equation 2. For example:

Day	Rainfall [mm]
1	10
2	5
3	2*
4	7

* Not included in the summation as it is considered as a trace amount (<3 mm)

The total EP for this wet period would be 22 mm, the summation of all the rainfall events except for Day 3. Days with only a trace of rainfall (<3 mm) during a wet period would not be added.

> ***ACTION***
> - Enter the **Effective Precipitation (EP)** in the table.

STEP 3 DETERMINE NET DEPTH OF IRRIGATION WATER APPLIED (IRR)

The application rate and the length of time the irrigation system runs determines the amount of water applied. The amount applied by a sprinkler irrigation system can be calculated using Equation 3.

$$IRR = \frac{227 \times Q \times T \times AE}{S_1 \times S_2 \times 100\%} \qquad \textbf{[Equation 3]}$$

where IRR = net depth of irrigation water applied [mm]
Q = sprinkler flow rate [US gpm]
T = irrigation time [hr]
AE = application efficiency [%]
S_1 = sprinkler spacing along lateral [m]
S_2 = lateral spacing [m]

> ***ACTION***
> - Enter the **Net Irrigation (IRR)** in the table on the date when irrigation occurs.

STEP 4 DETERMINE CROP EVAPOTRANSPIRATION (ET_C)

Finding Reference Evapotranspiration

Daily reference evapotranspiration (ET_o) rates are available at www.farmwest.com for various climate stations throughout British Columbia.

Finding the Right Crop Coefficient

A crop coefficient must be applied to the ET_o value to determine the crop evapotranspiration (ET_c) which is also referred to as crop water use. The crop coefficient depends on the crop type and on the crop's stage of development. This value will change over the growing season as the crop matures. The Factsheet 577.100-5 Crop Coefficients for Use in Irrigation Scheduling provides information on crop coefficients for crops common in B.C.

ACTION

- Enter the **Reference ET (ET_o)** in the table.
- Enter an appropriate **Crop Coefficient (K_c)** for the crop's stage of development in the table.
- Multiply ET_o by K_c to obtain **Crop Water Use (ET_c)**, and enter this value in the appropriate column.

STEP 5 CALCULATE WATER BALANCE

Obtain the Current Soil Water Storage (CSWS) by adding EP and IRR to the PSWS and subtracting ET_c from it.

Date	Previous Soil Water Storage	+	Effective Precipitation	+	Net Irrigation	−	Ref. ET	x	Crop Coefficient	=	Crop Water Use	=	Current Soil Water Storage
	PSWS		EP		IRR		ET_o		K_c		ET_c		CSWS

ACTION

- Enter the calculated **Current Soil Water Storage (CSWS)** in the table.
- Enter this CSWS value as the **Previous Soil Water Storage (PSWS)** in the next row to prepare for the calculation in the following day.

The values that are entered can be a daily value or a cumulative value over a specified time period as long as the cumulative values correspond to the same dates.

NOTE: ***Irrigation scheduling using the water balance method is based on estimation and should therefore be checked with soil moisture periodically. It is important to monitor soil water content in the field and compare the calculated soil water content to the actual measured water use once a week or every other week, and correct the calculated water balance when necessary.***

Example 1 – Daily Water Budget Method

(See spreadsheet on next page)

The soil has a soil water storage capacity of 110 mm. The maximum allowable deficit is 55 mm. Therefore, when 55 mm of moisture has been depleted from the soil, a total of 55 mm can be added by the irrigation system. At the beginning of the season, it has been determined that the soil reservoir is full, storing 110 mm of water.

For the month of May, the crop irrigated had a crop coefficient (K_c) of 0.75.

May 1st The ET_o rate was 4 mm. Multiplying this ET_o by the K_c value of 0.75 gives an ET_c of 3 mm. At the end of the day, the CSWS is therefore:

$$(110 - 3)\text{ mm} = 107\text{ mm.}$$

May 2nd The ET_o rate was 4.2 mm. Multiplying this ET_o by the K_c value of 0.75 gives an ET_c of 3.2 mm. At the end of the day, the CSWS is therefore:

$$(107 - 3.2)\text{ mm} = 104\text{ mm.}$$

May 3rd The ET_o rate was 1 mm, and there was 10 mm of effective precipitation (EP). Subtracting 0.75 mm of ET_c ($ET_c = ET_o \times K_c = 1\text{ mm} \times 0.75$), and adding 10 mm of EP gives a balance of:

$$(104 + 10 - 0.75)\text{ mm} = 113\text{ mm.}$$

However, since the maximum soil water storage (SWS) capacity is 110 mm which the balance cannot exceed, the CSWS is equal to 110 mm. The rest of the water is therefore assumed to be lost due to deep percolation and/or runoff. Repeat the same procedures to continue the balance calculation.

Example 2 – Water Budget Method over a Time Period

(See spreadsheet on next page)

The soil water holding capacity and maximum allowable deficit (MAD) are the same as the previous example.

The irrigation system takes 10 days to cover the field (irrigation interval = 10 days). After 10 days, the water budget should be calculated.

For the month of June, the crop irrigated had a crop coefficient (K_c) of 0.80.

June 2nd The soil water storage was full at 110 mm.

June 12th Since June 2nd, there was 10 mm of total effective precipitation (EP) and the total ET_o was 60 mm. Multiplying this ET_o by the K_c value of 0.80 gives an ET_c value of 48 mm. The CSWS is therefore:

$$(110 + 10 - 48)\text{ mm} = 72\text{ mm}$$

There is still 17 mm (72 mm – 55 mm) of soil moisture remaining until the next irrigation needs to begin. Estimate ET_o over the next few days to determine when the 17 mm is likely to be used up. ET_o forecast is available at www.farmwest.com.

June 16th The total ET_o over the past four days was 15 mm. Multiplying this ET_o by the K_c value of 0.80 gives an ET_c value of 12 mm. The CSWS is therefore:

$$(72 - 12)\text{ mm} = 60\text{ mm.}$$

The average ET_c value over the past four days was 3 mm per day. Since there is 5 mm left in the soil, irrigation should begin in the next day or two.

SPRINKLER IRRIGATION SCHEDULING WATER BUDGET EXAMPLE WORKSHEET

Soil Water Storage (SWS) Capacity: 110 **mm**

Maximum Allowable Deficit (MAD): 55 **mm** (once the current water storage reaches this level, irrigation should begin)

Date	Previous Soil Water Storage	+	Effective Precipitation	+	Net Irrigation	–	Reference ET	x	Crop Coefficient	=	Crop Water Use	=	Current Soil Water Storage
	PSWS		EP		IRR		ET_o		K_c		ET_c		CSWS

Example 1: Daily Water Budget Method

Start after irrigation when the soil moisture profile is full, monitor daily until the maximum allowable deficit (MAD) is reached.

May 1	110	+	0	+	0	–	4	x	0.75	=	3	=	107
May 2	107	+	0	+	0	–	4.2	x	0.75	=	3.2	=	104
May 3	104	+	10	+	0	–	1	x	0.75	=	0.75	=	110
		+		+									
		+		+									
		+		+									
		+		+									

Even though the total water storage would be (104 + 10 – 0.75) mm = 113 mm, the maximum soil water storage can only be 110 mm. The rest of the water is therefore assumed to be lost due to deep percolation and/or runoff.

Example 2: Water Budget Method over a Time Period – Irrigation Interval of 10 Days

Start after irrigation when the soil moisture profile is full. After 10 days, when the next irrigation would normally begin, check the soil moisture budget.

June 2													110
June 12	110	+	10	+	0	–	60	x	0.80	=	48	=	72

There is still 17 mm of moisture in the soil before the maximum allowable deficit is reached. Check the forecast and monitor the amount of ET_o and EP. If the forecast is for hot weather, check in the next 3 to 4 days. If the forecast is for cool weather, check in the next 5 to 7 days.

June 16	72	+	0	+	0	–	15	x	0.80	=	12	=	60

There is less than 5 mm of moisture remaining in the soil before the maximum allowable deficit (MAD) of 55 mm is reached. The average ET_c has been about 3 mm per day. The next irrigation should begin in the next day or two.

SPRINKLER IRRIGATION SCHEDULING WATER BUDGET BLANK WORKSHEET

Soil Water Storage (SWS) Capacity: _______ mm
Maximum Allowable Deficit (MAD): ________ mm (once the current water storage reaches this level, irrigation should begin)

Date	Previous Soil Water Storage	+	Effective Precipitation	+	Net Irrigation	−	Reference ET	x	Crop Coefficient	=	Crop Water Use	=	Current Soil Water Storage
	PSWS		EP		IRR		ET_o		K_c		ET_c		CSWS
		+		+		−		x		=		=	
		+		+		−		x		=		=	
		+		+		−		x		=		=	
		+		+		−		x		=		=	
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		+		+		−		x		=		=	

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