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# Engineering Logbook

Senior Capstone - Portland State University

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Beginning 4 January 2016



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# Monday, 4 January 2016

## 1 Irrigation Policy - Research Summary

Water balancing method of irrigation scheduling appears suitable for computational methods and requires no field work.<sup>1</sup>

Water balancing accounting is performed by calculating how much water leaves the soil and how much water is absorbed by the soil. Moisture can leave the soil through the following mechanisms:

- Evapotranspiration ( $E_{tc}$ ):
  1. Moisture leaves the soil to the surrounding air.
  2. Water is absorbed by the plants.
- Surface Runoff (SRO): Runoff occurs when irrigation or rainwater is applied at a rate faster than the soil can absorb.
- Deep Percolation (DP): Drainage of water away from the root zone

Water enters the soil through the precipitation, irrigation, or upwelling. (P, Irr, U)  
If these terms can be estimated, a water deficit can be calculated by:

$$D = E_{tc} - P - Irr - U + SRO + DP \quad ^2$$

The goal of our device will be to restore water lost from the soil by irrigating the correct amount so as to correct the water deficit. We can simplify the equation above by assuming the SRO and DP terms to be negligible. This requires the delivery of water via irrigation to not exceed the rate of uptake by the soil. The application rate will be determined outside of this system. U will be assumed to be negligible as well. Irrigation will be set equal to the deficit, leaving the resulting equation:

$$Irr = D = E_{tc} - P$$

This approach will require a method to estimate  $E_{tc}$  and precipitation. Can we skip a day if precipitation is detected? Can we detect precipitation using sensors for determining evapotranspiration? Humidity perhaps?

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<sup>1</sup>CSUE Fact Sheet No. 4708

<sup>2</sup>CSUE Fact Sheet No. 4707

# Wednesday, 6 January 2016

## 1 $E_{tc}$ Estimations

$$E_{tc} = E_{to} \cdot K_c \cdot K_s \quad ^1$$

Where  $E_{to}$  is a reference evapotranspiration rate,  $K_c$  is the crop specific coefficient, and  $K_s$  is the crop stress coefficient. This equation will be simplified by setting both coefficients equal to 1, resulting:

$$E_{tc} = E_{to}$$

$E_{to}$  is usually determined by following the Penman-Montieth method.<sup>2</sup> Since this method requires many environmental variables, it is not suitable for our application. Instead, a reduced set method such as Hardgreaves(HARG)<sup>3</sup> will be used. HARG:

$$E_{to_H} = HC \cdot R_a \cdot (T_{max} - T_{min})^{HE} \cdot \left( \frac{T_{max} + T_{min}}{2} + HT \right)$$

HC, HE, and HT are all constants that can be calibrated. The Hardgreaves method requires only ambient air temperature and calendar day since  $R_a$  can be supplied from meteorological data given date and latitude. At this point we can determine Irrigation (Irr) needed with the following:

- Calendar Day (Requires Table of  $R_a$  stored in memory)
- Maximum/Minimum Ambient Temperature (Daily?)
- Precipitation (Sensing Pad?, Humidity?)

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<sup>1</sup>CSUE Fact Sheet No. 4707

<sup>2</sup>FAO Irrigation and Drainage Paper 56

<sup>3</sup>Hardgreaves and Other Reduced-Set Methods for Calculating Evapotranspiration

# Saturday, 9 January 2016

## 1 $R_a$ Estimations

The Hardgreaves method requires the extraterrestrial radiation( $R_a$ ) in mm/day. In order to calculate this term we can use methods outlined in Chapter 3 of FAO-56 (Allen, 1998). Using latitude in radians and calendar day  $R_a$  can be calculated by:

$$R_a = \frac{24(60)}{\pi} \cdot 0.082 \cdot 0.408 \cdot d_r [\omega_s \sin(j) \sin(d) + \cos(j) \cos(d) \sin(\omega_s)]$$

Where

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365} \cdot D_y\right)$$

and

$$d = 0.409 \sin\left(\frac{2\pi}{365} \cdot D_y - 1.39\right)$$

and

$$\omega_s = \arccos(-\tan(j) \tan(d))$$

Where  $D_y$  = day of the year (1-365) and  $j$  = latitude in radians.

With this calculation, the table of radiation values mentioned previously will not be needed.

## 2 Comparison of Historical Evapotranspiration Data and Hardgreaves Approximation

Now an algorithm can be clearly stated that will determine the water lost from soil in mm/day. Given day of the year( $D_y$ ), latitude in radians( $j$ ), maximum daily temperature( $T_{max}$ ), and minimum daily temperature( $T_{min}$ ):

1. Calculate  $d_r$
2. Calculate  $d$
3. Calculate  $\omega_s$
4. Calculate  $R_a$
5. Calculate  $E_{to}$

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In order to see if this algorithm shows any promise I wanted to compare the output with historical data from the Portland area. The only data I found was for Aurora, Oregon. I used historical records of average monthly high and low temperatures for Portland, OR, and used a latitude of 45.5 degrees.

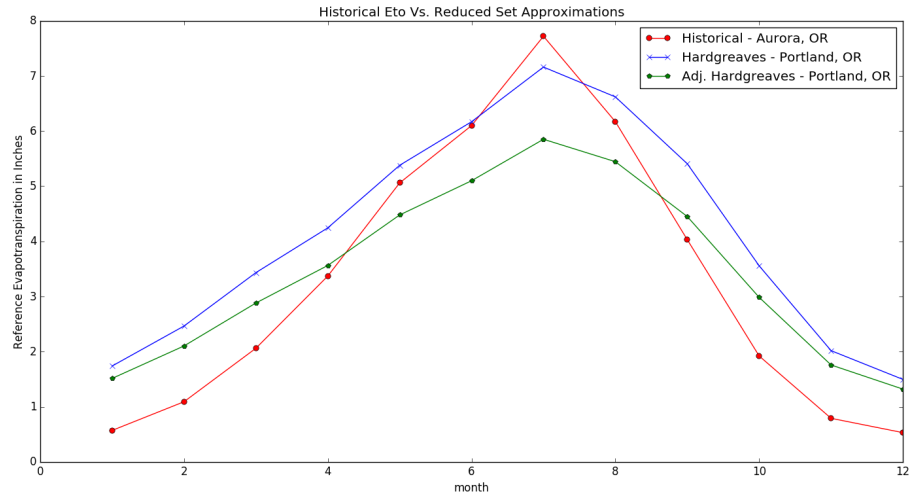


Figure 2 Historical Evapotranspiration Comparison with Hardgreaves Method The Hardgreaves approximation tracks well with the historical data, especially considering the differences in location and temperature data. I believe this figure shows that this algorithm is suitable for future consideration.



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## Sources

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