Evapotranspiration

ASM/ SWES 404/504
Crop Water Requirements

- Rate of water use depends on kind of crop, maturity, and atmospheric conditions.
- Seasonal water requirement is needed to:
  - match crops with available water supply
  - variation within season needed for irrigation scheduling
- What determines whether irrigation is economically feasible in humid and some subhumid regions?
Evapotranspiration

- **Definition**
  - also known as consumptive water use
  - expressed as inches/day, inches/month, inches/season

- **Factors affecting evaporation**

- **Factors affecting transpiration**
Evapotranspiration

Methods for determining ET

- tank and lysimeter experiments
- experimental field plots
- soil-water studies
- analysis of climatological data
- integration methods
- inflow-outflow method
Evapotranspiration

Methods for predicting ET
- Mass transfer
- Energy balance
  - Penman
  - Jensen-Haise
- Empirical
  - Blaney-Criddle

ETc = (Kc)(ETo)
Blaney-Criddle Method

- One the oldest methods of estimating ET
  - a bit simplistic
    - mean monthly temperature
    - monthly percent of annual daylight hours
    - crop coefficient
Blaney-Criddle Method

Equations

- monthly: \( u = \frac{ktp}{100} = kf \)

where:

- \( u \) = monthly ET, inches
- \( k \) = monthly ET coefficient
- \( t \) = mean monthly temp, °F
- \( p \) = monthly % annual daytime hours
- \( f = \frac{(tp)}{100} = \text{monthly ET factor} \)
Blaney-Criddle Example

Compute the evapotranspiration for corn at Yuma (valley) for the month of May using the Blaney-Criddle method. Assume a $k$ of 0.7.
Blaney-Criddle Method

Equations

seasonal: \[ U = KF = K \sum f = \sum kf \]

where

\( U \) = seasonal water use, inches

\( K \) = seasonal ET coefficient

\( F \) = sum of monthly ET factors \( f \) for the period

\( f = (tp)/100 \) = monthly ET factor

\( t \) = mean monthly temperature, °F

\( p \) = monthly % of annual daytime hours
Blaney-Criddle Example

Compute the evapotranspiration for corn at Yuma (valley) for the growing season using the Blaney-Criddle method.
Blaney-Criddle Method

- Advantages and disadvantages?
  - advantages
  - disadvantages
Penman Method

- Energy Balance and Mass Transfer Approach

\[ R_n = E + A + S + C \]

- Estimates ET for well-watered short grass, i.e., estimates ET₀
Penman Method

- Equations
  - $\lambda ET_o$
  - $ET_o$
  - $ET_c$
- Actual ET for crop:

$$ET_c = (K_c)ET_o$$
Penman Method

Advantages and Disadvantages?

- Advantages

- Disadvantages
Jensen-Haise Method

- Energy Balance (solar radiation) Approach
- Simpler than Penman
- Based on extensive field data
- Estimates $\lambda ET_r$

$$\lambda ET_r = C_t (T - T_x) R_s$$

$\lambda ET_r$ = alfalfa-based reference ET
$R_s$ = solar radiation = $(0.35 + 0.61 \frac{n}{N}) R_{so}$
$T$ = mean air temperature for calculation period
$C_t$ = calc. value based on elevation and vapor pressures
Jensen-Haise Method

- Crop ET estimated from $K_c$ for alfalfa-based reference ET
  - $ET_c = (K_c)ET_o$
  - grass-based $K_c \neq$ alfalfa-based $K_c$

- Advantages and disadvantages
  - advantages
  - disadvantages
Pan Evaporation Method

\[ \text{ET}_o = (K_p)(E_{\text{pan}}) \]

- Pan coefficient, \( K_p \)
  - determined by avg daily wind speed and mean relative humidity

Advantages and disadvantages

- advantages: real-time evaporation rates, on-site data, relatively easy
- disadvantages: data influenced by pan placement and type, climate; water in pan stores and releases water differently than crop
### Table: Case A and Case B

<table>
<thead>
<tr>
<th>Class A Pan</th>
<th>Case A</th>
<th>Case B</th>
<th>Case B U</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- pan surrounded by short green crop -</td>
<td>- pan surrounded by dry-fallow land -</td>
<td></td>
</tr>
<tr>
<td>Mean relative humidity (%)</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>&lt;40</td>
<td>40-70</td>
<td>&gt;70</td>
<td>&lt;40</td>
</tr>
<tr>
<td>Average daily wind run (mi/d)</td>
<td>Upwind distance of green crop (ft)</td>
<td>Upwind distance of dry fallow (ft)</td>
<td></td>
</tr>
<tr>
<td>Light 120</td>
<td>0</td>
<td>0.55</td>
<td>0.65</td>
</tr>
<tr>
<td>120</td>
<td>30</td>
<td>0.65</td>
<td>0.75</td>
</tr>
<tr>
<td>300</td>
<td>0.7</td>
<td>0.8</td>
<td>0.85</td>
</tr>
<tr>
<td>3,000</td>
<td>0.75</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>Moderate 120-240</td>
<td>0</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>120-240</td>
<td>30</td>
<td>0.6</td>
<td>0.7</td>
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Reference evapotranspiration and crop coefficient

- Reference evapotranspiration, ETo
  - obtained directly
  - computed through empirical methods
  - Internet (http://Ag.Arizona.Edu/azmet/etrain.htm)

- Reference ET is converted to crop ET with a seasonal crop coefficient.
  - crop coefficient dependent on stage of growth and location

- Reliability
How is ET data used?

- Reference ET converted to crop ET to estimate how much water is needed for the crop during a time period.
- Knowing the irrigation efficiency, determine the inches of water to apply.

Irrigation Water Requirement, inches = \( \frac{ET_c}{\text{Irrigation Efficiency}} \)