# Chapter 19: Evapotranspiration

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### Introduction

Evapotranspiration (ET) is a vital component of the hydrologic cycle that combines two simultaneous processes: **evaporation** from soil and water surfaces, and **transpiration** from vegetation. It represents the loss of water to the atmosphere and plays a significant role in agricultural water demand, hydrological modeling, irrigation scheduling, and water resource planning. A precise understanding and estimation of evapotranspiration are essential for effective management of water resources, especially in arid and semi-arid regions.

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### 19.1 Evapotranspiration – Definition and Concept

Evapotranspiration is defined as the total water loss from a vegetated surface due to the combined processes of:

- **Evaporation**: Physical loss of water as vapor from soil, plant surfaces, and water bodies.
- **Transpiration**: Biological process through which plants absorb water via roots and release it as vapor through stomata.

ET depends on various climatic, soil, and vegetative factors and is measured over a reference crop or actual crop conditions.

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### 19.2 Components of Evapotranspiration

1. **Evaporation (E)**
    - Occurs from bare soil, wet vegetation, and water bodies.
    - Controlled by temperature, solar radiation, wind speed, and humidity.
2. **Transpiration (T)**
    - Water movement from roots to leaves and subsequent release into the atmosphere.
    - Regulated by plant type, leaf area index, stomatal conductance, and soil moisture.

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### 19.3 Factors Affecting Evapotranspiration

Evapotranspiration is influenced by:

- **Climatic Factors**

- Solar radiation
- Temperature
- Wind speed
- Humidity
- Precipitation

- **Crop Factors**
  - Type of crop
  - Growth stage
  - Leaf area index (LAI)
  - Canopy structure

- **Soil Factors**
  - Texture
  - Moisture availability
  - Albedo and reflectance

- **Management Practices**
  - Irrigation techniques
  - Mulching
  - Tillage practices

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### 19.4 Potential and Actual Evapotranspiration

- **Potential Evapotranspiration (PET):** Maximum possible ET from a large expanse of vegetation under optimal soil moisture conditions.
- **Actual Evapotranspiration (AET):** Actual ET under prevailing moisture conditions, often lower than PET due to limited water availability.

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### 19.5 Methods of Estimating Evapotranspiration

Various methods are used depending on data availability, accuracy required, and scale. They are broadly categorized as:

#### (a) Empirical Methods

- Based on observed climatological data and regression equations.

1. **Blaney-Criddle Method**
   - Uses mean daily temperature and daylight hours.
   - Suitable for monthly PET estimates.

$$ET = p(0.46T + 8)$$

- where $p$ = monthly % of annual daylight hours, $T$ = mean monthly temperature (°C)

2. **Hargreaves Method**
   - Simple temperature-based method.

$$ET = 0.0023(T_{mean} + 17.8)(T_{max} - T_{min})^{0.5} Ra$$

- where $Ra$ is extraterrestrial radiation.

3. **Pan Evaporation Method**
   - Based on evaporation from a Class A evaporation pan.

$$ET = K_p \cdot E_p$$

- where $K_p$ = pan coefficient, $E_p$ = pan evaporation.

### (b) Energy Balance Methods

- Based on the conservation of energy at the land surface.

1. **Energy Budget Equation:**

$$R_n - G - H = \lambda E$$

- where $R_n$ = net radiation, $G$ = soil heat flux, $H$ = sensible heat flux, $\lambda E$ = latent heat of vaporization × ET.

### (c) Combination Methods

1. **Penman Method**
   - Combines energy balance and aerodynamic approach.

$$ET = \frac{\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

- where $\Delta$ = slope of vapor pressure curve, $\gamma$ = psychrometric constant, $u_2$ = wind speed at 2m, $e_s - e_a$ = vapor pressure deficit.

2. **FAO Penman-Monteith Method**
   - Recommended standard method by FAO for reference ET estimation:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

- Uses standard grass reference crop.
- Accurate and widely applicable globally.

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### 19.6 Measurement Techniques for ET

1. **Lysimeter**
   - Direct and accurate device to measure ET by observing mass change in soil-plant column.
2. **Atmometer (Evaporimeter)**
   - Measures evaporation rate as a proxy for ET.
3. **Eddy Covariance System**
   - Advanced micrometeorological method using high-frequency wind and humidity measurements.
4. **Bowen Ratio Energy Balance Method**
   - Involves measuring temperature and humidity gradients.
5. **Remote Sensing Techniques**
   - Use satellite data to estimate ET over large areas using vegetation indices (e.g., NDVI).

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### 19.7 Crop Coefficient (Kc) Concept

- ET of different crops is calculated as:

$$ET_c = K_c \cdot ET_o$$

- where $K_c$ = crop coefficient (depends on crop type and growth stage), $ET_o$ = reference evapotranspiration.
- **Typical Kc Values:**
  - Initial Stage: 0.3 – 0.5
  - Mid-Season: 1.0 – 1.2
  - Late Season: 0.6 – 0.8
- Helps in irrigation scheduling and water budgeting.

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### 19.8 Applications of Evapotranspiration Data

- **Irrigation Water Requirement Estimation**
- **Crop Water Balance Studies**
- **Hydrologic and Climate Modeling**
- **Drought Monitoring**

- **Water Resource Allocation**
- **Environmental Impact Assessments**

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### 19.9 Evapotranspiration under Changing Climate

- Climate change affects ET through altered temperature, precipitation, and wind patterns.
- Expected increase in PET in warmer regions.
- Necessitates real-time and predictive models incorporating climate variables.

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