Proposed Irrigation-Need Function

$$\text{Irrigation-Need} = ET_c - (P + SM_{avail})$$

Where:

- **ET_c**: Crop evapotranspiration demand, influenced by temperature, humidity, and solar radiation.
- **P**: Effective precipitation.
- **SM_avail**: Available soil moisture in the root zone.

This calculates net irrigation need by subtracting precipitation and existing soil moisture from total water demand.

From Theory to Application: Deriving the Irrigation Need Formula

Directly computing ETc typically requires complex parameters like solar radiation, wind speed, and crop-specific coefficients — data that is often unavailable or inconsistent in field conditions.
To make this formula more practical and data-driven, we restructured it into a normalized model using readily available environmental variables as proxies. The resulting formula is:

$$\max(0, (1 - \text{Soil\_Moisture\_\%} / 40) \times (\text{Temp\_C} / 30) \times (1 - \text{Humidity\_\%} / 100) \times (1 - \text{Rain\_mm} / 50))$$

This adjusted formula captures the same core logic:

- Higher **temperature** increases water demand (acting as a proxy for ETc),
- Higher **rainfall** and **soil moisture** reduce irrigation need (representing P + SM_avail),
- **Humidity** reduces evapotranspiration, acting as a dampening factor.

This simplification enables easier integration into machine learning workflows and automated irrigation systems while still aligning with fundamental agronomic principles.

Justification and Supporting References

1. **Evapotranspiration (ET) as a Core Metric**
   - Evapotranspiration is the sum of water loss via evaporation + transpiration. Core to irrigation estimation.
   - Colorado State University notes that irrigation is essential when ET exceeds rainfall and stored moisture.
     https://extension.colostate.edu/topic-areas/agriculture/effects-of-weather-on-irrigation-requirements-4-721/

2. **Importance of Soil Moisture Monitoring**
   - Soil sensors enable precise water scheduling based on real-time soil data.
   - University of Minnesota Extension highlights sensors as highly effective tools for irrigation management.
     https://extension.umn.edu/irrigation/soil-moisture-sensors-irrigation-scheduling

3. **Integration of Weather Data**
   - Using weather forecasts (temp, humidity, rainfall) refines irrigation timing and quantity.

- SAI Platform discusses tools that use local weather data to optimize irrigation practices. https://www.saiplatform.org/uploads/Library/Technical%20Brief%206.%20Irrigation%20Scheduling.pdf

4. **Data-Driven Approaches in Irrigation Management**
    - Advanced models leverage sensor data to forecast soil moisture and optimize irrigation.
    - A study on ScienceDirect details predictive modeling of soil moisture using real-time data. https://www.sciencedirect.com/science/article/pii/S2772375524002971