RainTank Water Demand Model

Technical Reference

Purpose. RainTank produces a 365-day daily water-demand profile for a rainwater harvesting system. The profile combines two independent estimates: household demand and garden irrigation demand. A climate-classification step supplies parameters for the household estimate.

Scope and approximation. This is a transparent planning model, not a measurement of a household's actual water use. Baseline household rates, crop coefficients, equivalent plant areas, and irrigation efficiency are fixed modelling assumptions. They provide a useful starting point that users may review and override in the app. The model is intended to make assumptions visible and to test a proposed system against seasonal conditions, rather than to claim a precise prediction of demand.

1 Input data and local calculation

The model uses recent daily temperature and precipitation records, together with latitude and elevation. Historical records are obtained before the calculation; once they are present, the demand calculation runs on the device. A minimum of three years of weather data is required for climate classification; five or more years are recommended.

2 Climate classification

RainTank classifies the location using the Koppen-Geiger framework of Peel, Finlayson and McMahon [4]. From daily records it derives annual and monthly statistics: mean annual temperature, coldest- and warmest-month mean temperatures, annual precipitation, and the seasonal distribution of rainfall.

The broad climate group is determined in this order:

1. Polar (E): warmest-month mean temperature below 10 °C.
2. Arid (B): annual precipitation below the aridity threshold.
3. Tropical (A): coldest-month mean temperature at least 18 °C.
4. Continental (D): coldest-month mean temperature below 0 °C and warmest-month mean temperature at least 10 °C.
5. Temperate (C): all remaining locations.

The aridity threshold is

$$P_{\text{threshold}} = \begin{cases} 20T, & \text{if at most 30\% of annual precipitation falls in the warmer half-year,} \\ 20T + 280, & \text{if at least 70\% falls in the warmer half-year,} \\ 20T + 140, & \text{otherwise,} \end{cases}$$

where T is mean annual temperature in degrees Celsius and the threshold is in millimetres. The warmer half-year is identified from the six months with the highest mean temperatures, rather than assumed from calendar months.

The broad group is further refined using the standard precipitation-pattern and temperature-pattern rules. This can produce a full code such as Cwb or BSh. The calculation reports high, medium, or low confidence according to the number of years available and the completeness of temperature records.

3 Household demand

For demand estimation, the full Koppen-Geiger code is reduced to four broad buckets: arid (BW or BS), tropical (A), cold (D or E), and temperate (all other codes). Each bucket has a fixed per-person baseline, in litres per person per day:

Use category	Arid	Tropical	Temperate	Cold
Drinking and cooking	18.0	20.0	17.0	17.0
Personal hygiene	32.0	50.0	35.0	28.0
Toilet	20.0	21.0	21.0	20.0
Laundry	13.0	14.0	14.0	13.0
Cleaning and miscellaneous	12.0	15.0	13.0	12.0

Only the uses selected by the user are included in the household total. Two adjustments are then applied:

- **Temperature adjustment.** Applied only to personal hygiene, using that month's mean temperature. The multiplier is 0.8 at or below 15 °C, 1.0 from 15 °C to 25 °C, and increases linearly to a maximum of 1.4 above 40 °C.
- **Elevation adjustment.** Applied to every category:

$$f_{\text{elevation}} = 1 + 0.0001z,$$

  where z is elevation in metres.

These values are deliberately simple parameter choices. They should be adjusted when a user has better information about the household's actual use.

4 Garden irrigation demand

Garden demand is independent of the Koppen-Geiger classification. It is driven by reference evapotranspiration, ET_0, calculated from daily temperature and solar geometry with the Hargreaves-Samani equation [3]:

$$ET_0 = 0.0023(T_{\text{mean}} + 17.8)\sqrt{T_{\max} - T_{\min}}R_a.$$

Here R_a is extraterrestrial solar radiation calculated from latitude, day of year, solar declination, and sunset hour angle. The implementation uses the radiation units appropriate to the Hargreaves-Samani

coefficient. The estimate is then adjusted with the same elevation factor used for household demand:

$$ET_{0,\text{adjusted}} = ET_0(1 + 0.0001z).$$

Each garden component is assigned a crop coefficient (K_c):

Component	K_c	Modelled as
Lawn or turf	0.85	Area
Vegetables	0.95	Area
Small plants	0.60	0.20 m^2 per plant
Medium plants	0.75	0.80 m^2 per plant
Large plants	0.85	7.00 m^2 per plant

The daily irrigation volume for each component is

$$V_{\text{garden}} = \frac{ET_{0,\text{adjusted}} K_c A}{0.75}.$$

The fixed efficiency of 0.75 represents typical residential sprinkler losses to evaporation, runoff, wind drift, and deep percolation. It is an assumption, not a statement about every irrigation system. The crop coefficients are based on FAO guidance [1] and ASCE guidance [2].

5 Combining demand

The household and garden sub-models are evaluated for each day of a 365-day year and summed. RainTank therefore supplies a daily demand profile, along with household and garden breakdowns, mean temperature, and ET_0 for transparency.

The two streams respond to climate through different mechanisms. Climate classification affects only household baseline rates. Garden irrigation is calculated directly from temperature and solar geometry; the climate code does not alter garden demand.

References

[1] R. G. Allen, L. S. Pereira, D. Raes, and M. Smith. *Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements*. FAO Irrigation and Drainage Paper 56, Food and Agriculture Organization of the United Nations, 1998.

[2] ASCE-EWRI. *The ASCE Standardized Reference Evapotranspiration Equation*. Environmental and Water Resources Institute, 2005.

[3] G. H. Hargreaves and Z. A. Samani. Reference crop evapotranspiration from temperature. *Applied Engineering in Agriculture*, 1(2):96–99, 1985.

[4] M. C. Peel, B. L. Finlayson, and T. A. McMahon. Updated world map of the Koppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11:1633–1644, 2007.