Global Aridity Index and Potential Evapo-Transpiration (ET_0) Database v3

Robert J. Zomer [1, 2], Antonio Trabucco[3 ,4]

1. *Centre for Mountain Futures, Kunming Institute of Botany, Chinese Academy of Science, Kunming 650201, Yunnan, China*
2. *CIFOR-ICRAF China Program, World Agroforestry (ICRAF), Kunming, China*
3. *Euro-Mediterranean Center on Climate Change, IAFES Division, Sassari, Italy.*
4. *Department of Science for Nature and Environmental Resources (DIPNET), University of Sassari, Via De Nicola 9, 07100 Sassari, Italy*

The **Global Aridity Index (*Global-AI*) and Global Reference Evapo-Transpiration (*Global-ET_0*)** datasets provided in Version 3 of the **Global Aridity Index and Potential Evapo-Transpiration (ET_0) Database (*Global-AI_PET_v3*)** provide high-resolution (30 arc-seconds) global raster data for the 1970-2000 period, related to evapotranspiration processes and rainfall deficit for potential vegetative growth, based upon implementation of the FAO-56 Penman-Monteith Reference Evapotranspiration (ET_0) equation.

These geo-spatial datasets have been produced with the support of the National Key Basic Research Program of China (Grant No. 2014CB954100), and National Science Foundation China (Grant No. 31270524), a Presidential Fellowship from the Chinese Academy of Science at the Center for Mountain Futures, Kunming Institute of Botany, and a mini-grant provided by CGIAR-CSI (funding from IFPRI Project No. 203008.000.002 515-01-01).

These datasets can be downloaded and are available from the CGIAR-CSI GeoPortal (https://cgiarcsi.community). The **Consortium for Spatial Information (CGIAR-CSI)** is an initiative of the Consultative Group for International Agriculture Research (CGIAR), linking the international science, research and development communities, with CGIAR scientists, national and international partners, and others working to apply and advance geospatial science for sustainable development, conservation, and poverty alleviation in developing countries.

The **Global-AI** and **Global-ET_0** datasets are provided for non-commercial use in standard GeoTiff format, at 30 arc seconds or ~ 1km at the equator, to support studies contributing to sustainable development, biodiversity and environmental conservation, poverty alleviation, and adaption to climate change, among other global, regional, national, and local concerns.

Comments, feedback, suggestions or bug reports regarding downloading of the Global-ET0 and Global-Aridity datasets should be sent to: csi@cgiar.org. Technical questions regarding the **Global-AI** and **Global-ET_0** datasets can be directed to Antonio Trabucco: antoniotrabucco@cmcc.it .

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Methodology and Dataset Description

Global Reference Evapo-Transpiration (*Global-ET_0*)

Potential Evapo-Transpiration (*PET*) is a measure of the ability of the atmosphere to remove water through Evapo-Transpiration (*ET)* processes. Among several equations to estimate PET, a FAO application of the Penman-Monteith equation (Allen et al. 1998), here referred as FAO-56, is currently widely considered as a standard method (Walter et al. 2000). The FAO introduced the definition of *PET* as the *ET* of a reference crop (ET0) under optimal conditions, having the characteristics of well-watered grass with an assumed height of 12 centimeters, a fixed surface resistance of 70 seconds per meter and an albedo of 0.23 (Allen et al. 1998). The FAO-56 is a predominately physically based approach, which can be used globally because it does not require estimations of additional site-specific parameters. However, a major drawback of the FAO-PM method is its relatively high need for specific data for a variety of parameters (i.e. windspeed, relative humidity, solar radiation, etc.).

A new version of the Worldclim dataset (Fick and Hijmans, 2017) was released in 2021 (WorldClim 2.1), and used to update this latest current version. In addition to being updated with improved data and analysis, it includes several climate variables, such as temperature (average, minimum and maximum), precipitation, solar radiation, wind speed and water vapor pressure, which are sufficient to effectively parameterize the FAO-PM equation to estimate evapo-transpiration. The WorldClim 2.1 is an updated high-resolution global geo-database (30 arc seconds or ~ 1km at equator) of monthly average data (1970-2000), based on spatial interpolation using thin-plate splines of a high number of climate station observations, with covariates including elevation, distance to the coast and other satellite data.

From the original Penman-Monteith equation, given the specific properties of the reference crop, the FAO-56 Penman-Monteith method (FAO-56) to estimate ET0 can be calculated as:

$$ET_0 = \frac{0.408 * \Delta * (R_n - G) + \gamma \frac{900}{T_{avg} + 273} * u_2 * (e_s - e_a)}{\Delta + \gamma \left(1 + \frac{r_s}{r_a}\right)}$$

Where

ET_0 is the evapotranspiration for reference crop, as mm day^{-1}

R_n is the net radiation at the crop surface, as MJ m^{-2} day^{-1}

G is the soil heat flux density, as MJ m^{-2} day^{-1}

T_{avg} is the mean daily air temperature at 2 m height, as °C

u_2 is the wind speed at 2 m height, as m s^{-1}

e_s is the saturation vapour pressure, as kPa

e_a is the actual vapour pressure, as kPa

e_s - e_a is the saturation vapour pressure deficit, as kPa

Δ is the slope vapour pressure curve, as kPa $°C^{-1}$

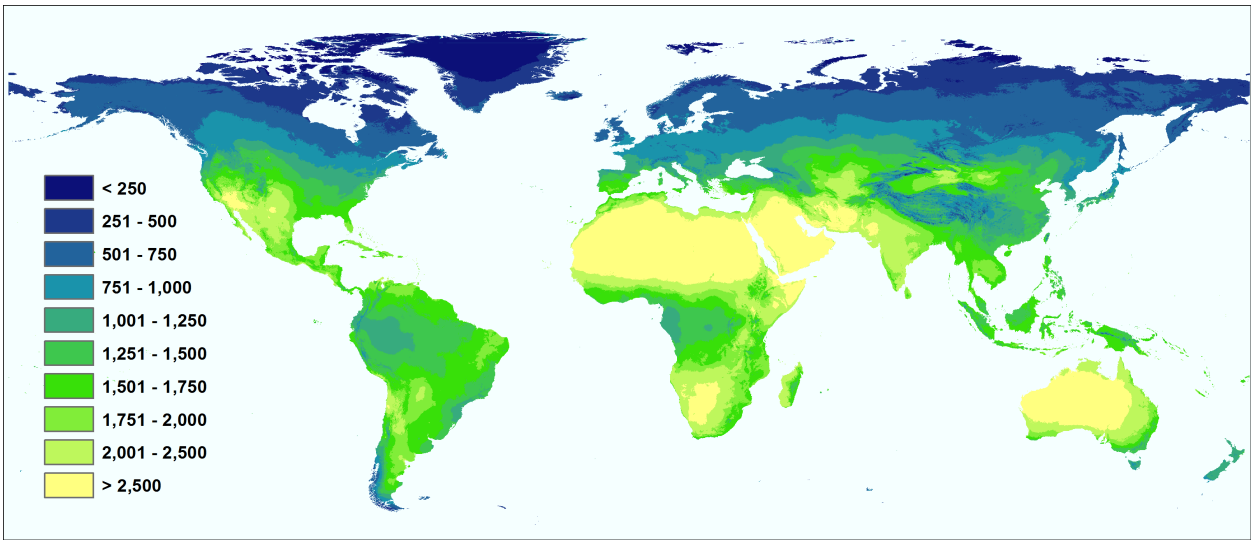
γ is the psychrometric constant, as kPa $°C^{-1}$

rs is the bulk surface resistance, as m s^{-1}

ra is the aerodynamic resistance, as m s^{-1}

The variables available from the Worlclim 2.1 dataset (Minimum, Maximum and Average Temperature; Solar Radiation; Wind Speed, Water Vapor Pressure) allow to calculate any specific parameter needed for the FAO-56 method. See (Article in Press: add link)I for a detailed description of the methods used to derive these parameters using the WorldClim2 variables.

Figure 1. Global reference evapotranspiration (Global-ET_0) calculated for the entire globe (mm).



Global Aridity Index (*Global-AI*)

Aridity is usually expressed as a generalized function of precipitation, temperature and reference evapo-transpiration (*ET0)*. An Aridity Index (UNEP, 1997) can be used to quantify precipitation availability over atmospheric water demand.

Global mapping of mean Aridity-Wetness Index from the 1970-2000 period at 30' spatial resolution is calculated as:

$$\text{Global-Aridity Index } (AI) = MA\text{-}Pr \,/\, MA\text{-}ET_0 \qquad [1]$$

where:

MA-Pr = Mean Annual Precipitation

$MA\text{-}ET_0$ = Mean Annual Reference Evapo-Transpiration

Mean annual precipitation (MA-Pr) values were obtained from the WorldClim2 Global Climate Data version 2.1 (Fick and Hijmans, 2017), for years 1970-2000, while ET0 layers estimated on a monthly average basis by the Global-ET_0 (i.e. modeled using the PM-FAO method, as described above) were aggregated to mean annual values (MA-ET_0).

The ***Global-Aridity*** surface (Figure 2) shows moisture availability for potential growth of reference vegetation excluding the impact of soil mediating water runoff events. UNEP (UNEP 1997) breaks up Aridity Index, in the traditional classification scheme presented in Table 2.

Note: In the ***Global-Aridity*** dataset, which uses this formulation, Aridity Index values increase for more humid conditions, and decrease with more arid conditions.

Figure 2. Global Aridity Index (*Global-AI)* calculated for the entire globe. Note that higher AI (green/blue colors) represents more humid conditions, with low AI (brown/yellow colors) representing higher aridity.

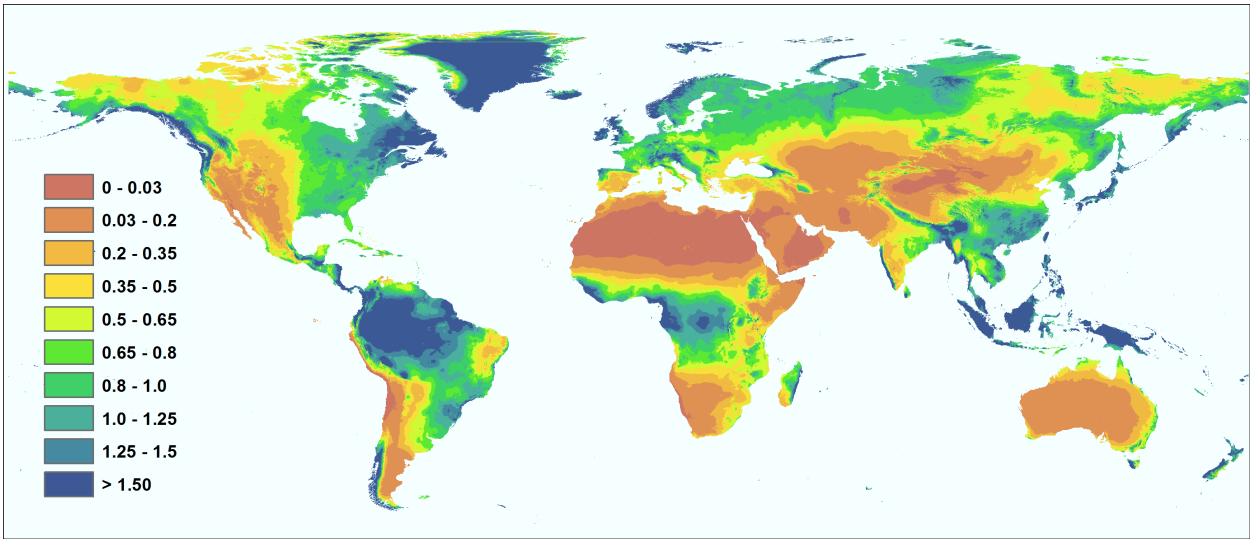


Table 2. Generalized climate classification scheme for Aridity Index values (UNEP 1997).

Aridity Index Value	Climate Class
< 0.03	Hyper Arid
0.03 – 0.2	Arid
0.2 – 0.5	Semi-Arid
0.5 – 0.65	Dry sub-humid
> 0.65	Humid

DATA FORMAT

Global-ET$_0$_v3: Geospatial raster datasets covering the entire world are available as monthly averages (12 data layers, i.e., one dataset for each month) or as an annual average (1 dataset) for the 1970-2000 period, plus the Standard Deviation of the annual average.

Global-AI_v3: geospatial layers are available as monthly averages (12 data layers, i.e. one layer for each month) or as an annual average (1 data layer) for the 1970-2000 period.

Prefix is either:

et0_v3	Global-ET$_0$ layers
ai_v3	Global-AI layers

Suffix is either:

1, 2, ... 12	Month of the year
yr	Annual average
yr_sd	Standard deviation (std)

Examples:

et0_v3_2	is the ET$_0$ average for the month of February
et0_v3_yr	is the ET$_0$ annual average
eto_v3_yr_sd	is the standard deviation of the ET$_0$ annual average
ai_v3_yr	is the AI annual average

The ***Global-ET$_0$*** geodataset values are defined as the total mm of ET$_0$ per month or per year.

The **Aridity Index** values reported within the **Global-AI** geodatasets have been multiplied by a factor of 10,000 to derive and distribute the data as integers (with 4 decimal accuracy). This multiplier has been used to increase the precision of the variable values without using decimals (real or floating values are less efficient in terms of computing time and space compared to integer values).

Global-AI values need to be multiplied by 0.0001 to retrieve the values in the correct units.

The geospatial dataset is in geographic coordinates; datum and spheroid are WGS84; spatial units are decimal degrees. The spatial resolution is 30 arc-seconds or 0.008333 degrees. Arc degrees and seconds are angular distances, and conversion to linear units (like km) varies with latitude, as below:

Latitude	Linear distance equivalent to 30 arc sec
0°	0.9266 km
20°	0.8707 km
40°	0.7098 km
60°	0.4633 km

The ***Global-ET$_0$*** and ***Global-AI*** data layers are processed and finalized as GeoTIFF data format. These rasters have been zipped (.zip) into monthly series or individual annual layers available for online access in 4 zipped directories.

Data Use and Distribution

This data has been generated by not-for-profit institutions with the objective of supplying accessible and useful information to developing country organizations. We actively encourage use of these products for scientific purposes. This is not however the case for commercial purposes. The entire dataset is available for commercial use at a modest cost, but permission must be sought. Commercial sectors interested in using this data can contact Robert Zomer and Antonio Trabucco: r.zomer@mac.com and antoniotrabucco@cmcc.it .

References:

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The **Global-AI_PET_v**3 is archived on Figshare and avallabile online for download at:

https://cgiarcsi.community/2019/01/24/global-aridity-index-and-potential-evapotranspiration-climate-database-v3/.