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# High-Resolution Global Soil-Water Balance
# Explicit for Climate – Standard Vegetation and Soil Conditions

A global spatially distributed soil-water balance was implemented on the high-resolution WorldClim and CGIAR-CSI PET climate dataset using ArcAML (ESRI) as modeling tool. The cell size and coordinate system for analyses are the same used for WorldClim: 30 arc-seconds (920 meters at equator) and geographic coordinate system. All the layers are available as ESRI grids, zipped into rar files.

## *1.1. Soil-Water Balance*

This model uses spatially distributed values (average over 1950-2000 period) of monthly precipitation (Prec) and monthly Potential EvapoTranspiration (*PET*) and returns monthly spatially-distributed values defining Actual EvapoTranspiration (*AET*), Runoff (*R*) and Soil Water Content (*SWC*). The modelling is spatially explicit to represent varying climate conditions, while vegetation and soil properties are assumed as uniformly standard (characterized by crop coefficient equal to 1, rain interception coefficient equal to 0.15 and maximum SWC in the rooting zone equal to 350 mm). The results highlight specifically the climatic influence on hydrological dimensions regulating vegetation suitability.

A soil water balance budget is computed as height of water in mm for each month (*m*), as:

$$\Delta SWC_m = E\,\mathrm{Pr}\,ec_m - AET_m - R_m \qquad \text{mm/month}$$

where: $\Delta SWC_m$ is the change in soil water content, $E\,\mathrm{Pr}\,ec_m$ is the effective precipitation, $AET_m$ is the actual evapotranspiration, and $R_m$ is the runoff component, which includes both surface runoff and subsurface drainage. *SWC* can never exceed a maximum value, $SWC_{\max}$, which is the total maximum *SWC* available in the soil for evapotranspiration. All the monthly water input exceeding $SWC_{\max}$ is accounted as runoff ( $R_m$ ). The simulation has been repeated throughout several years, to achieve more realistic conditions of initial SWC.

### *1.2. Effective Precipitation*

Rain interception is the process by which precipitation is intercepted by the vegetation canopy and litter, where it is subject to evaporation. Interception has an important role in the water budget, as it reduces the amount of precipitation available for *SWC*. Vegetation interception is a mechanical function of the storage space of vegetation structure. Effective precipitation (*EPrec*) is calculated as the gross precipitation (*GPrec*) minus the precipitation intercepted by canopy cover and litter. The quantity of rain intercepted is proportional to the interception coefficient $K_{int}$, calculated as a fraction of *GPrec*.

For each month $E\Pr ec_m$ is calculated as:

$$E\Pr ec_m = G\Pr ec - (G\Pr ec * K_{int}) = G\Pr ec * (1 - K_{int}) \qquad \text{mm/month}$$

### *1.3. Actual EvapoTranspiration*

*AET* is the effective quantity of water that is removed from the soil due to evaporation and transpiration processes. *AET* is dependent on the available atmospheric energy ( $PET_m$ ), vegetation characteristics, quantity of water available in the soil and soil hydrological properties:

$$AET_m = PET_m * K_{veg} * K_{soil} \qquad \text{mm/month}$$

$K_{veg}$ = vegetation coefficient dependent on vegetation characteristics (set to 1 as standard x this simulation)

$K_{soil}$ = reduction factor dependent on volumetric soil moisture content (0-1)

We used CGIAR-CSI PET to determine monthly *PET* globally (Hargreaves method). This method performs almost as well as the FAO Penman-Monteith method, but requires less parameterization and allows applications at finer spatial resolution. Hargreaves uses mean monthly temperature ($Tmean_m$), number of days in the month ($N_m$), mean monthly temperature range ($TD_m$) and extraterrestrial radiation ($RA_m$, radiation on top of atmosphere) to calculate monthly $PET_m$:

$$PET_m = 0.0023 * RA_m * (Tmean_m + 17.8) * TD_m^{0.5} * N_m \qquad \text{mm/month}$$

The vegetation coefficient ($K_{veg}$) used in this model is spatially standardized, assumed as reference crop (Kveg = 1, typical of agronomic crops at maturity and tree), in order to define results explicit just to climate conditions.

The soil stress coefficient ($K_{soil}$) represents an adimensional reduction factor resulting from the limit imposed by the monthly soil water content ($SWC_m$). The model uses a linear soil moisture stress function that is considered appropriate for monthly computation:

$$K_{soil_m} = SWC_m / SWC_{\max}$$

The maximum amount of soil water available for *ET* processes within the plant rooting depth zone ($SWC_{max}$ = 350 mm) is equal to the *SWC* at field capacity ($SWC_{fc}$) minus the *SWC* at wilting point ($SWC_{wp}$) times the rooting depth (RD).

$$SWC_{max} = RD * (SWC_{fc} - SWC_{wp}) \quad \text{mm}$$

The Maximum Soil Water Content for evapotranspiration processes is assumed at a fixed spatial value of 350 mm, which corresponds to average soil texture for a plant rooting depth of 2 meters.

### *1.4. Soil-Water Balance results*

Global AET layers define the average (1950-2000 period) evapotranspiration (mm) of reference vegetation on monthly and annual bases. These individual layers follow a naming convention where the AET prefix is followed by a suffix defining either months (i.e. 1 to 12, as January to December) or yearly average (i.e. YR as suffix).

The SWC_fr defines the monthly fraction of Soil Water Content available for evapotranspiration processes (as percentage of Maximum Soil Water Content). It is therefore a measure of soil stress, and equals to the soil water stress coefficient (Ksoil) as percentage (i.e. 0 - 100). These layers, as for AET factors, are defined by SWC_FR prefix followed by a monthly (1-12) or yearly ("YR") suffix.

Priestley-Taylor alpha coefficient is generalized as the ratio (dimensionless) of annual AET over annual PET. As alpha coefficient approaches 1, vegetation is uninfluenced by water stress. This variable may be effectively considered to describe overall aridity stress on vegetation, as it integrates monthly soil water availability for vegetation requirements through a generalized soil-water balance. The alpha coefficient layer is defined by ALPHA prefix followed by the yearly ("YR") suffix.