Technical Manual
Valiantzas EvapoTranspiration Calculation

Version 1.0
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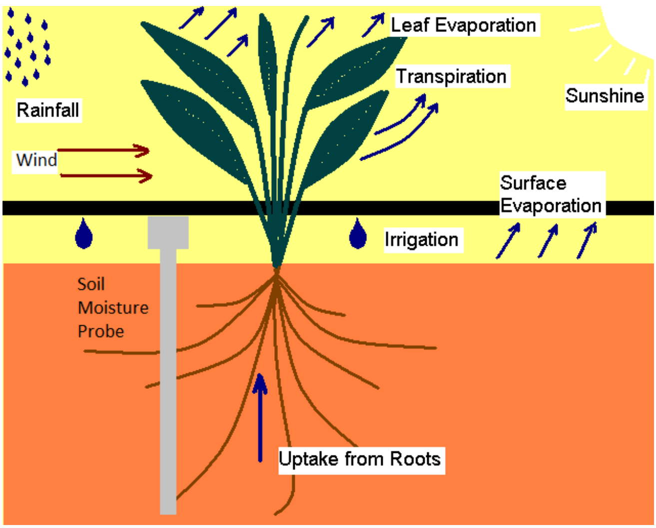
Contents

1 Introduction

This manual has been written to provide background to use and understanding of the Valiantzas Evapo-transpiration model.

The model primarily used for Evapotranspiration modelling in agriculture is the FAO56 Modified Penman Monteith model (often referred to as FAO56). The model replicates the physiological processes which determine water use by a plant.



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

The full Penman Monteith model incorporates crop specific information such as the albedo (reflectance) and crop height. The FAO56 variant is based on water use of a stand of well watered turf, which is then referred to as the Reference Crop Evapotranspiration, ETo. The water use of other crops is then related to this using a crop coefficient (Kc).

ETc = ETo x Kc

The bulk of the FAO56 model's complexity comes from the calculation of net radiation (Rn) - which requires not just the measurement of solar radiation, but a calculation of the expected incoming radiation, which is based on the latitude and time of the year - and the psychrometric constant (ɣ).

The Valiantzas models weres developed as a simplification of the FAO56 Modified Penman Monteith ETo formula. The developer's aim was to reduce the complexity of the calculations involved and to make it easier for vendors to implement. Valiantzas solved a number of complex equations in order to remove the extra complexity required to calculate Rm and ɣ.

There are 3 variants of the Valintzas mode, each with different sensor requirements. Version 1, which uses the full complement of climate sensors: air temperature, relative humidity, solar radiation and wind speed, provides results very close to the full FAO56 model..

Combinatory	Valiantzas [26]	$ET_0 = 0.0393Rs\sqrt{T+9.5} - 0.19Rs^{0.6}\varphi^{0.15} + 0.048(T+20)\left(1-\frac{Hr}{100}\right)u2^{0.7}$	Val 1	(19)
	Valiantzas [26]	$ET_0 = 0.0393Rs\sqrt{T+9.5} - 0.19Rs^{0.6}\varphi^{0.15} + 0.078(T+20)\left(1-\frac{Hr}{100}\right)$	Val 2	(20)
	Valiantzas [26]	$ET_0 = 0.0393Rs\sqrt{T+9.5} - 0.19Rs^{0.6}\varphi^{0.15} + 0,0061(T+20)(1.12T - Tmin - 2)^{0.7}$	Val 3	(21)

Read: ET_0 reference evapotranspiration (mm); u2 represents the wind speed measured at 2 m from the ground (ms^{-1}); (es—ea) saturation deficit (kPa); T is the average temperature (°C); Tmax—maximum temperature (°C); Tmin—minimum temperature (°C); Ra is the extraterrestrial radiation (MJ $m^{-2}d^{-1}$); Δ is the saturating vapor pressure curve (kPa°C^{-1}); γ is the psychrometric constant (kPa°C^{-1}); λ is the latent heat of vaporization (MJ $m^{-2}d^{-1}$); Rs is the short wavelength solar radiation (MJ $m^{-2}d^{-1}$); Rn is the radiation net (MJ $m^{-2}d^{-1}$) and α is a constant value (1.26 for humid areas and 1.74 for semi-arid areas). These coefficients are considered to be constant for a given region [41]. φ represents the latitude of the station in radian degree, and λ is the latent heat of vaporization (MJ.$m^{-2}d^{-1}$).

2 Valiantzas Simplified ETo

The Valiantzas version 1 ETo equation is expressed as:

ETo= $(0.0393*Rs*(Ta+9.5)^{0.5})$ -

$- (0.19*Rs^{0.6}*\Psi^{0.15})$

$+ (0.048*(Ta + 20)*(1-RH/100)*u_2^{0.7})$

Where:

Rs	Average solar radiation in MJ/M^2/day
Ta	Average daily 2m temperature
RH	Average daily RH
u_2	Average daily wind speed at 2m m/sec
Ψ	Latitude (radians) = Pi * (mod(Latitude))/180

All of the required parameters are available through either sensor data or the site location. The model is typically run on a daily basis and daily values for each parameter must be calculated prior to performing the ETo calculation.

The conversion for the more commonly used engineering units (km/h to m/s, W/m^2 to $MJ/m^{2)}$ can be incorporated into the formula:

Rs = SR W/m^2 * 0.0864 (for daily Av from 15 min samples)

u = WS km/h / 3.6

Ψ = Pi * (mod(Latitude))/180) = 0.01746*(mod(Latitude))

(the mod function removes the sign of the latitude)

ETo = $(0.0393*Rs*(Ta+9.5)^{0.5})$ -

$- (0.19*Rs^{0.6}*\Psi^{0.15})$

$+ (0.048*(Ta + 20)*(1-RH/100)*u_2^{0.7})$

$=0.0393*(0.0864*R)*(Ta+9.5)^{0.5}$

$- 0.019*(0.0864*R)^{0.6}*(0.01746*L)^{0.15}$

$+ 0.048*(Ta + 20)*(1-RH/100)*(u/3.6)^{0.7}$

$= (0.003396*R)*(Ta+9.5)^{0.5}$

$- 0.019*(0.0864*R)^{0.6}*(0.01746*L)^{0.15}$

$+ 0.048*(Ta + 20)*(1-RH/100)*(u/3.6)^{0.7}$

To make the calculation simpler, you can calculate the Latitude factor and include it as a constant:

- taking the middle term and removing the sign from the latitude so it is always positive:
  $0.019*(0.0864*R)^{0.6}*(0.01746*L)^{0.15}$

  $= 0.019*(0.01746*L)^{0.15} * (0.0864*R)^{0.6}$

For Latitude = -34 degrees -> 34:

Middle term = $0.019*(0.01746*34)^{0.15} * (0.0864*R)^{0.6}$

$= 0.019*(0.59364)^{\wedge 0.15} * (0.0864*R)^{0.6}$

$= 0.019*0.925* (0.0864*R)^{0.6}$

$= 0.01758* (0.0864*R)^{0.6}$

ETo $= (0.003396*R)*(Ta+9.5)^{0.5}$

$- 0.01758* (0.0864*R)^{0.6}$

$+ 0.048*(Ta + 20)*(1-RH/100)*(u/3.6)^{0.7}$

For Latitude = -37.8 degrees -> 37.8:

Middle term = $0.019*(0.01746*37.8)^{0.15} * (0.0864*R)^{0.6}$

$= 0.019*(0.660)^{\wedge 0.15} * (0.0864*R)^{0.6}$

$= 0.019*0.9396* (0.0864*R)^{0.6}$

$= 0.01785* (0.0864*R)^{0.6}$

ETo $= (0.003396*R)*(Ta+9.5)^{0.5}$

$- 0.01785* (0.0864*R)^{0.6}$

$+ 0.048*(Ta + 20)*(1-RH/100)*(u/3.6)^{0.7}$

=0.003396*w*(x+9.5)^0.5- (0.01786*(0.0864*w)^0.6) + (0.048*(x+20)*(1-y/100)*(z/3.6)^0.7)

3 Creating Valiantzas ETo Calculations

The section below describes how to add the Valiantzas ETo calculation to the addVANTAGE Pro and Sensori servers.

3.1 addVANTAGE Pro

First calculate the radian value of the latitude:

Lrad = Mod(0.01746*Lat)

e.g Latitude = -34 L= 34*0.01746 = 0.59364

Create the following Statistic extensions:

- Daily Median Temperature
  - Input Air temperature 2m
  - Interval Daily
  - Computation (Min + Max) / 2
  - Output Tag Air Temperature (MID)
- Daily Avg RH
  - Input Relative humidity 2m
  - Interval Daily
  - Computation Average
  - Output Tag Relative Humidity (AVG)
- Daily Wind Speed
  - Input Wind Speed Average 2m (km/h)
  - Interval Daily
  - Computation Average
  - Output Tag Wind Speed (AVG)
- Daily Avg Solar Radiation w/m2
  - Input Solar radiation w/m2
  - Interval Daily
  - Computation Average
  - Output tag Average Daily SR
- a Formula extension to calculate the ETo
  - Name Calculate Valiantzas ETo
  - Input x Air Temperature (MID)

    y Relative Humidity (AVG)

z Wind Speed (AVG)

w Daily SR W/m2/day

- Interval Daily
- Formula

(0.030396*w*((x+9.5)^0.5))-(0.01642*(w^0.6)*()+(0.048*(x+20)*(1-y/100)*(z/3.6)^0.7)

$$0.030396 * Rs * (Ta+9.5)^{0.5} - 0.01642 * Rs^{0.6*} (0.01746 * L)^{0.15} + 0.078 * (Ta + 20) * (1 - RH/100) * u_2^{0.7}$$

(0.030396*w*((x+9.5)^0.5))-(0.19*0.9249*(w^0.6))
+(0.048*(x+20)*(1-y/100)*(z/3.6)^0.7)

- Output Tag ETo Valiantzas (mm)

e.g. For -37.8 Latitude

L= 37.8*0.01746 = 0.66

0.003396*w*(x+9.5)^0.5- (0.01786*(0.0864*w)^0.6) +
(0.048*(x+20)*(1-y/100)*(z/3.6)^0.7)

3.2 Sensori

To create the Valiantzas ETo calculation in Sensori, first create Aggregates to calculate the daily values, then incorporate them in to another Aggregate module which runs the formula.

To setup the model, first select the Workspace which contains the Device whose sensors will be used for the model.

Then create 4 Aggregates to create the daily summaries

- Calc Daily Avg Solar Radiation
  - Operation Mean (Avg)
  - Interval Type Time Range, 1 Day
  - Input Solar radiation
  - Operation Mean (Avg)
  - Task Details Run 1 Day

- Task Run Time set to UTC value for midnight (e.g. 14:00)
- Output tag Daily SR W/m2/day

- Calc Daily Avg Temp
  - Operation Mean (Avg)
  - Interval Type Time Range, 1 Day
  - Input Daily Max Temp
  - Task Details Run 1 Day
  - Task Run Time set to UTC value for midnight (e.g. 14:00)
  - Output tag Daily Avg Temp C
- Calc Daily Avg RH
  - Operation Mean (Avg)
  - Interval Type Time Range, 1 Day
  - Input Relative Humidity
  - Operation Mean (Avg)
  - Task Details Run 1 Day
  - Task Run Time set to UTC value for midnight (e.g. 14:00)
  - Output tag Daily RH %
- Calc Daily Avg Wind Speed
  - Operation Mean (Avg)
  - Interval Type Time Range, 1 Day
  - Input Wind Speed
  - Operation Mean (Avg)
  - Task Details Run 1 Day
  - Task Run Time set to UTC value for midnight (e.g. 14:00)
  - Output tag Daily Wind Speed km/h

Create the Aggregate to combine the values in a formula:

- Calc ETo Valiantez
  - Operation Formula
  - Driver Interval
  - Formula Add formula "Calc ETo Valiantzas"
    - Inputs t - Daily Avg Temperature
      h - Daily Avg RH
      w - Daily Avg Wind Speed
      s - Daily Avg Solar Radiation
- Task Details Run 1 Day
- Task Run Time set to UTC value for midnight (e.g. 14:00)
- Output tag ETo mm

The formula needs to be adjusted to suit the latitude of the site, which is expressed in radians:

Latitude Radians = mod(Latitude * Pi/360)

(the mod just indicates to ignore the sign of the latitude)

e.g for -34, Lat(rad) = 34*3.1428 / 180 = 0.5667

(0.0396*s*(t+9.5)^0.5) -(0.19*(s*0.0864)^0.6*0.9249) + (0.048)*(t+20)*(1-h/100)*(w/3.6)^0.7))

$0.030396*Rs*(Ta+9.5)^{0.5} - 0.015188*Rs^{0.6}$

$+ 0.078*(Ta + 20)*(1-RH/100)*u_2^{0.7}$

e.g. For -37.8 Latitude

(0.0396*s*(t+9.5)^0.5) -(0.15435*(s*0.0864)^0.6)+ (0.048*(t+20)*(1-h/100)*(w/3.6)^0.7))

$0.030396*Rs*(Ta+9.5)^{0.5} - 0.015435*Rs^{0.6}$

$+ 0.048*(Ta + 20)*(1-RH/100)*u_2^{0.7}$

= (0.003396*s*(t+9.5)^0.5)- (0.01786*(0.0864*s)^0.6)

+ (0.048*(t+20)*(1-h/100)*(w/3.6)^0.7)

0.003396*w*(x+9.5)^0.5- (0.01786*(0.0864*w)^0.6) + (0.048*(x+20)*(1-y/100)*(z/3.6)^0.7)