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Investigation of 16 calibrated Valiantzas' evapotranspiration equations against standard FAO56-PM model in Indian humid climatic condition

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ABSTRACT

The study was conducted with an objective to evaluate the performance of calibrated versions of different Valiantzas evapotranspiration (ET) equations over their original counterparts for humid climatic conditions prevailing at Dehradun district of Uttarakhand in comparison to standard FAO56-PM model as an index. The calibration coefficients were found to decrease in the range from 3.23% (Val 7) to 40.87% (Val 15). All calibrated Valiantzas equations (except Val 2, Val 7 and Val 13) showed significant increment in agreement index (D) between 0.01% (Val 5) and 34.84% (Val 15). With calibrated versions of Val 2, Val 7 and Val 13 equations, value of D was found to decrease to the tune of less than 1% with increased RMSE values, while calibrated versions of remaining 13 Valiantzas equations showed significant decrement in RMSE values. The calibrated versions of all Valiantzas equations showed reduction in MAXE values in between 14.29% (Val 7) to 84.55% (Val 15). Except Val 7 equation, the values of MBE and PE for calibrated Valiantzas equations decreased in the range from 87.22% (Val 16) to 196.49% (Val 6) and 3.49% (Val 6) and 93.32% (Val 15), respectively while SEE values with calibrated equations decreased in the range from 2.77% (Val 6) to 40.87% (Val 15). Almost all calibrated Valiantzas equations extended best R-values (near to 1.00) and they performed much better in comparison to their original versions.

1. INTRODUCTION

Water is becoming a scarce commodity with growing human population, severe neglect, and over-exploitation. It is estimated that annual national per capita availability of water in country has reduced from 1816 m^3 in 2001 to 1544 m^3 in 2011 (CWC, 2015) which is further expected to drop down to 1140 m^3 in 2050 (Lal and Stewart, 2012). Similarly, exhaustion of groundwater in India has posed serious problems for groundwater managers in the form of drying of aquifers, groundwater pollution, salinity, saltwater intrusion, water table depletion, waterlogging, etc. It is also reported that in many parts of the country, water table is declining annually at the rate of 1-2 m (Singh and Singh, 2002). Due to all these issues of extremely serious nature, it is expected that availability of freshwater for domestic, irrigation, and industrial uses will reduce considerably and the country may face major water crisis in near future. Due to variation in climatic conditions and crop canopy, it is important to apply available irrigation water resources in such a way that it will match crop water requirement substantially at different growth stages (Doorenbos and Pruitt, 1977).

Evapotranspiration (ET) is the sum of amount of water returned to the atmosphere through combined process of evaporation and transpiration (Hansen *et al.*, 1980; Watson and Burnett, 1995). It is one of the basic elements of hydrological cycle and is very essential and important parameter for scientific studies related to crop water requirement, development of best management practices for minimizing degradation of groundwater and surface water, irrigation scheduling, optimal crop production, management of irrigated areas & watershed, water budget etc. (Irmak *et al.*, 2003; Temesgen *et al.*, 2005; Aytek, 2009; Chattopadhyay *et al.*, 2009; Sabziparvar and Tabari, 2010; Sabziparvar *et al.*, 2011).

The calculated values of ET help in determining reference evapotranspiration (ET_0), which can be estimated either with lysimeters or meteorological data (Lopez-Urrea *et al.*, 2006; Xing *et al.*, 2008) as it considers only evaporative power of atmosphere at a specific location and time of year. The ET_0 values can directly be measured by lysimeter if change in soil moisture from known volume of soil is considered with vegetation (Watson and Burnett, 1995), but its use is very expensive, takes more time to install, and requires more maintenance. Therefore, researchers developed several methods to indirectly estimate ET_0 from observed meteorological parameters using large number of empirical or semi-empirical equations creating confusion to select any method as "standard" or "index". Therefore, FAO proposed Penman-Monteith model in its Irrigation and Drainage Paper No. 56 (referred to as FAO56-PM model) as "standard" for determining ET_0 values.

Across the globe, researchers confirmed superior performance of FAO56-PM model in comparison to other ET_0 methods under different climatic conditions (Allen *et al.*, 1998; Walter *et al.*, 2000; Fontenot, 2004; Garcia *et al.*, 2004; Gavin and Agnew, 2004; Donatelli *et al.*, 2006; Popova *et al.*, 2006; Cai *et al.*, 2007; Ali and Shui, 2009; Xu *et al.*, 2013), however, serious limitation of FAO56-PM model is data requirement for a large number of meteorological parameters which are not always available for most locations, especially in developing countries (Wang *et al.*, 2007; Aytek, 2009).

Various scientists and researchers revealed a widely varying performance of available ET_0 equations under diverse climatic conditions and necessitated their local calibration (Allen *et al.*, 1998; Pereira *et al.*, 2006; Wang *et al.*, 2009) as these methods work optimally only for specific climatic conditions. The standard FAO56-PM model can be utilized to calibrate and validate empirical methods for new regions as per the recommendation of "FAO Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements" (Smith *et al.*, 1992) and, therefore, calibration of existing ET_0 equations against a more reliable reference in the form of FAO56-PM model may provide a useful and powerful tool for estimating ET_0 values for agricultural and environmental related studies (Fontenot, 2004). A large number of available ET_0 equations were calibrated by researchers throughout the world for different climatic conditions considering standard FAO56-PM model as an index (Xu and Singh, 2000; Xu and Singh, 2002; Irmak *et al.*, 2003; Berengena and Gavilan, 2005; Trajkovic, 2005; Fooladmand and Haghighat, 2007; Trajkovic, 2007; Ahmadi and Fooladmand, 2008; Landeras *et al.*, 2008; Sepaskhah and Razzaghi, 2009; Zhai *et al.*, 2009; Lee, 2010; Tabari and Talaee, 2011; Ravazzani *et al.*, 2012; Thepadia and Martinez, 2012; Criestia *et al.*, 2013; Lima *et al.*, 2013; Mendicino and Senatore, 2013; Tabari *et al.*, 2013; Xu *et al.*, 2013; Heydari and Heydari, 2014; Heydari *et al.*, 2014; Kra, 2014; Valipour, 2015; Almorox and Grieser, 2016; Cobaner *et al.*, 2016; Ahooghalandari *et al.*, 2017; Cadro *et al.*, 2017; Feng *et al.*, 2017; Issaka *et al.*, 2017; Valipour, 2017).

From above, it is evident that various studies were conducted to calibrate ET_0 equations however, very little information is available for Indian conditions and no such study has been conducted with Valiantzas ET_0 equations for Indian humid locations. Therefore, in the present study, an attempt has been made to calibrate and evaluate the performance of 16 Valiantzas ET_0 equations at humid Dehradun district of Uttarakhand considering standard FAO56-PM model as an index.

2. MATERIALS AND METHODS

Study Area and Meteorological Dataset

The study on evaluation and calibration of different Valiantzas ET_0 equations was carried out for humid Dehradun district (78°04'E longitudes, 32°19'N latitudes and 516.5 m above msl) of Uttarakhand state using 31 years (1989-2019) of daily meteorological dataset consisting of air temperature (maximum and minimum), relative humidity (maximum and minimum), wind speed and actual sunshine hours. Prior to analysis, quality control of meteorological dataset was ensured by removing days with missing data and detecting outliers. For calibration purpose, 65% meteorological dataset (20 years, 1989-2008) was utilized while remaining 35% dataset of 11 years (2009-2019) was considered for validation purpose.

Reference Evapotranspiration (ET_0) Estimation

(a) FAO56-PM model: The recommended form of FAO 56-PM model consisting of aerodynamic and surface resistance terms (Allen *et al.*, 1998) is:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T_{mean} + 273}\right)U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad ...(1)$$

ET_0 is reference evapotranspiration (mm day^{-1}), Δ is slope of saturated vapour pressure curve (kPa °C^{-1}), R_n is net radiation at crop surface (MJ m^{-2} day^{-1}), G is soil heat flux density (MJ m^{-2} day^{-1}), γ is psychrometric constant (kPa °C^{-1}), T_{mean} is mean daily air temperature (°C), U_2 is wind speed at 2 m height (m sec^{-1}), e_s is saturated vapour pressure (kPa), e_a is actual vapour pressure (kPa), and e_s-e_a is vapour pressure deficit (kPa).

The nature of climate system allows soil heat flux (G) on daily timescale to be ignored as on daily basis, its value is nearly zero.

(b) Valiantzas ET_0 equations: The pertinent details of different Valiantzas equations considered in this study are presented in Table 1.

Calibration Coefficient Determination

In order to get calibration coefficient of different Valiantzas ET_0 equations considering standard FAO56-PM

Table: 1
Details of considered Valiantzas ET_0 equations

S.No.	Mathematical form	Symbol	Reference
1.	$ET_0 = 0.051 \times (1-\alpha) R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 + 0.048 \times (T+20) \times (1-0.01RH) \times (0.5 + 0.536U_2) + 0.00012Z$	Val 1	Valiantzas (2013b)
2.	$ET_0 = 0.051 \times (1-\alpha) R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 + 0.052 \times (T+20) \times (1-0.01RH) \times (a_u - 0.38 + 0.54U_2)$	Val 2	Valiantzas (2006)
3.	$ET_0 = 0.051 \times (1-\alpha) R_s \sqrt{T+9.5} - 0.188 \times (T+13) \left(\frac{R_s}{R_a} - 0.194\right) \left(1 - 0.00014 \times (0.70 \times T_{max} + 0.30 \times T_{min} + 46)^2 \times \sqrt{0.01RH}\right) + 0.049 \times (T_{max} + 16.3)(1-0.01RH)(0.50 + 0.536U_2)$	Val 3	Valiantzas (2006)
4.	$ET_0 = 0.051 \times (1-\alpha) R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 + 0.048 \times (T+20) \times (1-0.01RH) \times (0.50 + 0.536U_2)$	Val 4	Valiantzas (2006)
5.	$ET_0 = 0.051 \times (1-\alpha) R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 - 0.024 \times (T+20) \times (1-0.01RH) - 0.0165 \times R_s U_2^{0.7} + 0.0585 \times (T+17) \times U_2^{0.75} \times [(1.03 + 0.00055TR^2) - 0.01RH] + 0.0001Z$	Val 5	Valiantzas (2013b)
6.	$ET_0 = 0.0393 \times R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 - 0.024 \times (T+20) \times (1-0.01RH) + 0.066 \times W_{aero} \times (T+20) \times \left(1 - 0.01\ RH\right) U_2^{0.6}\right)$ $W_{aero} = 0.78$, when RH > 65%; and $W_{aero} = 1.067$, when RH ≤ 65%.	Val 6	Valiantzas (2013c)
7.	$ET_0 = 0.0393 \times R_s \sqrt{T+9.5} - 0.19 \times R_s^{0.6} \varphi^{0.15} + 0.048 \times (T+20) \times (1-0.01RH) U_2^{0.7}$	Val 7	Valiantzas (2013a)
8.	$ET_0 = 0.0393 \times R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 + C_u \times (T+20) \times (1-0.01RH)$ $C_u = 0.054$ when RH > 65%; and $C_u = 0.083$ when RH ≤ 65%	Val 8	Valiantzas (2015)
9.	$ET_0 = 0.0393 \times R_s \sqrt{T+9.5} - 0.19 \times R_s^{0.6} \varphi^{0.15} + 0.078 \times (T+20) \times (1-0.01RH)$	Val 9	Valiantzas (2013a)
10.	$ET_0 = 0.0393 \times R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 - 0.024 \times (T+20) \times (1-0.01RH) + 0.1W_{aero}(T+20) \times (1-0.01RH)$ $W_{aero} = 0.78$, when RH > 65%; and $W_{aero} = 1.067$, when RH ≤ 65%	Val 10	Valiantzas (2013a)
11.	$ET_0 = 0.0393 \times R_s \sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 + C_u \times (T+20) \times (1-0.01RH)$ $C_u = 0.076 - 0.0119(RH-50)^{0.2}$, when RH>50%; and $C_u = 0.076 + 0.0084(50-RH)^{0.2}$, when RH≤50%	Val 11	Valiantzas (2015)
12.	$ET_0 = 0.0393 \times R_s \sqrt{T+9.5} - 0.19 \times R_s^{0.6} \varphi^{0.15} + 0.0061 \times (T+20) \times (1.12T - T_{min} - 2)^{0.7}$	Val 12	Valiantzas (2013b)

Table: 1
Continued

S.No.	Mathematical form	Symbol	Reference
13.	$ET_0 = 0.0393 \times R_s\sqrt{T+9.5} - 0.19 \times R_s^{0.6}\varphi^{0.15} + 0.0059 \times (T+20) \times (T - T_{min} - 0.45TR + 3.45)^{0.8}$	Val 13	Valiantzas (2015)
14.	$ET_0 = 0.038 \times R_s\sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 + 0.075 \times (T+20) \times (1 - 0.01RH)$	Val 14	Valiantzas (2013a)
15.	$ET_0 = 0.047 \times R_s\sqrt{T+9.5} - 2.4 \times \left(\frac{R_s}{R_a}\right)^2 + 0.09 \times (T+20) \times (1 - 0.01RH)$	Val 15	Valiantzas (2006)
16.	$ET_0 = 0.00668 \times R_a\sqrt{(T+9.5)(T_{max} - T_{dew})} + 0.0696 \times (T_{max} - T_{dew}) - 0.024 \times (T+20) \times (1 - 0.01RH) - 0.00455 \times R_a\sqrt{(T_{max} - T_{dew})} + 0.0984 \times (T+17)(1.03 + 0.00055TR^2 - 0.01RH)$ $T_{dew} = T_{min} - 0.12T + 2$	Val 16	Valiantzas (2013b)

ET_0 is reference evapotranspiration (mm day^{-1}), α is albedo, R_s is solar radiation (MJ m^{-2} day^{-1}), R_a is extra-terrestrial radiation (MJ m^{-2} day^{-1}), T is mean air temperature (°C), RH is relative humidity (%), U_2 is wind speed at 2 m height (m sec^{-1}), TR is temperature difference (°C), Z is altitude above mean sea level (m), T_{dew} is dew point temperature (°C), T_{max} is maximum air temperature (°C), T_{min} is minimum air temperature (°C), φ is latitude (radian), and U_{av} is long-term average wind speed (m sec^{-1}), Val 1 is Valiantzas 1, Val 2 is Valiantzas 2, Val 3 is Valiantzas 3, Val 4 is Valiantzas 4, Val 5 is Valiantzas 5, Val 6 is Valiantzas 6, Val 7 is Valiantzas 7, Val 8 is Valiantzas 8, Val 9 is Valiantzas 9, Val 10 is Valiantzas 10, Val 11 is Valiantzas 11, Val 12 is Valiantzas 12, Val 13 is Valiantzas 13, Val 14 is Valiantzas 14, Val 15 is Valiantzas 15, Val 16 is Valiantzas 16.

model as an index, following steps were taken in accordance with Tabari and Talaee (2011):

(i) Calculating ratio of $ET_{0\,Val}$ to $ET_{0\,FAO56\text{-}PM}$ (R).

$$R = \frac{ET_{0\,Val}}{ET_{0\,FAO56\text{-}PM}}$$

(ii) Multiplying inverse of this ratio (1/R) with original coefficient to get calibration coefficient.

(iii) Calibrated ET_0 values were determined as:

$$\text{Calibrated } ET_0 = \frac{\text{Calibration coefficient} \times \text{Original value } ET_{0\,Val}}{\text{Original coefficient}} \quad ...(2)$$

(iv) Repeating steps (i-iii) will yield calibration coefficients and ET_0 values of different considered Valiantzas equations.

Statistical Analysis

Details of various statistical indices used in this study to compare ET_0 values calculated by Valiantzas equations and standard $FAO_{56\text{-}PM}$ model are presented in Table 2. Microsoft™ Excel® was used as computing tool to analyse obtained results in order to draw fruitful interferences from them.

3. RESULTS AND DISCUSSION

Calibration Coefficient

The values of original coefficient, calibration coefficient and percent deviation of calibration coefficient with respect to original coefficient for different Valiantzas ET_0 equations (Table 3) shows that calibration coefficients

Table: 2
Computational form of considered statistical indices

Statistical index	Notation	Computational form
Agreement index	D	$1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(\lvert P_i - \bar{O}\rvert + \lvert O_i - \bar{O}\rvert)^2}$
Root mean square error	RMSE	$\sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}}$
Maximum absolute error	MAXE	$MAX[\lvert O_i - P_i\rvert]_{i=1}^{n}$
Mean bias error	MBE	$\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)$
Percentage error of estimate	PE	$\left\lvert\frac{\bar{P} - \bar{O}}{\bar{O}}\right\rvert \times 100\%$
Standard error of estimate	SEE	$\left[\frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n-1}\right]^{0.5}$

$\bar{O}$ is mean of FAO-56 PM ET_0 (mm day^{-1}), O_i is FAO-56 PM ET_0 (mm day^{-1}), $\bar{P}$ is mean of FAO-56 PM ET_0 (mm day^{-1}), P_i is predicted value of ET_0 (mm day^{-1}) estimated by using Valiantzas equations, n is total number of observations.

decreased in the range from 3.23% (Val 6) to 40.87% (Val 15). For Val 1,Val 2, Val 3, Val 4, and Val 5 equations, calibration coefficients as 0.04267, 0.04673, 0.04606, 0.04358 and 0.04918, respectively were lowered to the tune of 16.33%, 8.37%, 9.69%, 14.55% and 3.57% in comparison to their original coefficient (0.051), whereas for Val 6, Val 7, Val 8, Val 9, Val 10, Val 11, Val 12 and Val 13 equations, in comparison to their original coefficient (0.0393), about 3.23%, 5.37%, 23.51%, 23.69%, 23.51%, 24.27%, 26.64% and 20.59% lower values were obtained. Likewise, calibration coefficient for Val 14 and Val 15 equations were found 24.39% and 40.87% lower in comparison to their original coefficient of 2.4, while calibration coefficient of Val 16 equation (0.01618) was found 32.58% lower in comparison to its original coefficient (0.024).

Evaluation of Original and Calibrated Valiantzas ET_0 Equations vs FAO56-PM Model

The value of statistical indices and ratio (R) of $ET_{0\ Val}$ to $ET_{0\ FAO56\text{-}PM}$ obtained for all original and calibrated versions of Valiantzas equations (Table 4) reveal that in maximum cases, calibrated equations resulted in significant increment in value of D and decrement in errors (RMSE, MAXE, MBE, PE, and SEE) while value of R near to 1.00 indicated closer estimate of calibrated ET_0 equations in comparison to that obtained with standard FAO56-PM model. The calibration of Valiantzas equations revealed improvement in their performance as except Val 2, Val 7 and Val 13 equations, significant increment in D value was observed with all other considered equations in the range from 0.01% (Val 5) to 34.84% (Val 15), while its value decreased to the tune of less than 1.00% for these three equations. Similarly, in calibrated equations, RMSE values decreased in the range from 4.75% (Val 5) and 79.08% (Val 15), while calibrated Val 2 and Val 7 equations yielded increased RMSE value to the tune of 0.17% and 26.81%, respectively.

After calibration, the values of MAXE, MBE, PE and SEE decreased in the range from 14.29% (Val 7) to 84.55% (Val 15), 87.22% (Val 16) to 196.49% (Val 6), 3.49% (Val 6) to 93.32% (Val 15), and 2.77% (Val6) to 40.87% (Val 15), respectively, whereas values of MAXE, MBE, and PE with calibrated Valiantzas equations were increased in the range of 0.17% (Val 2) to 26.81% (Val 7); 300.21% (Val 7), and 299.89% (Val 7) while no increment in SEE values with any calibrated Valiantzas equations was observed. In calibrated Valiantzas equations, value of ratio (R) gets lowered in the range from 3.58% (Val 5) to 40.87% (Val 15).

Except calibrated version of Val 16 equation, all other equations produced best results in terms of ratio (R) as near to 1.00 while, worst result was found with calibrated Val 16 equation (R = 1.12).

Table: 3
Original and calibration coefficients of Valiantzas ET_0 equations

S.No.	Equation(s)	Coefficient	
		Original	Calibration
1.	Val 1	0.051	0.04267 (-16.33%)
2.	Val 2		0.04673 (-8.37%)
3.	Val 3		0.04606 (-9.69%)
4.	Val 4		0.04358 (-14.55%)
5.	Val 5		0.04918 (-3.57%)
6.	Val 6	0.0393	0.03803 (-3.23%)
7.	Val 7		0.03719 (-5.37%)
8.	Val 8		0.03006 (-23.51%)
9.	Val 9		0.02999 (-23.69%)
10.	Val 10		0.03006 (-23.51%)
11.	Val 11		0.02976 (-24.27%)
12.	Val 12		0.02883 (-26.64%)
13.	Val 13		0.03121 (-20.59%)
14.	Val 14	2.4	1.81469 (-24.39%)
15.	Val 15		1.41906 (-40.87%)
16.	Val 16	0.024	0.01618 (-32.58%)

Val 1 is Valiantzas 1, Val 2 is Valiantzas 2, Val 3 is Valiantzas 3, Val 4 is Valiantzas 4, Val 5 is Valiantzas 5, Val 6 is Valiantzas 6, Val 7 is Valiantzas 7, Val 8 is Valiantzas 8, Val 9 is Valiantzas 9, Val 10 is Valiantzas 10, Val 11 is Valiantzas 11, Val 12 is Valiantzas 12, Val 13 is Valiantzas 13, Val 14 is Valiantzas 14, Val 15 is Valiantzas 15, Val 16 is Valiantzas 16.

Figures in parenthesis shows percent deviation in comparison to original coefficient, (+) represents increment and (-) shows decrement w.r.t. original coefficient.

4. CONCLUSIONS

The performance of calibrated versions of 16 Valiantzas ET_0 equations for humid Dehradun district of Uttarakhand evaluated in comparison to standard FAO56-PM model in terms of statistical indices and ratio of ET_0 Val/ ET_0 FAO56-PM (R) revealed that they extended higher value of D (0.01-34.84%) with lowered values of RMSE (4.75-79.08%), MAXE (14.29-84.55%), MBE (87.22-196.49%), PE (3.49-93.32%), and SEE (2.77-40.87%). Likewise, all calibrated Valiantzas equations (except Val 16) yielded best value of ratio (R) as near to 1.00. The study further confirmed that calibrated versions of Valiantzas ET_0 equations at humid Dehradun district of Uttarakhand should be preferred over their original counterparts for calculating at par FAO56-PM ET_0 estimates over their original counterparts.

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Table: 4
Comparative performance of original and calibrated Valiantzas equations vs FAO56-PM model during validation period (2009-2019)

S.No.	Equation(s)	Features	Statistical indices						R
			D	RMSE	MAXE	MBE	PE	SEE	
1	Val 1	Original	0.9677	0.4494	0.7800	0.4228	15.3798	0.1499	1.20
		Calibrated	0.9887	0.2400	0.2600	-0.0957	3.4814	0.1251	1.00
		% variation	2.17	-46.60	-66.67	-122.63	-77.36	-16.54	-16.36
2	Val 2	Original	0.9945	0.1784	0.3300	0.1524	5.5437	0.0864	1.08
		Calibrated	0.9940	0.1787	0.1600	-0.0904	3.2886	0.0793	0.99
		% variation	-0.05	0.17	-51.52	-159.32	-40.68	-8.22	-8.36
3	Val 3	Original	0.9901	0.2457	0.4300	0.2292	8.3354	0.0846	1.10
		Calibrated	0.9967	0.1355	0.1600	-0.0593	2.1557	0.0762	1.00
		% variation	0.67	-44.85	-62.79	-125.87	-74.14	-9.93	-9.68
4	Val 4	Original	0.9753	0.3915	0.7200	0.3607	13.1188	0.1503	1.17
		Calibrated	0.9904	0.2243	0.2400	-0.0920	3.3453	0.1287	1.00
		% variation	1.55	-42.71	-66.67	-125.51	-74.50	-14.37	-14.55
5	Val 5	Original	0.9975	0.1220	0.2818	0.0666	2.4234	0.1018	1.04
		Calibrated	0.9976	0.1162	0.1104	-0.0339	1.2317	0.0982	1.00
		% variation	0.01	-4.75	-60.82	-150.90	-49.17	-3.54	-3.58
6	Val 6	Original	0.9970	0.1350	0.3900	0.0541	1.9668	0.1156	1.02
		Calibrated	0.9974	0.1241	0.2200	-0.0522	1.8982	0.1124	0.98
		% variation	0.04	-8.07	-43.59	-196.49	-3.49	-2.77	-4.08
7	Val 7	Original	0.9860	0.2764	0.6300	-0.0484	1.7621	0.2455	1.01
		Calibrated	0.9766	0.3505	0.5400	-0.1937	7.0464	0.2324	0.96
		% variation	-0.95	26.81	-14.29	300.21	299.89	-5.34	-5.38
8	Val 8	Original	0.9028	0.8757	1.8714	0.7619	27.7146	0.3623	1.32
		Calibrated	0.9834	0.3031	0.4628	-0.0636	2.313	0.2771	1.01
		% variation	8.93	-65.39	-75.27	-108.35	-91.65	-23.52	-23.51
9	Val 9	Original	0.9109	0.7623	1.4025	0.6321	22.9922	0.4255	1.32
		Calibrated	0.9534	0.4729	0.6629	-0.1689	6.1441	0.3247	1.00
		% variation	4.67	-37.96	-52.73	-126.72	-73.28	-23.69	-23.69
10	Val 10	Original	0.9032	0.8732	1.864	0.7604	27.6611	0.3606	1.32
		Calibrated	0.9834	0.3027	0.4571	-0.0647	2.3539	0.2758	1.01
		% variation	8.88	-65.33	-75.48	-108.51	-91.49	-23.52	-23.51
11	Val 11	Original	0.9071	0.8272	1.9754	0.7469	27.167	0.3253	1.332
		Calibrated	0.9794	0.3259	0.4957	-0.1018	3.7026	0.2463	1.01
		% variation	7.97	-60.60	-74.91	-113.63	-86.37	-24.29	-24.28
12	Val 12	Original	0.8886	0.8397	1.4283	0.7862	28.5984	0.2773	1.39
		Calibrated	0.9489	0.4682	0.6379	-0.1557	5.6618	0.2034	1.02
		% variation	6.79	-44.24	-55.34	-119.80	-80.20	-26.65	-26.64
13	Val 13	Original	0.9501	0.5158	1.0296	0.4527	16.4683	0.1575	1.25
		Calibrated	0.9483	0.4672	0.583	-0.2064	7.507	0.125	0.99
		% variation	-0.19	-9.42	-43.38	-145.59	-54.42	-20.63	-20.59
14	Val 14	Original	0.9033	0.8285	1.5234	0.7692	27.9789	0.2952	1.35
		Calibrated	0.9772	0.3358	0.4455	-0.0889	3.2325	0.2232	1.02
		% variation	8.18	-59.47	-70.76	-111.56	-88.45	-24.39	-24.39
15	Val 15	Original	0.7198	1.7914	3.0658	1.7074	62.1048	0.3859	1.73
		Calibrated	0.9706	0.3748	0.4737	-0.1141	4.1515	0.2282	1.02
		% variation	34.84	-79.08	-84.55	-106.68	-93.32	-40.87	-40.87
16	Val 16	Original	0.7350	1.7989	3.6100	1.6393	59.6299	0.4850	1.66
		Calibrated	0.9748	0.3886	0.99	0.2095	7.6218	0.327	1.12
		% variation	32.63	-78.40	-72.58	-87.22	-87.22	-32.58	-32.58

D is Agreement index, RMSE is Root mean square error (mm day^{-1}), MAXE is Maximum absolute error (mm day^{-1}), MBE is Mean bias error (mm day^{-1}), PE is Percentage error of estimate (%), SEE is Standard error of estimate, R is Ratio of $ET_{0\ Val}/ET_{0\ FAO56\text{-}PM}$, Val 1 is Valiantzas 1, Val 2 is Valiantzas 2, Val 3 is Valiantzas 3, Val 4 is Valiantzas 4, Val 5 is Valiantzas 5, Val 6 is Valiantzas 6, Val 7 is Valiantzas 7, Val 8 is Valiantzas 8, Val 9 is Valiantzas 9, Val 10 is Valiantzas 10, Val 11 is Valiantzas 11, Val 12 is Valiantzas 12, Val 13 is Valiantzas 13, Val 14 is Valiantzas 14, Val 15 is Valiantzas 15, Val 16 is Valiantzas 16.

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