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A comparative analysis of reference evapotranspiration from the surface of rainfed grass in Yaounde, calculated by six empirical methods against the penman-monteith formula

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Abstract

Six reference evapotranspiration (ETo) methods including: Papadakis (1966), Turc (1961), Blaney and Criddle (1950), Blaney and Criddle modified by Shih et al. (1977), Penman modified by Frere and Popov (1979) and Stephens and Stewart (1963) modified by Jansen and Haise, were compared with the FAO-56 Penman-Monteith formula using rain-fed grass data within the period of 15 years (1967 to 1982) in Yaoundé, extracted from the records of climatological observations from meteorological stations published by the National Meteorological Center of Cameroon. The methods compared daily ETo using linear regression and statistical indices of a quantitative approach to model performance evaluation. The average FAO-56 PM ETo was 3.16 mm/day, but Penman modified by Frere and Popov (1979) overestimated ETo by 25% (12.72 mm/day) and Papadakis (1966) underestimated ETo by 8% (0.28 mm/day). In general, the Stephens and Stewart (1963) modified by Jansen and Haise method produced best statistics result (R^2 = 0.96, RMSE = 0.072, MBE = -1.260, RMSEs = 0.980 and RMSEu = 0.693) and generated ETo results of 2.76 mm/day (2% underestimate), closest to that of FAO-56 PM method. The results of statistical comparisons delivered a confident statistical justification for the ranking of the compared methods based on performance indices.

Keywords: Reference evapotranspiration, Empirical methods comparison, Penman-Monteith formula, Rain-fed grass

Introduction

Water deficit is a key regulating element of plant growth and development under the panoply of environmental conditions around the world. Irrigation offers an important feature of agricultural (cropping design) scheduling in areas where rainfall is insufficient to meet crop water requirements. Nevertheless, under rainfed agriculture, it is crucial to determine the optimum time for sowing to benefit from the existing soil moisture and precipitation, while under irrigated agriculture, it is imperative to establish the required amount of water and time of application. Generally, the determination of irrigation water demand employs the procedures for estimating evapotranspiration (E), which (apart from precipitation) is an important component of the hydrological budget [2]. The latter reckoned that weather stations must be sited on standardized vegetation surfaces (grass or alfalfa) in order to calculate crop reference or potential evapotranspiration (ETo). The high installation and maintenance cost constraints limits many nations in Sub-Saharan Africa from having vegetation reference sites or installed ETo-networks. Consequently, the systematic usage of incongruous climatic data for calculating ETo from sites that do not tally with standardization definitely results to systematic aggregate errors in irrigation scheduling and confounding conclusions.

Over the years, empirically based equations were established and used under various climatic regimes to estimate

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ETo from climatological data. To test the accurateness of these methods in a different environment employs the use of costly equipments (such as lysimeters) and profesionals or standard reference surface conditions (protocols). Also, many of these equations have limited global validity. Intending to reduce the alterations associated with tree canopy characteristics, FAO and working groups of the International Commission on Irrigation and drainage tested different formulas among empirical model equations extensively, and then recommended the standardized Penman-Monteith reference evapotranspiration as the potential evapotranspiration (ETo) for short grass or a tall reference crop (alfalfa), whose characteristics have been well defined [4, 18, 24].

Fortunately, there exist unconventional, empirical and less weather demanding equations for accurate determination of ETo [18]. Since effective water resource planning and management, irrigation scheduling and controlled agricultural productivity relies on the accuracy of estimated values of ETo, numerous researches have been carried out in different parts of the world to ascertain appropriate models suitable for applications in such parts.

Hari et al. [10] estimated ET using four different methods for the Bapatla region in India and reported no significant differences and similar trend between the FAO-56 Penman-Monteith and Blaney and credible method. Similarly, Zarei et al. [27] also compared several methods to estimate reference ET in the South East of fars province, Iran and reported a strong similarity between the Pan Evaporation and the Penman-Monteith methods. The latter reported a significant difference between Penman-Monteith and the Jensen-Haise and Thornthwait methods, while the Penman-Monteith results did not differ significantly with those of Pan evaporation, Hargreaves-Samani modified 2 and Blaney and credible methods. Oluwaseun et al. [14] evaluated four different methods for IITA stations in Ibadan, Onne and Kano states in Nigeria and reported that the Blaney-Morin-Nigeria method was the best to be used for estimating ET in these stations as it showed strong correlation with the Penman-Monteith method, required less volume of data for its application and the ease of its use.

Alexandris et al. [18] compared the ET results from the surface of rain-fed grass in central Serbia, using six empirical methods against the Penman-Monteith method and reported that Turc's and Makkink methods produced underestimated results while the Priestley-Taylor, Hargreaves-Samani, and Copais methods performed well for the region and generated results closest to the Penman-Monteith method. Similar studies were carried out in Abeokuta, Ijebu-Ode and Itoikin in Nigeria [1] and Bulgaria [19], these and many other studies emphasized the necessity of comparison, sensitivity testing and calibration of methods in a local context.

The objective of this paper is to compare and evaluate the performance of six globally used methods of ETo computation namely: Papadakis [15], Turc [23], Blaney and Criddle [6], Blaney and Criddle modified by Shih et al. [21], Penman modified by Frere and Popov [9] and Stephens and Stewart [22] modified by Jansen and Haise [11]. The aim is to determine which method apart from the FAO56-PM [3], can best be applied in Yaounde for the estimation of ETo, that is easiest to use in terms of parameters required and that can accurately and consistently capture evapotranspiration losses in the region. This will guide irrigation engineers, hydrologists, agronomists and meteorologists in the calculation of reference and crop evapotranspiration as well as estimating crop water demands for rain-fed and irrigated agriculture.

Description of the equations

FAO-56 Penman-Monteith [3]

This is a combination of Penman [16]; Penman [17] method which is based on Bowen ratio principle (comprising radiation, wind and humidity factors) and Montieth [12, 13] method which considers the resistance factors (including surface resistance and aerodynamic resistance). The equation was used by Allen et al. [3] on an hourly basis with the resistance term having a constant value of 70 s/m throughout the day and night and recommended the FAO-56 Penman Monteith equation as the sole standard method for determining reference evapotranspiration in all climates, especially when there was availability of data. The equation has the form:

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}U_2\right)(e_s - e_s)}{\Delta + \gamma(1 + 0.34U_2)}$$

Where: ETo is the reference evapotranspiration (mm/day), R_n is the net radiation at the crop surface (MJ/m^2/day), G is the soil heat flux density (MJ/m^2/day), T is the mean daily air temperature at 2 m height (°C), U_2 is the wind speed at 2 m height (m/s), e_s is the saturation vapour pressure (kPa), e_a is the actual vaour pressure (kPa), (e_s-e_a) is the saturated vapour pressure deficit (kPa/°C), Δ is the slope vapour pressure curve (kPa/°C) and ɣ is the psychrometric constant (kPa/°C).

Turc [23]

Turc's method is based on the assumption that ETo (mm/month) is a function of the average relative humidity. The method calculated ETo using relative humidity, average temperature, and solar radiation. Since relative humidity was >50%, the correction term was ignored and the following formula was used:

$$ETo = K(Rs + 50)\frac{t}{t + 15}$$

Where: K is monthly crop coefficient, R_s is solar radiation (MJ/m/day), t is the average monthly air temperature, and ETo is the reference evapotranspiration (mm/day).

Papadakis [15]

Papadakis method is based on saturation vapor pressure corresponding to monthly temperatures to estimate ETo (mm/month). The equation is presented as follows:

$$ETo = 0.5625(e_{aTmax} - e_d)$$

Where e_{aTmax} is the water pressure corresponding to average maximum temperature (kPa), and e_d is the saturation water pressure corresponding to the dewpoint temperature (kPa).

Stephens and Stewart [22] modified by Jansen and Haise [11]

The Stephens and Stewart [22] method is a radiation method adjusted for mean monthly temperature. It is basically the same form as the original Jensen and Haise [11] method. The equation is of the form:

$$ETo = 0.01476(T_m + 40905)R_s/\lambda$$

Where: Tm is the monthly potential ET in mm, Rs is the monthly solar radiation in cal/cm^2, and λ is the latent heat of vaporization of water, 59.559 - 0.055Tm, cal/cm^2.mm.

Blaney and Criddle [6]

This method is very simple and is based on temperature, percent daylight hours and crop coefficient. The equation is of the form:

$$ETo = 25.4P(1.8T_m + 32)/100$$

Where: P is the monthly % annual daylight hours, and T_m is the mean monthly temperature (°C).

Blaney and Criddle modified by Shih et al. [21]

Shih et al. [21] modified the Blaney-Criddle [6] method by substituting the measured solar radiation instead of the percent of daylight hours. The equation was expressed as:

$$ETo = 25.4R_s(1.8T_m + 32)/TR_s$$

Where; R_s is the monthly incoming solar radiation in cal/cm^2, TR_s is the annual sum of mean monthly solar radiation in cal/cm^2, and T_m is the mean monthly temperature (°C).

Penman modified by Frere and Popov [9]

This is a mass-transfer method commonly used for estimating free water surface evaporation because of its simplicity and reasonable accuracy [26]. The equation is of the form:

$$ETo = \frac{(R_n.C + A)}{\overline{C+1}}$$

Where R_n is the net solar radiation in cal/cm^2/day, C is an empirically determined constant involving some function of windiness and A is the aerodynamic term.

Methods

The study area is Yaoundé, situated between Latitude 3° 85" N, Longitude 11° 32" E, with an altitude of about 750 m asl (Fig. 1). The 15 years (within the period of 1967 to 1982) climatic data Yaoundé was extracted from the records of climatological observations, published by the National Meteorological Centre of Cameroon. The variables of the equations included: average monthly temperatures, total precipitation, vapor pressure, durations of sunshine, wind speed, relative humidity and solar radiation.

Statistical analysis

Quantitative approaches to the evaluation of models performance were applied. Fox [8] recommends, in essence, that at least four types of different measures be calculated and reported. The average difference between model performances was measured by root mean square error (RMSE). Its values can range from zero to infinity and, of course, lower values are better. The relative bias was explained by the mean bias error (MBE). Furthermore, RMSEs and RMSEu are the systematic and unsystematic components respectively and are computed and reported in addition to RMSE. Normally, the systematic RMSE is the estimated distance between the linear regression best-fit line and the 1:1 line, while unsystematic RMSE is estimated distance between the data point and the linear regression best fit-line [25]. Berengenal and Gavilan [5] expounded that, the unsystematic component represents the "noise" level in the model under test and it measures the scatter about the regression line (this can be inferred to as a measure of the potential accuracy). It is assumed that the systematic component represents the space available for local adjustment. A good model is considered to have a very low RMSEu and the RMSEs close to the RMSE. The correlation measure (R^2), the intercepts (b) and slopes (a) for the least squared regression analysis are also reported. All computations were done with the aid of Microsoft Office Excel 2010 and SPSS version 17 statistical

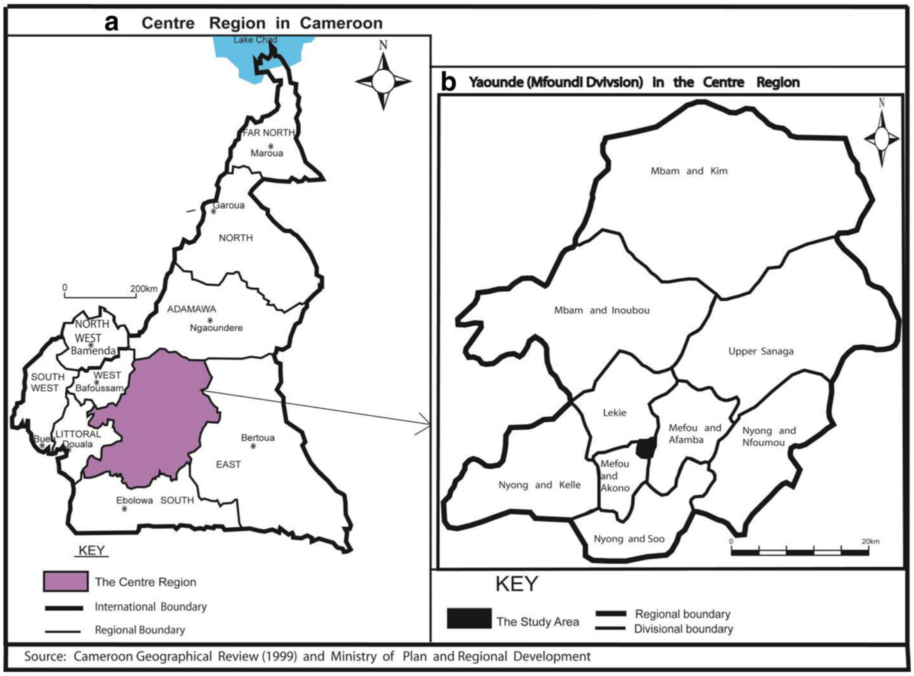

Fig. 1 Location of (**a**) Centre region, and (**b**) Yaoundé (Mfoundi Division) in the Centre Region of Cameroon

package. Computational forms of some indices are given bellow:

$$MBE = N^{-1}\sum_{i=1}^{N}(P_i - O_i)$$

$$RMSE = \left[N^{-1}\sum_{i=1}^{N}(P_i + O_i)^2\right]^{0.5}$$

$$\mathrm{RMSEu} = \left[N^{-1}\sum_{i=1}^{N}\left(P_i + \hat{P}_i\right)^2\right]^{0.5}$$

$$\mathrm{RMSEs} = \left[N^{-1}\sum_{i=1}^{N}\left(\hat{P}_i + O_i\right)^2\right]^{0.5}$$

Where O_i stands for observed values (estimated by FAO 56-PM) and Pi stands for values predicted by the compared methods, $\hat{P}_i = aO_i + b$.

FAO 56-PM method was a reasonable benchmark because according to Allen et al. [3] it overcomes the weaknesses of the previous FAO Penman method and provides values that are more consistent with actual crop water use data worldwide. Recommendations have also been developed for using the method in case of limited climatic data, thereby largely eliminating the need for any other reference evapotranspiration methods and creating a consistent and transparent basis for a globally valid standard for crop water requirement calculations.

Result and Discussions

A summary of average monthly climatic data from 1967 to 1982 of Yaoundé are presented in Table 1. All parameters vary within the years. The results indicate that the average monthly temperature values ranged from 22.5 to 25.2 °C with the least obtained in July and August (coldest month) while February recorded the highest value indicating the annual hottest month. Average monthly precipitation ranged from 19.0 to 290.5 mm. Wind speed was low throughout the year ranging from 1.0 to 2.4 m/s. Insulation was highest in February.

The average ETo obtained from 1967 to 1982, by the FAO 56 PM (benchmark) method was 3.16 mm/day, but that of the Papadakis model was 0.28 mm/day (Table 2), indicating underestimation. The Penman modified by Frere and Popov model yielded considerable overestimates (12.72 mm/day). The progressive average monthly ETo values showing under/overvaluation difference of all the tested methods are represented in Fig. 2

Comparisons for each empirical equation were made between monthly reference evaporation values and monthly values calculated using the FAO 56-Penman M. method. The FAO 56-Penman M. was selected as a benchmark against which comparisons were made because of its global acknowledgment and its assorted use [2]. Drawing experience from the latter, the relationships

Table 1 Summary of some average daily climatic parameters per month for Yaoundé between the years 1967 – 1982

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av. T-Max (°C)	28.8	30.4	29.8	28.8	28.6	27.2	26.0	26.0	27.2	27.6	28.4	28.4
Av. T-Min (°C)	19.3	20.0	20.0	18.5	19.5	19.2	19.0	19.0	19.0	18.9	19.2	19.0
Av. Temp (°C)	24.1	25.2	24.9	23.7	24.1	23.2	22.5	22.5	23.1	23.3	23.8	23.7
Av. Precip (mm)	31.3	58.7	144.3	150.8	199.7	136.9	53.1	83.0	253.9	290.5	98.0	19.0
Av. WVP (mbar)	22.7	22.7	23.4	24.4	24.3	22.6	22.6	22.7	23.1	23.4	23.3	22.6
Av. RH (%)	76.2	73.7	77.7	76.4	81.5	82.9	79.8	83.3	82.2	81.6	79.2	77.5
Av. WS (m/s)	2.3	2.4	2.0	1.5	1.0	2.0	2.4	2.4	2.2	0.8	0.7	1.1
Av. Insol. (hrs)	6.1	6.3	5.4	5.4	5.4	4.3	3.1	2.6	3.5	4.4	5.9	6.3

Av. T-Max Average maximum temperature, *Av. T-Min* average minimum temperature, *Av. Temp* average temperature, *Av. Precip* Average precipitation, *Av. WVP* average water vapour pressure, *Av. RH* Average relative humidity, *Av. WS* average wind speed, *Av. Insol* average insolation

(regression equations) between monthly ETo estimates for each method against the FAO 56-PM ETo and the cross-correlation coefficient (R^2) are shown in Fig. 3, using the linear regression formula $Y = bx + a$ instead of regression through the origin ($Y = bx$).

Stephens and Stewart [22] modified by Jansen and Haise, and Turc [23] models, correlated very well ($R^2 = 0.96$ and $R^2 = 0.95$ respectively), while Blaney and Criddle [6] and Papadakis [6] equations showed a weak correlation with FAO-56 PM model ($R^2 = 0.357$ and $R^2 = 0.859$ respectively) throughout the years under local conditions. This result agrees with Adeboye et al. [1] who reported a strong correlation ($R^2 = 0.97$) by Jansen and Haise model with the FAO-56 PM model. With regards to regression equations, the Stephens and Stewart [22] modified by Jansen and Haise [11] equation resulted in a slope ($b = 1.39$) close to unity and an intercept close to zero ($a = -1.62$) which presumably gives the best predicted (P) values (Table 3). This result also conforms with the findings of Adeboye et al. [1]. The second best values were obtained by Blaney and Criddle modified by Shih et al. [21] ($b = 2.68$, $a = -3.25$). The Papadakis method systematically produced the greatest underestimates (-8%) while the Stephens and Stewart [22] modified by Jansen and Haise [11], model produced the least underestimate (-2%) giving the best estimates among all the tested methods. This is probably due to the limited data input for these two methods. The results are in agreement with Adeboye et al. [1] and Alexandris et al. [2] who reported underestimation of ETo by the Jansen and Haise and Turc's methods respectively. Conversely, Penman modified by Frere and Popov [9] method systematically overestimated by as much as 25%, giving worst estimates amongst all the tested methods. This is probably due to the effects of the advective conditions (dry/high wind speed) in the study area. This result conforms to the assertion that the Frere and Popov [9] method presents over estimates in areas

Table 2 Monthly climatology of ETo values (mm/day) calculated by six empirically based methods and FAO-56 PM during 1967 – 1982

Month	Methods (mm/day)						
	Turc's [23]	Stephens and Stewart [22], modified by Jensen and Haise	Blaney and Criddle [6]	Blaney and Criddle modified by Shih et al., [21]	Papadakis [15]	P.M modified by Frere and Popov [9]	FAO-56 P.M
Jan	8.7	3.09	5.06	5.7	0.31	13.12	3.3
Feb	9.44	3.45	5.8	6.96	0.39	15.48	3.63
Mar	8.82	3.18	5.25	5.81	0.32	13.54	3.58
Apr	8.6	3.03	5.31	5.79	0.33	14	3.42
May	8.32	2.94	5.23	5.42	0.28	12.97	3.32
Jun	7.1	2.42	5.29	4.65	0.23	11.82	2.92
Jul	6.17	2.03	5.03	3.81	0.22	10.53	2.61
Aug	5.96	1.95	4.99	3.66	0.2	10.45	2.59
Sep	6.82	2.3	5.19	4.44	0.24	11.83	2.9
Oct	7.56	2.6	5	4.84	0.26	12.21	3.07
Nov	8.67	3.06	5.19	5.85	0.28	13.64	3.3
Dec	8.69	3.07	5.02	5.68	0.28	13.07	3.27
Average	7.9	2.76	5.2	5.22	0.28	12.72	3.16

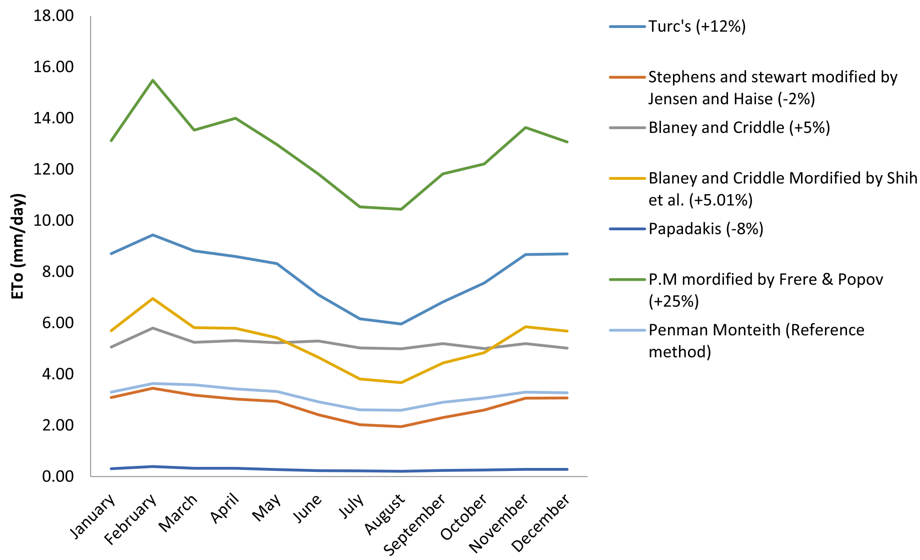

Fig. 2 Trends of Monthly climatology of ETo values (mm/day) calculated by six empirically based methods and FAO-56 PM during 1967 - 1982. (Positive sign (+) = grater, negative sign (-) = lower, relative to the reference method)

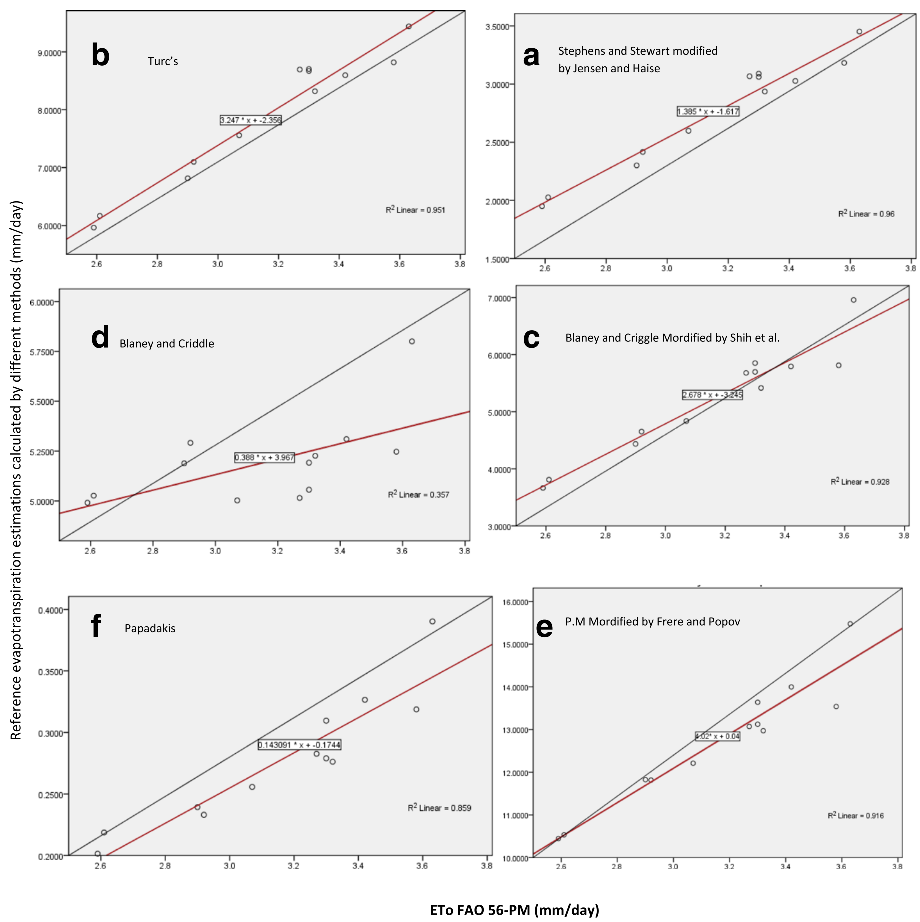

Fig. 3 Comparison of FAO-56 PM method versus (**a**) Stephens and Stewart (1963) modified by Jansen and Haise (1963) (**b**) Turc (1961), (**c**) Blaney and Criddle modified by Shih et al. (1977), (**d**) Blaney and Criddle (1950), (**e**) Penman modified by Frere and Popov (1979), and (**f**) Papadakis (1966) methods using regression analysis, during 1967 – 1982. (*N* = 12)

Table 3 Statistical summary of Monthly climatology of ETo values (mm/day) calculated by six empirically based methods during 1967 - 1982

	Turc's [23]	([a])	Stephens and Stewart [22], modified by Jensen and Haise [11]	([a])	Blaney and Criddle [6]	([a])	Blaney and Criddle modified by Shih et al., [21]	([a])	Papadakis [15]	([a])	P.M modified by Frere and Popov [9]	([a])
a (Slope)	3.25	5	1.39	1	0.39	2	2.68	4	0.14	3	4.02	6
b (Intercept)	-2.36	4	-1.62	3	3.97	6	-3.25	5	-0.17	2	0.04	1
R^2	0.951	2	0.960	1	0.357	6	0.928	3	0.859	5	0.916	4
RMSE	0.080	2	0.072	1	0.289	6	0.097	3	0.135	4	0.105	5
RMSEs	0.975	5	0.980	6	0.598	1	0.963	3	0.927	2	0.957	4
RMSEu	0.293	4	0.693	1	0.919	3	0.340	2	6.006	5	0.228	6
MBE	14.63	4	-1.260	1	9.321	3	3.872	2	-21.95	5	31.21	6
Rank	4		1		5		2		3		6	

([a]) Daily estimate rank number for each statistical index

under advective conditions [20]. The latter stated that the Frere and Popov method considers that the effect of wind on E or ETo is linear while FAO [7] explained that this effect is non-linear and that the effect of wind on E is higher than on ETo under advective conditions.

Generally, all the statistical measurements agree with the results attained by the regression analysis. All relevant statistics and rankings of daily methods are enumerated in Table 3, where the ranking of the methods against FAO-56 PM model is made, taking into account all the above mentioned statistical indices. It is requiered that a weighting coefficient for each statistical index in any complex evaluation system, be determined separately. Considering the same symptomatic tendency and the behavior of the indices, a simple grading of the determined index was made. With a MBE of -1.260 mm/day, RMSE of 0.072, RMSEs of 0.980 and RMSEu of 0.693, the Stephens and Stewart [22] modified by Jansen and Haise [11], model gave by far the best result and is therefore recommended for estimating ETo when input data parameters are limited in Yaoundé stations.

Conclusion

The overall results indicate that some of the simpler empirical equations compare reasonably well with the FAO-56 PM method while several other methods produced ETo estimates which differ from those obtained by the FAO-56 PM method. The Stephens and Stewart [22] modified by Jansen and Haise [11] method ranked first among the methods evaluated. The Blaney and Criddle modified by Shih et al. [21] method ranked second with regards to statistical analysis on monthly data basis. The third and fourth spaces were occupied by the Papadakis [15] and Turcs [23] methods respectively. The fifth was the Blaney and Criddle [6]. Finally, Penman modified by Frere and Popov [9] equation was ranked the least position amongst the other five methods due to its consistent high overestimates and this was also reported by Alexandris et al. [2].

These results provides a reference tool that offers concrete guidance on which method to select, based on available data, for accurate and consistent estimates of monthly ETo related to FAO-56 PM method, under arid-humid conditions.

Abbreviations

ETo: Reference Evapotranspiration; FAO: Food and Agricultural Organisation; PM: Penman-Monteith; RMSE: Root Mean Square Error; RMSEs: Systematic Root Mean Square Error; RMSEu: Unsystematic Root Mean Square Error

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I, Valentine Asong Tellen, holder of ORCID number 0000-0001-8513-788X hereby declare that this research article is written by the author whose name has been appropriately indicated.

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Authors' contributions

The author hereby certifies that he has participated sufficiently in the work to take public responsibility for the content. In addition, the author certifies that this material or similar material has not been and will not be submitted to or published in any other publication. VAT was responsible for the following: Conception and design of study, Acquisition of data, Data analysis and/or interpretation, Drafting/writing of Manuscript, Critical revision and approved the final version of the manuscript.

Competing interests

The author has no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript. All borrowed ideas have been well acknowledged by means of references and quotations and this manuscript has not been presented in any form for publication in any other journal.

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References

1. Adeboye OB, Osunbitan JA, Adekaluk O, Okanded A (2009) Evaluation of FAO- 56 penman-monteith and temperature based models in estimating reference evapotranspiration using complete and limited data, application to Nigeria. Agric Eng Int CIGR J 11:1–25
2. Alexandris R, Stricevic R, Petkovic S (2008) Comparative analysis of reference evapotranspiration from the surface of rainfed grass in central Serbia, calculated by six empirica methods against the Penman-Monteith formula. Eur Water 21(22):17–18
3. Allen RG, Pereire LS, Rase D and Smith M (1998) Crop Evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage paper number 56, FAO Rome
4. Allen RG, Walter IA, Elliot RL, Howell TA, Itenfisu D, Jensen ME and Snyder R (2005) The ASCE standardized reference evapotranspiration equation. ASCE and American Society of Civil Engineers
5. Berengenal J, Gavilan P (2005) Reference ET estimation in a highly advective semi-arid environment. J Irrg Drain Eng 131(2):147–63
6. Blaney HF and Criddle WD (1950) Determining water requirements in irrigated areas from climatological and irrigation data. Department of Agriculture, Washington. Soil conservation service technical paper 96
7. FAO (1977) The state of food and agriculture. Some factors affecting progress in food and agriculture in developing countries. The state of natural resources and the human environment for food and agriculture. World Review. FAO Agriculture Series no. 8. ISBN 92-5-100607-5. http://www.fao.org/docrep/017/ap657e/ap657e.pdf
8. Fox DG (1981) Judging air quality model performance: a summary of the AMS workshop on dispersion model performance. Bull Am Meteorology 125:67–82
9. Frère M and Popov GF (1979) Agometeorological crop monitoring and forecasting. FAO plant production and protection paper No 17. FAO, Rome. pp 64
10. Hari N, Ganesh BR and Murthy VRK (2016). Estimation of Evaporation with Different Methods for Bapatla Region. International Journal of Emerging Trends in Science and Technology. Vol. 03, Issue 07, Pp 4406-4414. ISSN 2348-9480. DOI: http://ijetst.in/article/v3-i7/19%20ijetst.pdf.
11. Jensen ME and Haise HR (1963) Estimating evapotranspiration from solar radiation. Journal of Irrigation and Drainage of the ASCE, New York. V. 89, p.15-41
12. Montieth JL (1965) Evaporation and Environment. In: Michael AM (ed) Irrigation theory and practice second edition, 2008. Cochin: Vikas Publishing House Pvt. Ltd, New Delhi, p 499
13. Montieth JL (1981) Evaporation and surface temperature. Q JR Meteorol Soc 107:1–27
14. Oluwaseun AI, Philip GO, Ayorinde AO (2014) Evaluation of Four ETo Models for IITA Stations in Ibadan, Onne and Kano, Nigeria. J Environ Earth Sci 4(5): 89–97
15. Papadakis J (1966) Crop Ecologic Survey in Relation to Agricultural Development in Western Pakistan. FAO, Roma, Italia, p 51
16. Penman H L (1948) Natural evaporation from open water, bare soil, and grass. Proceedings Royal Society of London, A193, (pp. 120-146).
17. Penman HL (1963) Vegetation and hydrology. In: Farhani H J, Howell TA, Shuttleworth WJ and Bausch WC. Evapotranspiration: Progress in measurement and modeling in agriculture. American Society of Agricultural and Biological Engineers. Vol. 50(5), 2007, p. 1627
18. Pereire LS, Perrier A, Allen RG and Alves I (1996) Evapotranspiration: Review of concepts and future trends. J. Irrig. And Drain. Eng., ASCE 25.
19. Popova Z, Kercheva M, Pereira LS (2006) Validation of the FAO Methodology for Computing ETo With Limited Data. Application to South Bulgaria. J Irrig Drain Eng 55(2):201–215
20. Reddy S J (1993) Agroclimatic agrometeorological techniques, as applicable to dry-land agriculture in developing countries. Jeevan Charitable Trust, Plot No. 6, ICRISAT Colony, Phase I, Tokatta, Secunderabad, A.P., India. Pg 204
21. Shih SF, Myhre DL, Mishoe JW and Kidder G (1977) Water management for sugarcane production in Florida Everglades. Proc. International Soc. of Sugar Cane Technologists, 16th Congress, San Paulo, Brazil. 2: 995- 1010
22. Stephens JC, Stewart EH (1963) "A comparison of procedures for computing evaporation and evapotranspiration.", Publication 62, International Association of Scientific Hydrology. International Union of Geodesy and Geophysics, California, USA, pp 123–133
23. Turc L (1961) Estimation of irrigation water requirements, potential evapotranspiration: A simple climatic formula evolved up to date. Ann Agron 12:13–14
24. Walter IA, Allen RG, Elliott R, Itenfisu D, Brown P and Jensen ME (2005) The ASCE Standardize Reference Evapotranspiration Equation. Final Report (ASCE-EWRI).Pr. Eds: Allen, R.G.; Walter, I.A.; Elliott, R.; Howell, T. and Jensen, M. Environmental and Water Resource Institute (2005). Task Committee on Standardization of Reference Evaporation of the Environmental and Water Resource Institute.
25. Willmott CJ (1981) On the validation of models. Phys Geog 2(2):184–194
26. Xu CY, Singh VP (2002) Cross Comparison of Empirical Equations for Calculating Potential Evapotranspiration with Data from Switzerland. Kluwer Academic Publishers. Printed in the Netherlands. Water Resour Manag 16: 197–219
27. Zarei AR, Zare S, Parsamehr AH (2015) Comparison of several methods to estimate reference evapotranspiration. West African J Applied Ecol 23(2):17–25