Comparison between various reference evapotranspiration equations for semiarid conditions

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Abstract: -Our work area (La Mancha, Central Spain) has limited water resources and water is extracted from aquifers in serious danger of overexploitation [1]. This situation requires to do an efficient use of water in the agriculture. For calculating crop water requirements is necessary the prior calculation of reference evapotranspiration (ET o). Numerous equations for the calculation of ET o exist which differ in their complexity and need for climatic variables. According to Allen et al. [2], the FAO-56 Penman-Monteith method (FAO-56 P-M) could be considered the worldwide reference because it is better adapted to the various climatic conditions that exist on the entire planet, as demonstrated in previous papers [3,4]. This research paper aims to evaluate six equations used in the semiarid climatic conditions of the work area to calculate ET o by comparing it to daily average estimates obtained through the FAO-56 Penman-Monteith equation. Its object is to find an alternative equation for ET o that relates well to the latter. The six methods of estimating daily ET o evaluated during 2000, 2001 and 2002, for the semiarid weather conditions of the province of Albacete were: FAO-24 Corrected Penman(I) (FAO-24 P-I) and (II) (FAO-24 P-II), Penman, FAO-24 Blaney-Criddle (FAO-24 B-C), FAO-24 Radiation and Hargreaves. Daily ET o values were calculated using the FAO-56 P-M equation as a reference. The Hargreaves and the FAO-24 Radiation methods were the most accurate. FAO-24 P-I, FAO-24 P-II and especially FAO-24 B-C produced important overestimations, while the Penman method considerably underestimated daily ET o values. The good performance that Hargreaves method presents must be emphasized, since it deals with a very simple equation that only requires maximum, minimum and mean air temperatures. This equation could be used when weather data are missing.

Key-words: Reference evapotranspiration, calculation of ET o, Penman-Monteith equation, weather station, air temperature, radiation.

1 Introduction

It is necessary to quantify ET for work dealing with water resource management or environmental studies. Referring to agricultural production, its measurement is greatly relevant in arid and semiarid regions, where it is essential for determining crop water demand and consequently for designing and managing irrigation systems, and in general any other system of water distribution and application to a plant cover [5].

ET quantification frequently must be preceded by the determination of reference evapotranspiration (ET o). In the last 30 years, research has been undertaken in various countries, orientated towards evaluating and calibrating various ET o computing equations [6,7,8,9,10]. One of the most important works of this type was carried out by Jensen et al. [11]. These researchers evaluated and calibrated different methods of calculation, comparing them with values obtained from lysimeters on grass or alfalfa crops. Three areas were regarded: arid, humid and miscellaneous. In all the cases, the Penman-Monteith equation [12,13] was the most accurate. The Food and Agriculture Organization of the United Nations proposes the Penman-Monteith equation for calculating ET o since it is the one best adapted to various climatic conditions [2]. This method of calculation had already been endorsed by others researchers [4,14,15], given its good results in different areas of the world in its validation with lysimeter measurements [11]. In other research work, Temesgen et al. [16] compared four ET o equations using weather data from 37
meteorological stations across the state of California. These researchers found a very good correlations between Hargreaves ET₀ and FAO-56 P-M ET₀, despite the few parameters that are use in the Hargreaves equation.

In the last years, some researcher works have been carried out at two semiarid locations in Spain (Zaragoza and Córdoba). In this studies several methods to estimate ET₀ were used for hourly and daily estimates [3,17,18,19]. Recently, Gavilan et al. [20] carried out a study to quantify the differences associated with using two different time steps (hourly and daily basis) for computing ET₀ using ASCE P-M and FAO-56 P-M equations under different climatic conditions in Andalusia (Spain).

This type of study is tremendously useful in the area where it is conducted, as well as because it offers the possibility of extrapolating results to other geographic areas with similar conditions. It also enables irrigation advisory services and technicians interested in the subject to distinguish the most precise equation for calculating average daily ET₀, the basis for determining crop water requirements [4].

This research paper aims to evaluate different methodologies for the semiarid climatic conditions of the work area (La Mancha, Central Spain) to calculate reference evapotranspiration (ET₀) by comparing it to daily average estimates obtained through the FAO-56 P-M equation. Its object is to find an alternative equation for ET₀ that relates well to the latter and we can use it in our study zone when weather data are missing.

2 Materials and methods

This study was carried out during the period from 2000 to 2002 in the “Las Tiesas” farm, located at the city limits between Barrax and Albacete (Spain). Its average geographical coordinates are 39º 14’ N, 2º 5’ W and 695 m elevation. The surroundings are fully representative of irrigated land in the area. Meteorological data were obtained during the experimental period from an automatic weather station located over a grass field.

The climate is characterized by pronounced seasonal variations due to its continental nature, with average temperatures of 4-5º C in the coldest month (January) and about 24 ºC in the hottest month (July). In the period from 2000 to 2002 the annual mean temperature was 13.7º C; the degree of sunshine was high with an average of 2800 h of sunshine per year. Mean precipitation was 283 mm year⁻¹ during the period under study. This precipitation is lower than the annual average for the work area (320 mm year⁻¹) due to low pluviometry in the year 2000 (167 mm).

The Thornthwaite agroclimatic classification characterizes the local climate as semiarid (D), mesothermal (B’2), with a total lack or a scarce excess of humidity (d), and with a moderate concentration of water demand in summer (b’3) [21].

An agro-meteorological station was installed in the centre of a 10,000 m² grassy plot (Festuca arundinacea Schreb., cv. Asterix) maintained in optimum conditions of growth. The following climatic data are registered in this station: air temperature and relative humidity at 2 m; net short and long wave radiation at 2 m; wind velocity at 2 m; soil heat flux at 0.05, 0.1, 0.2 and 0.3 m; atmospheric pressure at 2 m. All the sensors were connected to two dataloggers (model CR 10X, Campbell Scientific Inc., CSI, Logan, Utah). Recordings were made of all the meteorological data stored every ten min, hourly and daily. The dataloggers were collected daily from the workplace through a modem.

The ET₀ equations evaluated were:

FAO-24 Corrected Penman (I)

The FAO-24 Corrected Penman equation [11,22] is:

\[ ET₀ = \frac{\Delta}{\Delta + \gamma} Rn + \frac{\gamma}{\Delta + \gamma} f(U)(e_s - e_a) \]

where ET₀ is reference evapotranspiration (mm day⁻¹); \( \Delta \) the slope of saturation vapour pressure-temperature curve (kPa °C⁻¹); \( \gamma \) the psychrometric constant (kPa °C⁻¹); \( Rn \) the net radiation (mm day⁻¹); \( f(U) \) the wind function; \( e_s \) is the saturation vapour pressure (mbar); \( e_a \) is actual vapour pressure (mbar); \( c \) = adjustment factor [23].

The wind function is calculated as [22]:

\[ f(U) = 0.27 \left( 1 + \frac{U_2}{100} \right) \]

where \( U_2 \) is wind speed measured at 2 m (km day⁻¹).

FAO-24 Corrected Penman (II)

This method uses Eq. (1) and is only differentiated in the \( c \) adjustment factor, which is the one calculated according to Doorenbos and Pruitt [22], later developed by Allen and Pruitt [24].

The polynomial equations for the adjustment factor \( c \) developed by Frevert et al. [23] tended
to further increase the overestimates. However, the equation reported by Allen and Pruitt [24] give improved results for the adjustment factor given in FAO-24 [11].

Penman 1963

The Penman equation is expressed as [25]:

\[
ET_o = \left[ \frac{\Delta}{\Delta + \gamma} Rn + \frac{\gamma}{\Delta + \gamma} Ea \right] 0.8
\] (3)

where \( ET_o \) is reference evapotranspiration (mm day\(^{-1}\)); \( \Delta \) the slope of saturation vapour-pressure-temperature curve (kPa °C\(^{-1}\)); \( \gamma \) the psychrometric constant (kPa °C\(^{-1}\)); \( Rn \) the net radiation (mm day\(^{-1}\)); \( Ea \) is aerodynamic term (mm day\(^{-1}\)).

The aerodynamic term is calculated:

\[
Ea = 0.35 (1 + 0.22U_2)(e_s - e_a)7.4
\] (4)

where \( U_2 \) is wind speed measured at 2 m (m s\(^{-1}\)); \( e_s \) the saturation vapour pressure (kPa); \( e_a \) is actual vapour pressure (kPa).

FAO-24 B-C

For better defining the effects of climate on crop water requirements, the original Blaney-Criddle method [26] was modified by Doorenbos and Pruitt [22] to obtain \( ET_o \) considering general levels of minimum relative humidity, wind speed and sunshine. The Blaney-Criddle method modified by the FAO is:

\[
ET_o = a_o + b_o f
\] (5)

where \( ET_o \) is reference evapotranspiration (mm day\(^{-1}\)); \( a_o \) and \( b_o \) are coefficients of the linear equation that relate \( ET_o \) and \( f \). In this paper, to obtain greater precision in predicting \( ET_o \) the expressions proposed by Frevert et al. [23] were used for calculating coefficients \( a_o \) and \( b_o \); \( f \) is the Blaney-Criddle factor (mm day\(^{-1}\)), which is expressed as:

\[
f = p(0.46T + 8.13)
\] (6)

where \( p \) is mean daily percent of annual daytime hours; \( T \) is mean air temperature (°C).

FAO-24 Radiation

The FAO-24 Radiation equation is expressed as [22]:

\[
ET_o = a + b W R_s
\] (7)

where \( ET_o \) is reference evapotranspiration (mm day\(^{-1}\)); \( a = -0.3 \) (mm day\(^{-1}\)); \( b \) is an adjustment factor that varies with mean relative humidity and daytime wind speed [23]; \( W \) the weighting factor, including effects of temperature and altitude in the relationship between soil surface radiation and crop reference evapotranspiration [22]; \( R_s \) is solar radiation (mm day\(^{-1}\)).

Hargreaves 1985

The Hargreaves equation is expressed as [2,27]:

\[
ET_o = 0.0023(T + 17.8)(T_{max} - T_{min})^{0.5} Ra
\] (8)

where \( ET_o \) is reference evapotranspiration (mm day\(^{-1}\)); \( T \) the daily mean air temperature (°C); \( T_{max} \) the daily maximum air temperature (°C); \( T_{min} \) the daily minimum air temperature (°C); \( Ra \) is the extraterrestrial radiation (mm day\(^{-1}\)).

FAO-56 Penman-Monteith

The FAO-56 P-M equation is expressed as [2]:

\[
ET_o = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T + 273}(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}
\]

(9)

where \( ET_o \) is reference evapotranspiration (mm day\(^{-1}\)); \( \Delta \) the slope vapour pressure curve (kPa °C\(^{-1}\)), \( Rn \) the net radiation at crop surface (MJ m\(^{-2}\) day\(^{-1}\)); \( G \) the soil heat flux density (MJ m\(^{-2}\) day\(^{-1}\)); \( T \) the daily mean air temperature at 2 m height (°C); \( U_2 \) the wind speed at 2 m height (m s\(^{-1}\)); \( e_s \) the saturation vapour pressure (kPa); \( e_a \) the actual vapour pressure (kPa); \( (e_s - e_a) \) the saturation vapour pressure deficit (kPa); \( \gamma \) is psychrometric constant (kPa °C\(^{-1}\)).

The comparisons were accomplished through simple linear regression analysis [28] and a set of statistics proposed by Willmott [29]: the root mean square error (RMSE) and the index of agreement (d). For the simple regression, the model \( y = a + bx \) was used, where \( y \) is estimated \( ET_o \), \( x \) the calculated \( ET_o \) by FAO-56 P-M, \( a \) the intercept and \( b \) is the slope. The coefficient of determination (\( R^2 \)) was calculated too. The RMSE was calculated as:

\[
RMSE = \left[ N^{-1} \sum_{i=1}^{N} (P_i - O_i)^2 \right] ^{0.5}
\] (10)

where \( N \) is the number of observations; \( P_i \) are estimated \( ET_o \) values; \( O_i \) are estimated \( ET_o \) values by FAO-56 P-M equation.

The mean quadratic error expressed as a percentage of the mean \( ET_o \) value estimated by FAO-56 Penman-Monteith equation (Oavg) was used as a measurement of the relative error (ReIRMSE = (RMSE/Oavg)*100).

The index of agreement was computed as:

\[
d = 1 - \frac{\sum (P_i - O_i)^2}{\sum (P_i - O_{avg})^2 + \sum (O_i - O_{avg})^2}
\] (11)

The index (d) is intended to be a descriptive measure, and it is both a relative and bounded measure which can be widely applied in order to make cross-comparisons between models.
Because a model ought to explain most of the major trends or patterns present. Perfect agreement would exist between P and O if \( d = 1 \).

### 3 Results and discussion

#### 3.1 Evaluation of six methods for calculating \( E_{\text{To}} \)

During 2000-2002, daily \( E_{\text{To}} \) values were calculated using seven different methods. In this way, a wide series of values is available: 350 for the year 2000, 305 for the year 2001 and 344 for the year 2002, which gives a total of 999 \( E_{\text{To}} \) estimates through the different methods studied.

Table 1 presents the results of the comparison by means of simple regression analysis between values calculated with different methods and those estimated with the FAO-56 P-M equation, with an indication of the calculation of errors and of the index of agreement.

The values for A, B y \( R^2 \) were very significant (\( P \leq 0.01 \)) in every case.

**Table 1. Comparison between the FAO-56 P-M equation and the different methods (FAO-24 P-I and II, Penman, FAO-24 B-C, FAO-24 Radiation and Hargreaves) during the period 2000-2002.**

<table>
<thead>
<tr>
<th>Calculation methods</th>
<th>( \text{Pavg} ) (mm day(^{-1}))</th>
<th>( \text{Pavg}/\text{Oavg} ) (%)</th>
<th>( A )</th>
<th>( B )</th>
<th>( R^2 )</th>
<th>( \text{RMSE} ) (mm day(^{-1}))</th>
<th>( \text{RelRMSE} ) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAO-24 P-I</td>
<td>4.74</td>
<td>123</td>
<td>-0.13</td>
<td>1.26</td>
<td>0.94</td>
<td>1.32</td>
<td>34.22</td>
</tr>
<tr>
<td>FAO-24 P-II</td>
<td>4.52</td>
<td>117</td>
<td>-0.36</td>
<td>1.26</td>
<td>0.91</td>
<td>1.28</td>
<td>33.22</td>
</tr>
<tr>
<td>Penman (1963)</td>
<td>2.33</td>
<td>60</td>
<td>0.07</td>
<td>0.59</td>
<td>0.89</td>
<td>1.87</td>
<td>48.50</td>
</tr>
<tr>
<td>FAO-24 B-C</td>
<td>6.00</td>
<td>155</td>
<td>2.30</td>
<td>0.86</td>
<td>0.86</td>
<td>2.32</td>
<td>60.16</td>
</tr>
<tr>
<td>FAO-24 Radiation</td>
<td>3.86</td>
<td>103</td>
<td>-0.25</td>
<td>1.00</td>
<td>0.87</td>
<td>1.00</td>
<td>25.96</td>
</tr>
<tr>
<td>Hargreaves (1985)</td>
<td>3.73</td>
<td>97</td>
<td>0.08</td>
<td>0.95</td>
<td>0.84</td>
<td>0.97</td>
<td>25.08</td>
</tr>
</tbody>
</table>

Number of observations: 999. \( \text{Oavg} \): average of values estimated by FAO-56 P-M (3.86 mm day\(^{-1}\)); \( \text{Pavg} \): average of the values estimated by different methods; A: ordinate in the origin; B: regression coefficient (slope); \( R^2 \): determination coefficient; \( \text{RMSE} \): root mean square error; \( \text{RelRMSE} \): relative error ((\( \text{RMSE}/\text{Oavg} \))\(^{100} \)); d: index of agreement.

The FAO-24 P-I and II methods overestimated the values for \( E_{\text{To}} \) by 23 and 17% respectively, with a RMSE of approximately 1.3 mm day\(^{-1}\). The methods showing the best performance are FAO-24 Radiation and Hargreaves. The former overestimates and the latter underestimates, but very slightly (only 3% in each case), with a RMSE of 1 mm day\(^{-1}\). The Penman method greatly underestimated \( E_{\text{To}} \), with almost 2 mm day\(^{-1}\) RMSE, equivalent to a relative error close to 50%. The FAO-24 B-C method produced the greatest overestimations, presenting the highest RMSE and \( \text{RelRMSE} \) values.

Good coefficients of determination (\( R^2 \)) were obtained in all cases, with values over or equal to 0.84. The Penman method, due to its high underestimations, and the FAO-24 B-C method, because of its high overestimations, are limited in their practical application.

Figure 1 presents regression graphs from both methods with the best performance when compared to FAO-56 P-M. The Hargreaves equation produces a slight underestimation for values over 6 mm day\(^{-1}\), while the FAO-24 Radiation method starting at this value produces a very small overestimation. Other researchers have suggested possible overestimation of \( E_{\text{To}} \) by Hargreaves equation under humid environments and underestimate under windy conditions compared to the Penman-Monteith combination equation [2,7,9].

![Fig. 1. Daily reference evapotranspiration comparison between FAO-56 P-M equation and the FAO-24 Radiation and Hargreaves equations.](image-url)
was also studied during two different seasons of the year, one of high evaporative demand from the months of April to September, and the other of low demand from October through March. Both these times of the year were differentiated with the purpose of knowing the most precise equation in each of them. During the time of high evaporative demand crops with the highest water requirements are planted in the field, and therefore it is paramount to estimate ET<sub>o</sub> with the greatest accuracy possible.

Table 2 presents the results from comparing the six methods of calculation evaluated by the FAO-56 P-M equation in the period from April to September during the three years that the experimental work lasted. The various equations evaluated were taken as dependent variables, and the FAO-56 P-M method as an independent variable.

<table>
<thead>
<tr>
<th>Calculation methods</th>
<th>Pavg (mm day&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>Pavg/Oavg (%)</th>
<th>A</th>
<th>B</th>
<th>R&lt;sup&gt;2&lt;/sup&gt;</th>
<th>RMSE (mm day&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>RelRMSE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAO-24 P-I</td>
<td>6.97</td>
<td>126</td>
<td>0.23</td>
<td>1.21</td>
<td>0.86</td>
<td>1.73</td>
<td>31.21</td>
</tr>
<tr>
<td>FAO-24 Penman-II</td>
<td>6.77</td>
<td>122</td>
<td>0.13</td>
<td>1.2</td>
<td>0.80</td>
<td>1.69</td>
<td>30.41</td>
</tr>
<tr>
<td>Penman (1963)</td>
<td>3.42</td>
<td>62</td>
<td>0.64</td>
<td>0.50</td>
<td>0.73</td>
<td>2.40</td>
<td>43.19</td>
</tr>
<tr>
<td>FAO-24 B-C</td>
<td>7.77</td>
<td>140</td>
<td>0.64</td>
<td>0.85</td>
<td>0.78</td>
<td>2.40</td>
<td>43.21</td>
</tr>
<tr>
<td>FAO-24 Radiation</td>
<td>5.84</td>
<td>107</td>
<td>0.55</td>
<td>0.87</td>
<td>0.71</td>
<td>1.23</td>
<td>22.20</td>
</tr>
<tr>
<td>Hargreaves (1985)</td>
<td>5.55</td>
<td>100</td>
<td>1.31</td>
<td>0.76</td>
<td>0.62</td>
<td>1.21</td>
<td>21.78</td>
</tr>
</tbody>
</table>

Number of observations: 527. Note: see footnotes in Table 1 for heads. The values of A, B and R<sup>2</sup> were significant (P≤0.01) in all cases.

Again, during the period of high evaporative demand, the Penman and FAO-24 B-C equations show the worst performance. The former had underestimations close to 40% and a RMSE value of 2.40 mm day<sup>-1</sup>. The latter produced very high overestimations, with a RMSE value similar to that of the Penman method. The FAO-24 Radiation method is the one that worked the best, with an overestimation of 7% up to ET<sub>o</sub> values of 7 mm day<sup>-1</sup>. After this the slope of the straight line is near 1 and coincides perceptibly to the intercept, which indicates the correct performance of this equation. The Hargreaves method is limited, presenting plenty of dispersion, although the overestimation it produces, up to values of 4 mm day<sup>-1</sup>, is later compensated by an underestimation. It presents the lowest RMSE value, which is also equivalent to the smallest relative error of all the methods analysed. Finally, the FAO-24 P-I and II methods produced overestimates over 20% with RMSE values of 1.7 mm day<sup>-1</sup> approximately.

Figure 2 graphically shows the relationship between ET<sub>o</sub> calculated by the FAO-56 P-M method and those computed by the methods that showed the best performance during the period of high evaporative demand, which are: FAO-24 Radiation and Hargreaves. The former produces a small overestimation for values under 7 mm day<sup>-1</sup> and the latter produces a slight overestimation for values under 4 mm day<sup>-1</sup>, while above 6 mm day<sup>-1</sup> it underestimated ET<sub>o</sub> values.

<table>
<thead>
<tr>
<th>Calculation methods</th>
<th>Pavg (mm day⁻¹)</th>
<th>PropAvg (%)</th>
<th>A</th>
<th>B</th>
<th>R²</th>
<th>RMSE (mm day⁻¹)</th>
<th>ReRMSE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAO-24 P-I</td>
<td>2.26</td>
<td>115</td>
<td>0.14</td>
<td>1.07</td>
<td>0.78</td>
<td>0.60</td>
<td>30.66</td>
</tr>
<tr>
<td>FAO-24 Penman-II</td>
<td>2.00</td>
<td>102</td>
<td>-0.04</td>
<td>1.04</td>
<td>0.76</td>
<td>0.55</td>
<td>27.78</td>
</tr>
<tr>
<td>Penman (1963)</td>
<td>1.12</td>
<td>57</td>
<td>0.06</td>
<td>0.54</td>
<td>0.74</td>
<td>1.00</td>
<td>59.85</td>
</tr>
<tr>
<td>FAO-24 B-C</td>
<td>4.02</td>
<td>204</td>
<td>2.53</td>
<td>0.76</td>
<td>0.41</td>
<td>2.23</td>
<td>113.42</td>
</tr>
<tr>
<td>FAO-24 Radiation</td>
<td>1.75</td>
<td>89</td>
<td>-0.23</td>
<td>1.00</td>
<td>0.70</td>
<td>0.66</td>
<td>33.32</td>
</tr>
<tr>
<td>Hargreaves (1985)</td>
<td>1.69</td>
<td>86</td>
<td>0.26</td>
<td>0.73</td>
<td>0.69</td>
<td>0.50</td>
<td>38.37</td>
</tr>
</tbody>
</table>

Number of observations: 472. Note: see footnotes in Table 1 for heads.

Values for A, B and R² were very significant (P ≤ 0.01) in all cases.

The FAO-24 P-II method is the one that related best to the FAO-56 P-M method during this period. It showed a slight overestimation and a 0.55 mm day⁻¹ RMSE value. The FAO-24 P-I method, although it produced overestimations superior to the previous method, also showed good performance. The FAO-24 Radiation and the Hargreaves methods showed underestimations of 11 and 14% respectively, with RMSE values of approximately 0.6 mm day⁻¹. These two methods have the limitation of presenting some dispersion, with somewhat low coefficient of determination (R²) values. The original Penman method gives significant underestimations throughout the entire period, with 1 mm day⁻¹ RMSE value. The worst performance was shown by the FAO-24 B-C method with very high overestimations and with the highest RMSE and RelRMSE values.

Figure 3 presents the graphs where estimations conducted through the FAO-56 P-M method are compared to those obtained from the other two methods that performed best in the period of low evaporative demand, which are FAO-24 P-II and I.

### 4 Conclusions

The FAO-24 Radiation and the Hargreaves methods showed the best performance, as compared to the daily mean ET₀ values calculated by the FAO-56 P-M method. The FAO-24 P-I and II and especially the FAO-24 B-C equations considerably overestimated ET₀. On the other hand, the Penman method significantly underestimated the calculated ET₀.

During high evaporative demand periods, the FAO-24 Radiation equation was more precise than that of Hargreaves, because of the large dispersion showed by the latter. The FAO-24 P-I and II and FAO-24 B-C methods also showed large overestimation during this period, while the Penman equation significantly underestimated ET₀.

During low evaporative demand periods, the FAO-24 P-II equation was the most precise, and the FAO-24 P-I, FAO-24 Radiation and Hargreaves methods also performed well. However, the Penman equation continued to present high underestimations and the FAO-24 B-C method, even greater overestimations.

Generally, all six methods of calculation, compared to the daily calculations obtained by the FAO-56 P-M procedure, can be put in order from more to less precise in the following way:

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