**Short communication**

**Evaluation of three methods for estimating reference evapotranspiration (ET₀) at Dapoli, Maharashtra**

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The estimation of reference evapotranspiration (ET₀) is the most important step towards designing, planning and managing different irrigation networks, water distribution systems, water application, water balance and water management practices (Landeras et al, 2008 and Sentelhas et al. 2010). Many methods e.g pan evaporation method, Hargreaves-Samani, Jensen Haise, Turc, Thornwaite, Blaney-Criddle, Priestley-Taylor, Makkink and FAO 56 PM method have been proposed for estimating ET₀ based on weather data, and range from locally developed, empirical relationships to physically based energy and mass transfer models. To allow for greater understanding, sharing, and inter-comparison of evapotranspiration information worldwide, under varying climatic and agronomic conditions, FAO-56 Penman Monteith method is regarded as a standardized method of estimating evapotranspiration. FAO-56 Penman Monteith method demands much weather data that may be unavailable in various places hence there is need to come up with alternative methods.

For this study, 28 years (1985-2013) climatic data were collected from the Department of Agronomy, College of Agriculture, Dr.BSKKV, Dapoli. The climatic data included maximum and minimum air temperatures, sunshine hours, wind speed, maximum and minimum relative humidity, and rainfall.

**Methods for estimating reference evapotranspiration (ET₀)**

The daily reference evapotranspiration values were estimated using the following methods:

1. FAO-56 Penman Monteith Method (Allen et al., 1998)
2. Hargreaves-Samani Method (Hargreaves-Samani, 1985)
3. Jensen-Haise equation (James, 1988)
4. Pan Evaporation Method (Doorenboss and Pruitt, 1984)

Statistical indicators e.g. root mean square error (RMSE), mean bias error (MBE), index of agreement (d), correlation coefficient (r), coefficient of determination (R²), standard error (S.E), and confidence index (c) were used to evaluate the models.

**Reference Evapotranspiration (ET₀)**

The daily reference evapotranspiration values for each model were calculated and converted into monthly reference evapotranspiration. The trend in mean monthly ET₀ is presented in Table 1.

The highest monthly ET₀ values were recorded in summer season (March to May) and the lowest monthly ET₀ values were recorded in winter season (October to February). For all methods of estimating reference evapotranspiration, the highest monthly ET₀ values were recorded in May (162.3 mm, 159.0 mm, 160.3 mm and 155.6 mm for Hargreaves Samani, FAO 56 PM, pan evaporation and Jensen Haise models, respectively). The lowest monthly ET₀ values were recorded in December (87.1 mm, 64.1 mm, 56.7 mm and 35.9 mm for Hargreaves Samani, FAO 56 PM, pan evaporation and Jensen Haise models, respectively).

The pan evaporation method under-estimated monthly ET₀ by 8 % when compared to monthly ET₀ estimated from FAO 56 PM. It showed closer values than other models. Jensen Haise model also under-estimated monthly ET₀ by 37 % with largest deviation of monthly ET₀ when compared to ET₀ values from FAO 56 PM. Hargreaves-Samani model over-estimated monthly ET₀ by 15 % when compared to monthly ET₀ estimated from FAO 56 PM.

Comparisons were made between monthly reference evapotranspiration values obtained from each empirical method and monthly ET₀ values from FAO 56 PM model. The benchmark method for comparisons was FAO 56 PM model because it is globally accepted and can be used under a variety of climatic regimes and reference conditions.

With regard to statistical analysis, the best model is the one with the highest index of agreement (d), correlation coefficient (r), coefficient of determination (R²), and confidence index but also having low root mean square error.
Thermal time requirement and HUE in wheat

Table 1: Monthly and seasonal reference evapotranspiration (mm) by different methods

<table>
<thead>
<tr>
<th>Month</th>
<th>FAO 56 PM</th>
<th>Pan Evaporation</th>
<th>Jensen -Haise</th>
<th>Hargreaves Samani</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>68.0</td>
<td>58.8</td>
<td>40.9</td>
<td>89.1</td>
</tr>
<tr>
<td>February</td>
<td>80.0</td>
<td>75.1</td>
<td>50.7</td>
<td>105.5</td>
</tr>
<tr>
<td>March</td>
<td>128.1</td>
<td>124.9</td>
<td>100.2</td>
<td>146.0</td>
</tr>
<tr>
<td>April</td>
<td>148.4</td>
<td>136.1</td>
<td>109.6</td>
<td>159.6</td>
</tr>
<tr>
<td>May</td>
<td>159.7</td>
<td>150.3</td>
<td>115.6</td>
<td>162.3</td>
</tr>
<tr>
<td>June</td>
<td>115.3</td>
<td>110.4</td>
<td>70.4</td>
<td>123.7</td>
</tr>
<tr>
<td>July</td>
<td>97.4</td>
<td>86.5</td>
<td>53.7</td>
<td>107.7</td>
</tr>
<tr>
<td>August</td>
<td>86.4</td>
<td>77.4</td>
<td>42.3</td>
<td>95.7</td>
</tr>
<tr>
<td>September</td>
<td>96.6</td>
<td>88.7</td>
<td>53.2</td>
<td>112.5</td>
</tr>
<tr>
<td>October</td>
<td>88.7</td>
<td>77.6</td>
<td>48.6</td>
<td>110.1</td>
</tr>
<tr>
<td>November</td>
<td>75.0</td>
<td>68.7</td>
<td>40.9</td>
<td>102.4</td>
</tr>
<tr>
<td>December</td>
<td>64.1</td>
<td>56.7</td>
<td>35.9</td>
<td>87.1</td>
</tr>
<tr>
<td>Monsoon (June-September)</td>
<td>395.8</td>
<td>363.2</td>
<td>219.7</td>
<td>439.7</td>
</tr>
<tr>
<td>Winter (October-February)</td>
<td>376.0</td>
<td>337.1</td>
<td>217.3</td>
<td>434.3</td>
</tr>
<tr>
<td>Summer (March - May)</td>
<td>436.3</td>
<td>411.4</td>
<td>325.6</td>
<td>467.9</td>
</tr>
</tbody>
</table>

Table 2: Summary statistics of monthly ET\textsubscript{o} estimates computed using various models under test

<table>
<thead>
<tr>
<th>MODEL</th>
<th>RMSE</th>
<th>MBE</th>
<th>\textit{d}</th>
<th>\textit{r}</th>
<th>\textit{R}^2</th>
<th>S.E</th>
<th>C</th>
<th>Performance rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pan Evaporation</td>
<td>0.69</td>
<td>-0.51</td>
<td>0.99</td>
<td>0.88</td>
<td>0.79</td>
<td>0.38</td>
<td>0.87</td>
<td>Excellent</td>
</tr>
<tr>
<td>Hargreaves-Samani</td>
<td>0.94</td>
<td>0.84</td>
<td>0.99</td>
<td>0.86</td>
<td>0.75</td>
<td>0.41</td>
<td>0.85</td>
<td>Very good</td>
</tr>
<tr>
<td>Jensen -Haise</td>
<td>1.2</td>
<td>-0.84</td>
<td>0.97</td>
<td>0.71</td>
<td>0.50</td>
<td>0.56</td>
<td>0.69</td>
<td>Good</td>
</tr>
</tbody>
</table>

(RMSE), mean bias error (MBE), standard error (s.e), and t-stat. In reference to Table 2 below, pan evaporation method showed good correlation with FAO 56 PM model as compared to other methods.

All the statistical parameters given in Table 2 revealed that ET\textsubscript{o} estimated by pan evaporation is very close to that of FAO 56 Penman Monteith Model.

Analyses of 28 years climatic data of Dapoli indicated that pan evaporation method compared reasonably well with FAO 56 PM model. Hargreaves-Samani model is the second best and Jensen Haise model is ranked third. Similar results are obtained by Rao and Rajput (1993). This revealed that pan evaporation method can successfully be used in the absence of adequate climatic data that is required for the use of FAO 56 Penman Monteith model in the region.

REFERENCES


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