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Assessing suitability of temperature-based reference evapotranspiration methods for semi-arid basin of Maharashtra

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ABSTRACT

FAO Penman-Monteith (FAO-PM) is deemed as a sole standard method for estimating reference evapotranspiration (ET_o). However, limited availability of meteorological data at spatial and temporal scales restricts the application of this method. To address this issue, the FAO 56 experts suggested three methods when only maximum and minimum temperature data are available: (i) Temperature-based Penman-Monteith (PMT-1) method wherein $T_{dew} \approx T_{min}$ (ii) PMT-2 wherein $T_{dew} \approx T_{min}$-2.5, and (iii) Hargreaves method. These ET_o methods were assessed for a semi-arid basin of Western India which lacks adequate climatic data. The performances of the ET_o methods were evaluated against the standard FAO-PM method using salient statistical and graphical indicators, together with the sensitivity analysis. The results of the three temperature-based methods had a tendency of over-predication of ET_o in the study area. The PMT-1 method, however, provided superior ET_o estimates compared to PMT-2 and Hargreaves methods. For estimating monthly ET_o, the FAO-PM method was most sensitive to temperature. Further, ET_o of the monsoon season over the study area increased from 5 to 12% during 'drought' years compared to 'normal' years. It was concluded that PMT-1 method is the most suitable temperature-based method for estimating ET_o in semi-arid regions under limited climatic condition.

Keywords: FAO Penman-Monteith method, temperature-based Penman-Monteith method, Hargreaves method, ET mapping, limited data, semi-arid region

Evapotranspiration (ET) is one of the important components of the water cycle and plays a central role in water balance studies, hydrological modelling, planning and management of irrigation and drainage systems as well as in climatological studies. Crop Evapotranspiration (ET_c) is affected by the crop characteristics, soil factors and climatic parameters, and management practices leading to a high spatial and temporal variability in ET_c (Allen *et al.*, 1998). The concept of reference evapotranspiration (ET_o) evolved in the last decade of the 20th century to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. ET_o is a climate parameter because it is only affected by climatic factors. The best estimates of ET_o is done by using lysimeter but it is cumbersome, time consuming, costly, and its application at a larger scale is restricted. To overcome this problem, numerous empirical methods have been developed during past six decades for estimating ET_o indirectly under varying agro-climatic conditions (Tabari *et al.*, 2013; Jadhav *et al.*, 2015; Phad *et al.*, 2019). These methods can be classified into four groups (Jensen, 1990) of temperature-based methods (Thornthwaite and Hargreaves, etc.), radiation-based methods (Priestley-Taylor, and FAO-24 radiation, etc.), pan methods (Christiansen Pan and FAO-24 pan), and combination methods (Penman-Monteith, and FAO-24 corrected Penman, etc.). Among these methods, FAO Penman-Monteith (FAO-PM) has emerged as the sole standard method for ET_o computation (Allen *et al.*, 1998). Also, it can be applied in data-scarce situations.

Unfortunately, the application of FAO-PM method requires several meteorological data, some of them are missing or limited in spatial and temporal scales mostly in developing countries. According to the modern guidelines for computing crop water requirements (Allen *et al.*, 1998), the following three methods can be used under data-scarce conditions: (i) Temperature-based Penman-Monteith (PMT-1) method, wherein $T_{dew} \approx T_{min}$; (ii) PMT-2, wherein $T_{dew} \approx T_{min}$-2.5; and (iii) Hargreaves method. Among the less data-intensive ET_o methods used, temperature-based Hargreaves method has been found to be the best in arid and/or semi-arid climate of Spain (Lopez-Urrea *et al.*, 2006), Iran (Tabari, 2010, Sabziparvar and Tabari, 2010), and India (Nandagiri and