International Soil and Water Conservation Research 4 (2016) 52–63

HOSTED BY

Contents lists available at ScienceDirect

International Soil and Water Conservation Research

journal homepage: www.elsevier.com/locate/iswcr

Original Research Article

Evaluation of reference evapotranspiration methods for the northeastern region of India

Pankaj K. Pandey [a,*], Parmendra P. Dabral [a], Vanita Pandey [b]

[a] Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli, Itanagar, Arunachal Pradesh, India
[b] Department of Soil and Water Engineering, College of Agricultural Engineering and Post-Harvest Technology (CAEPHT), Ranipool, Gangtok, Sikkim, India

ARTICLE INFO

Article history:
Received 23 July 2015
Received in revised form
6 February 2016
Accepted 10 February 2016
Available online 17 February 2016

Keywords:
Reference evapotranspiration
Performance statistics
Calibration and validation
Empirical methods
North East
India

ABSTRACT

The study planed to identify a suitable alternative to the FAO-56 Penman-Monteith (FAO56PM) equation for calculating reference evapotranspiration (ET_0) from chosen temperature and radiation based models utilizing monthly meteorological data from 30 destinations in diverse agro-ecological regions of the Northeast (NE) India i.e., Assam Bengal Plain (ABP), eastern Himalaya (EH), and the northeastern hilly (NEH) region. Radiation-based IRMAK3 most appropriate in the ABP (weighted root mean square deviation, WRMSD$=$0.17 mm d^{-1}, $r^2=0.98$, for Nagrakata), and TURC model being in the first three rank of most of the sites, with the lowest error and highest correlation in NEH (WRMSD$=$0.10 mm d^{-1}, $r^2=0.92$, for Shillong), and EH (WRMSD$=$0.23 mm d^{-1}, $r^2=0.95$, for Gangtok). Findings reveal that IRMAK3 and TURC models performed equally well and were observed to be the best among selected models for the majority of stations followed by FAO24 Blaney-Criddle (FAO24BC), and 1957MAKK. Pair-wise regression equations were developed for preferred FAO56PM ET_0 estimates to ET_0 estimates by alternative methods. Cross-correlation of eighteen chose methods demonstrated that the five equations (i.e. four radiation- and one temperature-based) performed exceptionally well when contrasted with the FAO56PM model, thus being advised for assessing ET_0 under limiting data conditions as have yielded a better estimate of ET_0 with a small error.

Contents

* Corresponding author.
E-mail address: pkpnerist@gmail.com (P.K. Pandey).
Peer review under responsibility of International Research and Training Center on Erosion and Sedimentation and China Water and Power Press.

http://dx.doi.org/10.1016/j.iswcr.2016.02.003

1. Introduction

Evapotranspiration is the integrated process of evaporation and transpiration and is affected by meteorological variables, crop characteristics, and management practices, as well as environmental characteristics. ET_0 is the water evaporated from a reference surface, and was presented to quantify evaporative demand of the atmosphere, independent of the crop growth parameters and management practices (Allen, Pereira, Raes, & Smith, 1998; Zotarelli, Dukes, Romero, Migliaccio, & Morgan, 2010).

ET_0 is a highly nonlinear variable controlling varieties of issues in water management, hydrology, agriculture, irrigation scheduling, and proper planning of available fresh water resources. Among the different components of the hydrological cycle, a precise approximation of evapotranspiration is perhaps most difficult due to its complex interactions with the soil–plant–atmosphere system.

The reliable estimation of ET_0 is essential to estimate the net irrigation requirement, regional water resources planning, and management and to model the climate change effect. The direct approach to quantify ET_0 is using lysimeter measurement, or it could be indirectly calculated using the energy balance approach (or empirical models). However, the lysimetric approach is time-consuming and requires precise instrumentation. The indirect approach (methods) is based on site specific meteorological data, altitude, and latitude. The FAO56PM method is the most suitable indirect approach for accurate estimation of ET_0 and evaluation of other empirical models (Allen et al., 1998; Berti, Tardivo, Chiaudani, Rech, & Borin, 2014; Djaman et al., 2015; Lima et al., 2013; Pandey, Pandey, & Mahanta, 2014; Pereira, Allen, Smith, & Raes, 2015; Tabari et al., 2013; Widmoser, 2009).

The FAO Irrigation & Drainage Paper No. 56, (Allen et al., 1998), and ASCE Task Committee on Standardized Evapotranspiration Calculations (ASCE-EWRI, 2005) recommended that the FAO56PM method could be used as a standard equation to calculate ET_0. The FAO56PM method was validated against lysimeter measured data in diverse climatic conditions worldwide and reported the best method for ET_0 estimation (Allen et al., 2005; ASCE-EWRI, 2005; DehghaniSanij, Yamamoto, & Rasiah, 2004; Ghamarnia, Mousabeyg, Amiri, & Amirkhani, 2015; Itenfisu, Elliott, Allen, & Walter, 2003; Jain, Nayak, & Sudheer, 2008; Mohan & Arumugam, 1996; Xu, Peng, Ding, Wei, & Yu, 2013). Additionally, the FAO56PM now widely used as reference methods in the field of agronomy, irrigation water management, and other related fields for research purpose (Alexandris, Kerkides, & Liakatas, 2006).

The FAO56PM accounts for aerodynamic as well as physiological parameters, which requires several meteorological parameters such as air temperature, relative humidity, solar radiation or sunshine hour and mean wind speed at 2 m height. The accessibility of required information to utilize FAO56PM is poor under Indian conditions, particularly in NE, India because at most meteorological stations, the necessary information to utilize FAO56PM is not accessible, or if accessible then they have missing records this may be because of defective sensors or low upkeep.

The ET_0 estimation equations can be grouped in view of their data necessities as temperature based, radiation based, mass exchange based, and combination based. The execution of the particular ET_0 estimation method varies with climatic conditions and accessibility of meteorological information, and the data prerequisites change from method to method (Jensen et al., 1990).

To overcome data inadequacy issue, The FAO Revised and Improved Procedure for Crop Water Requirements (Smith et al., 1991) suggested that empirical methods be standardized for new destinations utilizing the FAO56PM model. Performance Assessment of the different ET_0 estimation methods is a challenging task. Jensen, Burman, and Allen (1990) ranked FAO56PM the best, followed by Kimberly Penman (Wright, 1982), and FAO24 Radiation (FAO24RD) (Doorenbos & Pruitt, 1977) regarding predictive power, in comparison with lysimeter based study. Steiner, Howell, and Schneider (1991) assessed Penman (Penman, 1963), FAO56PM, Jensen–Haise (JH) (Jensen et al., 1990), and Priestley–Taylor (PT) (Priestley & Taylor, 1972) models against lysimeter measured ET_0 under the climate of Southern Great Plains. Findings showed that the FAO56PM was the best to an approximation of ET_0, and well over the whole range of measured values. Yoder, Odhiambo, and Wright (2005) evaluated eight different ET_0 equations under climatic conditions of southern United States and concluded that TURC (Turc, 1961) may be an attractive alternative to FAO56PM model while Hargreaves (HAR) (Hargreaves & Samani, 1985) is not suitable for selected sites. Nandagiri and Kovoor (2006) assessed the performance of seven different ET_0 methods across the climatic conditions of India and reported the TURC is the best option under humid conditions. Suleiman and Hoogenboom (2007) compared the PT and FAO56PM under humid climate. Their outcomes demonstrated that the utilization of FAO56PM for calculating ET_0 would enhance the irrigation efficiency in Georgia, particularly in the mountainous and coastal areas. Fooladmand, Zandilak, and Ravanan (2008) compared different types of Hargreaves equations for 14 weather stations in the south of Iran taking FAO56PM as standard. The results support HAR equation is a better option under humid climate and low wind conditions. Tabari, Grismer, and Trajkovic (2013) compared 31 different ET_0 equations including developing two new radiation based equation (similar to that of Irmak et al. (2003)) in the northern, Iran (humid environment) considering FAO56PM as standard. Results revealed that developed equation performed better than other selected equations hence radiation-based model were the suitable option to estimate ET_0.

George and Raghuwanshi (2012) evaluated six different ET_0 models for four sites in India to identify the best and the worst performing methods at each location. The FAO24RD method identified as close agreement with FAO56PM for the humid site. Xu et al. (2013) evaluated PT, HAR, and TURC models for humid East China and reported TURC is a suitable choice for the region. Djaman et al. (2015) evaluated sixteen ET_0 methods against FAO56PM under Sahelian conditions in the Senegal River Valley and reported temperature–humidity based (Valiantzas1, Valiantzas, 2013), and solar radiation based (Valiantzas2, Valiantzas, 2013) over performed other selected methods are the suitable alternative of FAO56PM. Zhao et al. (2014) developed linear regression between two temperature-based models and standard FAO56PM. Good agreements were observed between the developed models and standard FAO56PM.

In spite of the advancement in studies identified with assessments of generally utilized ET_0 methods under humid conditions (Bogawski & Bednorz, 2014; Chen, Gao, Xu, Guo, & Ren, 2005;