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International Journal of Agriculture and Sustainable Development
IJASD

Review on Estimation and Forecast of Reference Evapotranspiration

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Citation | Ali. A, Haq. Z. U, Sheraz. K, "Review on Estimation and Forecast of Reference Evapotranspiration", IJASD, Vol. 07 Issue. 01 pp 65-92, March 2025.
DOI | https://doi.org/10.33411/ijasd/2025716592
Received | Feb 21, 2025 **Revised |** March 04, 2025 **Accepted |** March 06, 2025 **Published |** March 09, 2025.

The evapotranspiration process plays an essential role in the hydrological cycle, exerting a great influence on various aspects of life, including agricultural practices, water resource management, environmental assessments, and drought indices. However, many regions around the world lack reference sites or costly physical networks for direct evapotranspiration measurements, making estimation a vital criterion in these water-scarce areas. Over the years, researchers have employed empirical and/or physics-based models to compute reference evapotranspiration, a fundamental parameter for crop water requirements in diverse climatic regions. Moreover, forecasting reference evapotranspiration using climate data provides on-time information for irrigation scheduling and water resource management. Consequently, an array of techniques, from conventional statistical approaches to advanced deep learning techniques, have been employed by researchers to predict reference evapotranspiration. In this comprehensive review, a wide range of estimation and forecasting models for reference evapotranspiration is presented, encompassing both traditional techniques and cutting-edge forecasting methods.

Keywords: Evapotranspiration, Estimation of reference evapotranspiration, Forecasting of reference evapotranspiration

Introduction:

The term 'Evapotranspiration' was first defined by Thornthwaite in 1944 both actually and potentially, which is the major and largest element of the world water cycle. Evapotranspiration is the water loss from soil, open water surface, and crop surfaces to the atmosphere [1], [2], [3], [4], [5]. About 70% of the total global precipitation is accounted for by evapotranspiration, which consists of sublimation from snow packs, evaporation from open water surfaces and bare soil, and transpiration from vegetation through leaf stomata [6], [7]. Transpiration contributes 50% to 70% of the total evapotranspiration, which shows the impact of vegetation on overall evapotranspiration rates [8].

The rate of evapotranspiration that occurs if there is an unlimited and continuous supply of soil moisture is called potential evapotranspiration, or the theoretical rate of evapotranspiration in actual weather and vegetation conditions when soil moisture is not limiting (surface is saturated) Thornthwaite, [9]. Potential evapotranspiration is the empirical function of air temperature, day length, relative humidity, and wind speed. The rate at which the water from the ground and vegetation is evaporated to the atmosphere under actual conditions is called actual evapotranspiration. In a dry climate, the potential evapotranspiration is greater than the actual evapotranspiration, but in a rainy climate, the actual evapotranspiration is essentially equal to potential evapotranspiration [10], [11]. Considerable irrigation is required for crops that need to transpire water at a closer rate to the potential evapotranspiration rate in those areas where precipitation is less than the potential evapotranspiration [9].

The maximum rate of evapotranspiration for a specific crop when the availability of water to the crop is such that the maximum transpiration is satisfied is called crop evapotranspiration [10], [12]. Crop water requirements are directly related to crop evapotranspiration which is the product of reference evapotranspiration and a crop coefficient [13]. Reference evapotranspiration is the theoretical evapotranspiration for a reference crop (short well-watered green grasses i.e., alfalfa) [14], [15]. Crop evapotranspiration can be measured directly for a specific crop, but field measurement of crop evapotranspiration is laborious, requires more time, and is costly, due to which crop evapotranspiration can be calculated by using evapotranspiration from a reference surface and crop coefficient [16], [17]. A two-step approach is usually used to obtain the crop evapotranspiration [18];

i. Reference evapotranspiration is estimated which indicates the atmospheric demand of a reference crop at a substantial surface of growing green grass of the same height and having no shortage of water.

ii. Reference evapotranspiration is then converted into crop evapotranspiration by adjusting with a crop coefficient which depends on the type of crop, growth stage, density, and soil moisture [10], [19].

Therefore, precise quantification of reference evapotranspiration is necessary for crop water requirements, hydrological studies, environmental assessment, water resource management, and drought indices [20], [21], [22]. Atmospheric parameters (air temperature, wind speed, radiation, and difference in vapor pressure), types of vegetation, water availability on the surface, and soil moisture control the rate of reference evapotranspiration [23].

Objectives:

The primary objective of this study is to comprehensively assess and synthesize existing research on the estimation and forecasting of reference evapotranspiration, with a focus on evaluating the strengths, limitations, and applications of various models.

Novelty:

In this study a wide range of estimation and forecasting models for reference evapotranspiration is presented, encompassing both traditional techniques and cutting-edge forecasting methods.

Estimation of Reference Evapotranspiration:

Directly reference evapotranspiration is measured either by using lysimeters [24], [25], [26], [27], Eddy Covariance Techniques [28], [29], [30], [31], [32], [33], [34], and Bowen Ratio Energy Balance System, or from a reference crop such as a perennial grass [18], [35]. However, direct measurement of reference evapotranspiration is not always possible due to the requirement of highly accurate experimental design and high cost [36], [37]. Therefore, alternatively, reference evapotranspiration can be computed using mathematical approaches based on empirical relationships among the climatic variables [10], [38]. Different temperature-based [9], [18], radiation-based [18], [39], mass transfer-based [40], [41], [42], [43], and combination-based [10], [44], [45] approaches are used to estimate reference evapotranspiration.

The globally accepted and most widely used method for the estimation of reference evapotranspiration is the Penman-Monteith FAO56 (Food and Agriculture Organization Paper-56) method due to its better performance [46], [47]. However, a large number of required meteorological variables often restrict its applicability in regions of poorly observed and/or limited meteorological data [10], [48], [49], [50], [51], [52]. The missing variables can be calculated by analytical methods; however, they may result in inaccuracy. Similarly, the applicability of the Penman equation can be highly variable from region to region due to the non-availability of all the required meteorological parameters. As a result, it is necessary to have a substitute empirical method(s), which can be used for more precise computation of reference evapotranspiration in the area of interest with different input parameters and under different climatic conditions. Based on a literature survey it can be safely stated that most of the models used for estimation of reference evapotranspiration are given in Table 1. The abbreviation of variables, coefficients, and units is given in Table 2.

Table 1: Models for Estimation of Reference Evapotranspiration

S.No	Model Type	Model	Equation	Reference
1	Combination Based	Penman	$ET_o = \frac{(\frac{\Delta}{\Delta+\gamma})(R_n - G) + 6.43(\frac{\gamma}{\Delta+\gamma})(1 + 0.536u_2)(e_s - e_a)}{\lambda}$	[42]
2		Penman-Monteith	$ET_o = \left[\frac{\Delta(R_n - G) + K_{time}\rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma(1 + \frac{r_s}{r_a})}\right] / \lambda$	[53]
3		Wright-Penman	$ET_o = \frac{(\frac{\Delta}{\Delta+\gamma})(R_n - G) + 6.43(\frac{\gamma}{\Delta+\gamma})(a_w + b_w u_2)(e_s - e_a)}{\lambda}$ $a_w = 0.3 + 0.58\exp\left[-(\frac{J - 170}{45})^2\right]$ $b_w = 0.32 + 0.54\exp\left[-(\frac{J - 228}{67})^2\right]$ J is the Julian day of the year	[54]
4		Penman-Monteith FAO56	$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{(T_{mean}+273)} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$	[10]
5		Valiantzas	$ET_o = 0.051(1 - \alpha)R_s\sqrt{\lvert T_{mean} + 9.5\rvert} - 2.4(\frac{R_s}{R_a})^2 + 0.048(T_{mean} + 20)\left(1 - \frac{RH_{mean}}{100}\right)(0.5 + 0.536u_2) + 0.00012z$ Where $\alpha = 0.25$	[55]
6			$ET_o = 0.0393R_s\sqrt{\lvert T_{mean} + 9.50\rvert} - 0.19R_s^{0.6}(\varphi\frac{\pi}{180})^{0.15} + 0.048(T_{mean} + 20)(1 - \frac{RH}{100})u_2^{0.7}$	[56]
7			$ET_o =$	

			$0.0393R_s\sqrt{\lvert T_{mean}+9.50\rvert}-0.19R_s^{0.6}(\varphi\frac{\pi}{180})^{0.15}+0.0061(T_{mean}+20)(\lvert 1.12T_{mean}-T_{min}-2\rvert)^{0.7}$	
8			$ET_o = 0.0393R_s\sqrt{\lvert T_{mean}+9.50\rvert}-0.19R_s^{0.6}(\varphi\frac{\pi}{180})^{0.15}+0.078(T_{mean}+20)(1-\frac{RH_{mean}}{100})$	
9	Pan Evaporation Based	Singh	$ET_o = ET_{Pan}K_{pan}$ $K_{pan}=\frac{0.85(\Delta+\gamma)}{[\Delta+\gamma(1+0.33u_2)]}$	[57], [58]
10	Temperature Based	Blaney and Criddle	$ET_o = p(0.46T_{mean}+8.13)$	[59]
11			$ET_o = 25.4\frac{(1.8T_{mean}+32)}{180}p$	[60]
12		Linacre	$ET_o=\frac{\left(\frac{700(T_{mean}\pm 0.006z)}{100-\varphi}\right)+15(T_{mean}-T_{dew})}{80-T_{mean}}$	[61]
13		Modified Blaney and Criddle	$ET_o = a+b[p(0.46T_{mean}+8.13)]$ $a=0.0043RH_{min}-\left(\frac{n}{N}\right)-1.41$ $b=0.82-0.0041RH_{min}+1.07\left(\frac{n}{N}\right)+0.066u_{2d}-0.006RH_{min}\left(\frac{n}{N}\right)-0.0006RH_{min}u_{2d}$	[14]
14		Hargreaves and Samani	$ET_o = [0.0023R_a(T_{mean}+17.8)(T_{max}-T_{min})^{0.5}]/\lambda$	[39]
15		Trajkovic	$ET_o = [0.0023R_a(T_{mean}+17.8)(T_{max}-T_{min})^{0.424}]/\lambda$	[62]
16		Tabari & Talaee-1	$ET_o = [0.0031R_a(T_{mean}+17.8)(T_{max}-T_{min})^{0.5}]/\lambda$	[3]
17		Tabari & Talaee-2	$ET_o = [0.0028R_a(T_{mean}+17.8)(T_{max}-T_{min})^{0.5}]/\lambda$	[3]
18		Droogers & Allen-1	$ET_o = [0.003R_a(T_{mean}+20)(T_{max}-T_{min})^{0.4}]/\lambda$	[63]

19		Droogers & Allen-2	$ET_o = [0.0025R_a(T_{mean} + 16.8)(T_{max} - T_{min})^{0.5}]/\lambda$	[48]
20		Dorji	$ET_o = [0.002R_a(T_{mean} + 33.9)(T_{max} - T_{min})^{0.296}]/\lambda$	[64]
21		Baier & Robertson	$ET_o = [0.109R_a + 0.157\,T_{max} + 0.158\,(T_{max} - T_{min}) - 5.39]$	[65]
22		Ahooghalandari-1	$ET_o = \left[0.252\left(\frac{R_a}{\lambda}\right) + 0.221\,T_{mean}\left(1 - \frac{RH_{mean}}{100}\right)\right]$	[66]
23		Ahooghalandari-2	$ET_o = \left[0.29\left(\frac{R_a}{\lambda}\right) + 0.15\,T_{max}\left(1 - \frac{RH_{mean}}{100}\right)\right]$	[66]
24		Schendel	$ET_o = 16\frac{T_{mean}}{RH}$	[63]
25		Ramazan Method	$ET_o = [(0.817 + 0.00022z)(0.0023R_a)(T_{mean} + 17.8)(T_{max} - T_{min})^{0.5}]/\lambda$	[67]
26		Modified Hargreaves	$ET_o = [0.00193R_a(T_{mean} + 17.8)(T_{max} - T_{min})^{0.517}]/\lambda$	[68]
27			$ET_o = 0.1555R_a(T_{max} - T_{min})^{0.5}(0.09967 + 0.00428T_{mean})$	[69]
28			$ET_o = 10^{-4}(0.002z + 7)(T_{mean} + 36.6)(T_{max} - T_{min})^{0.5}R_a$	[70]
29		Heydrari-Heydari	$ET_o = 0.0023(T_{mean} + 9.519)(T_{max} - T_{min})^{0.611}.\frac{R_a}{\lambda}$	[71]
30		Hadria	$ET_o = 0.002(T_{mean} + 26.3)(T_{max} - T_{min})^{0.397}.\frac{R_a}{\lambda}$	[72]
31		Samani	$ET_o = 0.0135[0.00185(T_{max} - T_{min})^2 - 0.0433(T_{max} - T_{min}) + 0.4023](T_{mean} + 17.8)(T_{max} - T_{min})^{0.5}.\frac{R_a}{\lambda}$	[73]
32	Radiation Based	FAO-24 Radiation	$ET_o = (1.066 - 0.0013RH_{mean} + 0.045u_2 - 0.0002RH_{mean}u_2 - 0.000031RH_{mean}^2 - 0.0011u_2^2).\left(\frac{\Delta}{\Delta + \gamma}\right)\left(\frac{R_s}{\lambda}\right) - 0.3$	[18]

33		Makkink	$ET_o = 0.61\left(\frac{R_s}{\lambda}\right)\left(\frac{\Delta}{\Delta+\gamma}\right) - 0.12$	[74]
34		Modified Makkink	$ET_o = 0.7\left(\frac{\Delta}{\Delta+\gamma}\right)\left(\frac{R_s}{\lambda}\right)$	[75]
35			$ET_o = c\left[\left(0.25 + 0.50\frac{n}{N}\right)R_a\right]\left(\frac{\Delta}{\Delta+\gamma}\right)$ where c is the adjustment factor and a function of mean humidity and daytime wind conditions	[18]
36		Priestly & Tayler	$ET_o = 1.26\left(\frac{R_n - G}{\lambda}\right)\left(\frac{\Delta}{\Delta+\gamma}\right)$	[76]
37		Hargreaves	$ET_o = 0.0135(T_{mean} + 17.8)(R_s/\lambda)$	[77]
38		Abtew-1	$ET_o = 0.52\, T_{max}\, R_s/\lambda$	[78]
39		Abtew-2	$ET_o = (T_{max}/56)(R_s/\lambda)$	
40		Irmak-1	$ET_o = -0.611 + 0.149\, R_s + 0.079\, T_{mean}$	[79]
41		Irmak-2	$ET_o = 0.469 + 0.289\, R_n + 0.023\, T_{mean}$	
42		Tabari & Talaee-3	$ET_o = -0.642 + 0.174\, R_s + 0.0353\, T_{mean}$	[3]
43		Tabari & Talaee-4	$ET_o = -0.478 + 0.156\, R_s - 0.0112 T_{max} + 0.0733\, T_{min}$	
44		Oudin	$ET_o = \left[\left(\frac{R_s}{\lambda}\right)(T_{mean} + 5)/100\right]$, (for $T_{mean} + 5 > 0$)	[80]
45		Jensen & Haise	$ET_o = (0.025\, T_{mean} + 0.08)(R_s/\lambda)$	[81]
46		Jensen	$ET_o = C_T(T_{mean} - C_x)K_t R_a (T_{max} - T_{min})^{0.5}$ $K_t = 0.00185(T_{max} - T_{min})^2 - 0.0433(T_{max} - T_{min}) + 0.4023$ $C_T = \frac{1}{45 - \left(\frac{z}{137}\right) + \left(\frac{365}{e_{s.max} - e_{s.min}}\right)}$ $C_x = 22.5 - 0.14(e_{s.max} - e_{s.min}) - \frac{z}{500}$ $e_{s.max} = \exp\frac{19.08 T_{max} + 429.41}{T_{max} + 237.3}$	[11]

			$e_{s.max} = \exp\frac{19.08T_{min} + 429.41}{T_{min} + 237.3}$	
47		Turc	$ET_o = \frac{0.013T_{mean}}{T_{mean}+15}\left(\frac{23.8856R_s+50}{\lambda}\right)$ for RH ≤ 50% $ET_o = \left(1 + \frac{50-RH_{mean}}{70}\right)\frac{0.013T_{mean}}{T_{mean}+15}\left(\frac{23.8856R_s+50}{\lambda}\right)$ for RH ≥ 50%	[82]
48		Modified Turc	$ET_o = 0.013C_u(23.88R_s + 50)\ \frac{T_{mean}}{T_{mean} + 15}$ $C_u = -0.0211u_2^2 + 0.1109u_2 + 0.9004$	[83]
49		Turc (1961) with reduced wind data	$ET_o = (23.8856R_s + 50)\frac{0.013T_{mean}}{T_{mean} + 15}\left[1 + W_{RH}(0.71 - 1.43\frac{RH}{100})\right]$ $W_{RH} = 1$ for $RH < 50\%$, and $W_{RH} = 0$ for $RH \geq 50\%$	[84]
50		Valiantzas	$ET_o = 0.00668R_a\sqrt{\lvert T_{mean} + 9.5\rvert.(T_{max} - T_{min})} - 0.0696(T_{max} - T_{min}) - 0.024(T_{mean} + 20)\left(1 - \frac{RH_{mean}}{100}\right) - 0.00455R_a(T_{max} - T_{dew})^{0.5} + 0.0984(T_{mean} + 17)(1.03 + 0.00055(T_{max} - T_{min})^2 - \frac{RH_{mean}}{100})$ $T_{dew} = \frac{116.91 + 273.3\ln(e_a)}{16.78 - \ln(e_a)}$	[56]
51		Modified Bair-Robertson	$ET_o = 0.0039\ T_{max} + 0.184\ (T_{max} - T_{min}) + 0.1136R_a + 2.811(e_s - e_a) - 4$	[85]
52		Caprio	$ET_o = 0.1092708T_{mean} + (0.0060706)R_s$	[86]
53		Ritchie equation	$ET_o = \alpha_1[3.87 \times 10^{-3}R_s(0.6T_{max} + 0.4T_{min} + 29)]$ If $5 < T_{max} \leq 35^oC$, then $\alpha_1 = 1.1$ $T_{max} > 35^oC$, then $\alpha_1 = 1.1 + 0.05(T_{max} - 35)$	[87]

			$T_{max} < 5^{o}C$, then $\alpha_1 = 0.01exp\,[0.18(T_{max} + 20)]$	
54		Copais Equation	$ET_o = 0.057 + 0.277C_2 + 0.643C_1 + 0.0124C_1$ $C_1 = 0.6416 - 0.00784RH_{mean} + 0.372R_s - 0.00264R_s.RH_{mean}$ $C_2 = -0.0033 + 0.00812T_{mean} + 0.101R_s + 0.00584R_s.T_{mean}$	[88]
55		Castaneda-Rao	$ET_o = 0.7\left(\frac{\Delta}{\Delta+\gamma}\right)\left(\frac{R_s}{\lambda}\right) - 0.12$	[89]
56		McGuinness-Bordne	$ET_o = (0.00597T_{mean} - 0.0838)\,R_s$	[90]
57		Stephens	$ET_o = (0.0158T_{mean} + 0.09).\frac{R_s}{\lambda}$	[91]
58		Stephens and Stewart	$ET_o = (0.0148T_{mean} + 0.07).\frac{R_s}{\lambda}$	[92]
59	Mass Transfer Based	Dalton	$ET_o = (3.648 + 0.722\,u_2)(e_s - e_a)$	[40]
60		Meyer	$ET_o = (3.75 + 0.503u_2)(e_s - e_a)$	[41]
61		Rohwer	$ET_o = (3.3 + 0.891\,u_2)(e_s - e_a)$	[93]
62		WMO	$ET_o = (1.298 + 0.934\,u_2)(e_s - e_a)$	[94]
63		Brockamp & Wenner	$ET_o = 0.5435u_2^{0.456}(e_s - e_a)$	[95]
64		Mahringer	$ET_o = (0.286\,(u_2)^{0.5})\,(e_s - e_a)$	[96]
65		Penman	$ET_o = 0.376(e_s - e_a)\,u_2^{0.76}$	[42]
66		Modified Penman	$ET_o = (2.625 + 0.000479u_2)(e_s - e_a)$	[97]
67		Romanenko	$ET_o = 0.00006(100 - RH_{mean})(T_{mean} + 25)^2$	[43]
68		Modified Romanenko	$T_o = 4.5\left(1 + \frac{T_{mean}}{25}\right)^2\left(1 - \frac{e_a}{e_s}\right)$	[80]
69		Albrecht	$ET_o = (1.005 + 2.97\,u_2)(e_s - e_a)$	[98]
70		Trabert	$ET_o = 0.3075u_2^{0.5}(e_s - e_a)$	[99]
71		Szasz	$ET_o = 0.0053(T_{mean} + 21)^2(1 - RH_{mean}/100)^{\frac{2}{3}}.f(u)$ $f(u) = 0.0519u_2 + 0.905$	[100]

Table 2: Variables abbreviation used in Table 1

Notation	Description	Unit
ET_o	reference evapotranspiration	mm/day
Δ	the slope of saturation vapor pressure curve at mean air temperature	kPa/°C
γ	psychrometric constant = 0.054	kPa/°C
λ	latent heat of vaporization = 2.45	MJ/kg
R_n	net radiation	MJ/m^2-day
G	soil heat flux density ≈ 0	MJ/m^2-day
u_2	daily mean wind speed at 2m height	m/sec
e_a	saturation vapor pressure	kPa
e_s	actual vapor pressure	kPa
K_{time}	unit conversion equal to 86400 for ET in mm/day	
ϱ_a	mean air density at constant pressure	kg/m^3
c_p	specific heat of the air	MJ/kg_°C
r_s	bulk surface resistance	s/m
r_a	aerodynamic resistance	s/m
p	Mean annual percentage of daytime hours = 0.274	
T_{mean}	mean daily temperature	°C
T_{max}	daily maximum temperature	°C
T_{min}	daily minimum temperature	°C
R_s	solar radiation	MJ/m^2-day
R_a	extraterrestrial radiation	MJ/m^2-day
RH_{mean}	Mean daily relative humidity	%
RH_{max}	daily maximum relative humidity	%
RH_{min}	Daily minimum relative humidity	%
z	elevation above mean sea level	m
Φ	Latitude	degrees
ET_{pan}	Pan evapotranspiration	mm/day
n/N	relative sunshine duration	
T_{dew}	dew point temperature	°C

Empirical models have historically played a significant role in the estimation of reference evapotranspiration. Studies by Kashyap and Panda. [101], Landeras et al. [102], Sabziparvar et al. [103], and others investigated several equations for reference evapotranspiration estimation. DehghaniSanij et al. [104] compared various models with lysimeter data and underscored the reliability of the Penman-Monteith model. Additionally, in different climatic conditions, researchers found specific models to be more suitable: the Turc [82] model for humid conditions [83], the Abtew model for various global applications [105], [106], [107], [108], and the Priestly–Taylor, Hargreaves-Samani, and Makkink models for arid regions, semi-arid regions, and humid regions, respectively [67], [109], [110], [111]. This performance of different models in specific environments is due to; Climate and weather patterns (models that account for temperature and humidity such as the Penman-Monteith method tend to perform better in temperate climates with moderate temperature and humidity levels. Models that incorporate radiation and sunshine data such Hargreaves-Samani method tend to perform better in regions with high solar radiation and sunshine hours. Models that account for wind and precipitation patterns such as the FAO-56 method tend to perform better in regions with high wind speeds and precipitation variability), Vegetation, and land use (Crop types and growth stages: FAO-56 performs better in agricultural regions with diverse crop types and growth stages and Vegetation density and height), Topography and soil (Elevation and slope, soil type and moisture), Data availability and quality, Model complexity and Calibration, and Regional and local factors

Forecasting of Reference Evapotranspiration:

Accurate forecast reference evapotranspiration is pivotal for crop planning, irrigation scheduling, and water allocation. Several methods have been employed to forecast reference evapotranspiration which are broadly classified;

Statistical Models: Regression models have been used to forecast reference evapotranspiration based on historical meteorological data [112].

Artificial Neural Networks (ANNs): ANNs have shown promise in forecasting reference evapotranspiration using historical data by learning complex relationships between reference evapotranspiration and meteorological parameters [113].

Physical Models: Physical models such as the Penman-Monteith equation can be employed for forecasting by utilizing the current or forecasted meteorological data. These models require detailed meteorological data and may be computationally intensive [114].

Machine Learning: Machine learning algorithms, trained on historical meteorological data forecast reference evapotranspiration. While combining statistical and physical models, these algorithms provide accurate forecasts [115].

Autoregressive Integrated Moving Average (ARIMA) models have historically been used for time series forecasting [116], [117], [118]. However, recent years have seen increased interest in ANN models [119], [120], [121], [122], [123], [124], [125]. Moreover, advanced techniques in deep learning hold promise for the future of reference evapotranspiration forecasting [125], [126], [127], [128]. The summary of the published articles that used different models for a forecast of reference evapotranspiration is given in Table 3.

The studies presented in Table 3 reflect the capability of ANN and machine learning models in the forecast of reference evapotranspiration. The ANN models show greater performance compared to other conventional models. Deep learning models, particularly RNN and LSTM are well suited for handling temporal dependencies by distributing representations, temporal hierarchies, automatic feature learning, and flexibility and adaptability. Traditional statistical models like ARIMA and VAR rely on the explicit modeling of temporal relationships using predefined equations. These models have limitations of assuming stationarity, limited flexibility, and require manual feature engineering. Deep learning models yield outstanding performance in the forecast of reference evapotranspiration. However, Some of the ANN and most recent deep learning techniques such as Recurrent Neural Networks (RNN), Convolutional Neural Networks (CNN), Generative Adversarial Neural Networks (GANN), Gated Recurrent Units (GRU), Transformers, Temporal-Convolutional Neural networks (TCNN), Long-Short Term Memory (LSTM), and hybrid models have very limited utilization in forecast reference evapotranspiration.

Artificial Neural Network (ANN), Multivariate Relevance Vector Machine (MVRVM), Support Vector Machine (SVM), Gaussian Process Regression (GPR), Long short Term Memory (LSTM), Seasonal Auto-Regressive Integrated Moving Average (SARIMA), Group Method of Data Handling (GMDH), One-Dimensional Convolutional Neural Network (1D-CNN), Random Forest (RF), Multiple Linear Regression (MLR), Adaptive Neuro Fuzzy Inference System (ANFIS), Numerical Weather Prediction (NWP), Auto-Regressive Integrated Moving Average (ARIMA), Multilayer Perceptron (MP), Generalized Feed Forward (GFF), Linear Regression (LR), Probabilistic Neural Network (PNN), Genetic Programming (GP), Temporal Convolution Neural Network (TCNN), Adaptive Boosting Machine Learning (ABML), Vector Auto-Regression (VAR), K-Nearest Neighbor (K-NN), Deep Neural Network (DNN), Support Vector Machine (SVM), Least Square SVM (LSSVM), Genetic Expression Programming (GEP), Moving Average (MA), Auto-Regression (AR), Auto-Regressive Moving Average (ARMA), Generalized Regression Neural Network (GRNN), Auto Encoder-Decoder Bidirectional LSTM (AED-BiLSTM)

Table 3: Forecast of Reference Evapotranspiration

S. No	Forecast	Model(s)	References
1	Monthly	ANN	[129]
2	Daily	ANN and MVRVM	[130]
3	Daily	GPR and Wavelet-GPR	[131]
4	Monthly	SARIMA, GMDH, and SVM	[132]
5	Daily	LSTM, 1D-CNN, CNN-LSTM, ANN, and RF	[133]
6	Monthly	SVM, ANFIS, ANN, MLR	[134]
7	One-day Ahead	ANN	[119]
8	Daily	NWP	[135]
9	Summer ET_o	Multiple Global NWP	[136]
10	Daily	NWP	[137]
11	Daily	NWP	[138]
12	Daily ET_o	NWP	[139]
13	Weekly	ARIMA and ANN	[117]
14	Weekly	ANN	[123]
15	Near Future	GFF, LR, MP, and PNN	[124]
16	Monthly	GP, SVM, ANN, and SVM–Wavelet	[121]
17	Daily	VAR	[140]
18	Daily	SVM, ANN	[141]
19	Daily	k-NN, ANN, and ABML	[142]
20	Daily	DNN, LSTM, TCNN	[143]
21	Daily	SVR	[144]
22	Monthly	SVM and GEP	[145]
23	Daily	GEP and ANN	[146]
24	Daily	RF and GEP	[147]
25	Daily	Univariate AR and MA	[148]
26	Daily	LSTM	[149]
27	Daily	AR, MA, ARMA, ARIMA, LSSVM, ANFIS, and GRNN	[150]
28	Weekly	AED-BiLSTM	[151]

The accuracy of forecast reference evapotranspiration is evaluated by using different models and techniques. Ballesteros et al. [152], used the Penman-Monteith equation as a reference methodology and compared the forecast reference evapotranspiration from 2011 to 2012 by using ANN and Hargreaves-Samani equation. The Hargreaves-Samani model is also applied by Luo et al. [139], for daily forecast reference evapotranspiration with an allowable degree of accuracy. Pelosi et al. [138] used Hargreaves-Samani and Priestly-Taylor methods for daily forecast reference evapotranspiration with a short-term lead time of 1 to 5 days using Numerical Weather Prediction (NWP) outputs in Southern Italy. Yang et al. [153], utilized the public weather forecast for size locations of wide climatic ranges in China to forecast 7 days daily reference evapotranspiration.

Short, Medium, and Long-Term Forecast Reference Evapotranspiration:

Some studies forecasted the reference evapotranspiration through meteorological data for different periods [48], [154], [155]. [137], used two basic and primary approaches, the time series and ANNN, to forecast the medium to long-term reference evapotranspiration by using meteorological data. Tracy et al. [156], utilized metrological data and forecasted the yearly reference evapotranspiration by using the ARIMA model. Marino et al., [156], recommended the seasonal ARIMA model for accurate monthly forecast reference evapotranspiration. While assessing short-term to medium irrigation decisions, some investigators revealed that forecasting daily and weekly reference evapotranspiration is more effective in decision-making [102], [129], [157], [16]. Therefore, the trend is turned from a long-medium-term range to a medium-short-term range, because the forecast of daily reference evapotranspiration is more helpful in scheduling short-term irrigation activities. A modified daily mean model is presented by [152], [123], and [158] to forecast the daily reference evapotranspiration. Similarly, [137], forecasted the daily reference evapotranspiration with good results for 9 days lead time by using the Penman-Monteith equation.

Forecast of Reference Evapotranspiration by Satellite Observations:

In past studies, different data sources were utilized to forecast reference evapotranspiration. Most of the researchers have utilized the ground-based observed meteorological data to quantify the reference evapotranspiration and project it for the future [111], [135], [141], [143], [159], [160]. However, over the large areas, the meteorological variables are nonhomogeneous which have different effects on reference evapotranspiration. So, it is important to evaluate the forecast reference evapotranspiration by different models, from different data sources, and for different localities. Several remote sensing models have been developed for estimating reference evapotranspiration, including:

SEBAL (Surface Energy Balance Algorithm for Land) uses the combination of satellite data (e.g., Landsat, MODIS) and meteorological data to estimate the surface energy balance components, including reference evapotranspiration [161]. METRIC (Mapping Evapotranspiration at High Resolution with Internal Calibration) is another popular remote sensing model for estimating reference evapotranspiration [162]. It uses a combination of satellite data (e.g., Landsat, ASTER) and meteorological data to estimate reference evapotranspiration at high spatial resolution. MOD16 (Moderate Resolution Imaging Spectroradiometer Global Evapotranspiration) is a global reference evapotranspiration product derived from MODIS satellite data [163]. It provides daily reference evapotranspiration estimates at 1 km spatial resolution, which can be useful for regional and global water resources management.

Optical remote sensing uses visible and infrared radiation to estimate reference evapotranspiration with high spatial resolution (up to 1-2 meters). Some common optical remote sensing methods for estimation of reference evapotranspiration include Vegetation Indices, surface temperature, and albedo. While microwave remote sensing uses longer wavelengths (around 1-10cm) to estimate reference evapotranspiration. Soil moisture and vegetation water content estimates from microwave radiation are related to evapotranspiration.

Satellite-based estimation of reference evapotranspiration has several advantages e.g., high spatial resolution and coverage, ability to estimate reference evapotranspiration, and potential for real-time monitoring. While compared to ground-based meteorological data, all satellite-based data parameters have some level of uncertainty that needs to be considered.

Limitations are experienced in obtaining accurate reference evapotranspiration from remote sensing techniques due to the temporal resolution of satellite overpasses and/or gaps in images due to cloud covers [164]. Therefore, the comparison of reference evapotranspiration from satellite data with actual reference evapotranspiration needs proper attention. Satellite observations are combined with forecast reference evapotranspiration to schedule and control the irrigation by [165], [166], and [166]. The best results were observed by [167], while comparing the forecast reference Evapotranspiration from FRET and observed reference evapotranspiration.

Reliability of Forecasted Reference Evapotranspiration:

The reliability of estimated reference evapotranspiration from forecasted meteorological data must be analyzed with actual meteorological data for effective decisions in water management. The author in [168], compared the results to evaluate the estimated reference evapotranspiration, irrigation scheduling, and yield from forecasted meteorological data with observed data. Another study [160], separately considered the accuracy by using the past and forecasted data inputs, to evaluate the reliability of short-term weather forecasts. In contrast to the studies presented in Table 3, some studies have utilized the forecasted meteorological data to forecast reference evapotranspiration, such as public weather forecasts [124], [135], [137], [153]. However, it is not clear from the previous studies which scenario is more accurate to forecast reference evapotranspiration, either using future forecasted meteorological data or using the historical reference evapotranspiration data for future projections.

Sensitivity in Forecasting Reference Evapotranspiration:

According to [152], for high crop water demanding periods the accurate forecast reference evapotranspiration is of utmost importance. Because the poor quantification of crop water requirement can affect the crop yield and/or water utilization. Scheduling the next irrigation activity based on the previous week's reference evapotranspiration without taking into account the variation in weather conditions from one week to the next, can result in over and/or under irrigation [169]. In this context, accurate forecast reference evapotranspiration is important for improving irrigation efficiency. Usually, the output of the forecasting models is available to scientists and researchers but not to the end users, farmers, and irrigation managers. So, more precise techniques and models are needed to accurately forecast reference evapotranspiration to enhance the efficient use of water.

Conclusion:

Evapotranspiration is a critical parameter for various applications, including irrigation planning, and climatological and hydrological studies. However, the high cost associated with installing and maintaining physical networks for measuring evapotranspiration, limited data is available in many regions worldwide. Additionally, various local, regional, and global factors affect reference evapotranspiration, adding uncertainty to its estimation. This uncertainty is further compounded by the influence of climatic factors.

Over the past century, empirical and physically based models have been used to estimate reference evapotranspiration, with the Penman-Monteith FAO56 model widely accepted due to its superior performance. However, the limited availability of complete climatic data needed for this model has led to the use of temperature-based models which use fundamental meteorological data collected at most weather stations.

To meet the need for accurate crop water requirement estimation, forecast reference evapotranspiration is indispensable. Reference evapotranspiration is a complex, non-linear, and dynamic phenomenon. Researchers have employed diverse techniques, from traditional statistical models to more recent deep learning models, to forecast reference evapotranspiration. Deep learning models show remarkable promise in forecast reference evapotranspiration. Nonetheless, the hydrology and climatology fields are yet to fully explore the potential of the most recent deep-learning models, and future research should delve into these untapped possibilities.

Challenges and Future Directions:

The methods and models presented in this study have significantly enhanced our understanding of reference evapotranspiration, but challenges remain. Incorporating real-time data, addressing model accuracy, and considering the implications of climate change are avenues ripe for exploration. Further research in these areas promises to refine existing models and develop novel, robust forecasting techniques.

References:

[1] D. E. S. M. Bateni, "Surface heat flux estimation with the ensemble Kalman smoother: Joint estimation of state and parameters," *Water Resour. Res.*, 2012, doi: https://doi.org/10.1029/2011WR011542.

[2] D. E. S. M. Bateni, "Relative efficiency of land surface energy balance components," *Water Resour. Res.*, 2012, doi: https://doi.org/10.1029/2011WR011357.

[3] H. Tabari and P. H. Talaee, "Local Calibration of the Hargreaves and Priestley-Taylor Equations for Estimating Reference Evapotranspiration in Arid and Cold Climates of Iran Based on the Penman-Monteith Model," *J. Hydrol. Eng.*, vol. 16, no. 10, pp. 837–845, Jan. 2011, doi: 10.1061/(ASCE)HE.1943-5584.0000366.

[4] E. Tajfar, S.M. Bateni, V. Lakshmi, and M. Ek, "Estimation of surface heat fluxes via variational assimilation of land surface temperature, air temperature and specific humidity into a coupled land surface-atmospheric boundary layer model," *J. Hydrol.*, vol. 583, p. 124577, 2020, doi: https://doi.org/10.1016/j.jhydrol.2020.124577.

[5] Tongren Xu, Xinlei He, Sayed M. Bateni, Thomas Auligne, Shaomin Liu, Ziwei Xu, Ji Zhou and Kebiao Mao, "Mapping regional turbulent heat fluxes via variational assimilation of land surface temperature data from polar orbiting satellites," *Remote Sens. Environ.*, vol. 221, pp. 444–461, 2019, doi: https://doi.org/10.1016/j.rse.2018.11.023.

[6] S. P. Good, D. Noone, and G. Bowen, "Hydrologic connectivity constrains partitioning of global terrestrial water fluxes," *Science (80-.).*, vol. 349, no. 6244, pp. 175–177, Jul. 2015, doi: 10.1126/SCIENCE.AAA5931/SUPPL_FILE/AAA5931-GOOD-SM.PDF.

[7] Pankaj Kumar Pandey; Vanita Pandey, "Modification of the radiation-based Abtew reference evapotranspiration model under humid climate, Northeast India," *H2Open J.*, vol. 6, no. 2, pp. 208–222, 2023, doi: https://doi.org/10.2166/h2oj.2023.069.

[8] R. M. Maxwell and L. E. Condon, "Connections between groundwater flow and transpiration partitioning," *Science (80-.).*, vol. 353, no. 6297, pp. 377–380, Jul. 2016, doi: 10.1126/SCIENCE.AAF7891/SUPPL_FILE/MAXWELL.SM.PDF.

[9] C. W. Thornthwaite, "An Approach toward a Rational Classification of Climate," *Geogr. Rev.*, vol. 38, no. 1, p. 55, Jan. 1948, doi: 10.2307/210739.

[10] M. S. Richard G. Allan, L. S. Pereira, Dirk Raes, "Crop evapotranspiration-Guidelines for computing crop water requirements-," FAO Irrigation and drainage paper 56. Accessed: Mar. 06, 2025. [Online]. Available: https://www.researchgate.net/publication/235704197_Crop_evapotranspiration-Guidelines_for_computing_crop_water_requirements-FAO_Irrigation_and_drainage_paper_56

[11] M. E. Jensen and R. G. Allen, "Evaporation, Evapotranspiration, and Irrigation Water Requirements," *Evaporation, Evapotranspiration, Irrig. Water Requir.*, pp. 1–744, Apr. 2016, doi: 10.1061/9780784414057.

[12] P. Duce, R. L. Snyder, S. T. Soong, and D. Spano, "Forecasting reference evapotranspiration," *Acta Hortic.*, vol. 537, pp. 135–141, 2000, doi:

10.17660/ACTAHORTIC.2000.537.13.
[13] K. Chartzoulakis and M. Bertaki, "Sustainable Water Management in Agriculture under Climate Change," *Agric. Agric. Sci. Procedia*, vol. 4, pp. 88–98, 2015, doi: https://doi.org/10.1016/j.aaspro.2015.03.011.
[14] J. Doorenbos, "Crop Water Requirement," *FAOIRRIGATIONAND DRAINAGEPAPER*, pp. 1–144, 1977, [Online]. Available: https://www.fao.org/4/s8376e/s8376e.pdf
[15] M. E. Jensen, J. L. Wright, and B. J. Pratt, "Estimating Soil Moisture Depletion from Climate, Crop and Soil Data," *Trans. ASAE*, vol. 14, no. 5, pp. 954–0959, 1971, doi: 10.13031/2013.38430.
[16] S. S. Eslamian, S. A. Gohari, M. J. Zareian, and A. Firoozfar, "Estimating Penman-Monteith Reference Evapotranspiration Using Artificial Neural Networks and Genetic Algorithm: A Case Study," *Arab. J. Sci. Eng.*, vol. 37, no. 4, pp. 935–944, Apr. 2012, doi: 10.1007/S13369-012-0214-5/METRICS.
[17] A. Rahimikhoob and M. Hosseinzadeh, "Assessment of Blaney-Criddle Equation for Calculating Reference Evapotranspiration with NOAA/AVHRR Data," *Water Resour. Manag.*, vol. 28, no. 10, pp. 3365–3375, May 2014, doi: 10.1007/S11269-014-0670-7/METRICS.
[18] W. O. P. J. Doorenbos, "guidelines for predicting crop water requirements," *FAO Irrig. Drain. Pap.*, 1977, [Online]. Available: https://www.fao.org/4/f2430e/f2430e.pdf
[19] P. Martí, J. Manzano, and Á. Royuela, "Assessment of a 4-input artificial neural network for ETo estimation through data set scanning procedures," *Irrig. Sci.*, vol. 29, no. 3, pp. 181–195, May 2011, doi: 10.1007/S00271-010-0224-6/METRICS.
[20] S. Goroshi, R. Pradhan, R. P. Singh, K. K. Singh, and J. S. Parihar, "Trend analysis of evapotranspiration over India: Observed from long-term satellite measurements," *J. Earth Syst. Sci.*, vol. 126, no. 8, pp. 1–21, Dec. 2017, doi: 10.1007/S12040-017-0891-2/METRICS.
[21] O. Kisi and M. Zounemat-Kermani, "Comparison of Two Different Adaptive Neuro-Fuzzy Inference Systems in Modelling Daily Reference Evapotranspiration," *Water Resour. Manag.*, vol. 28, no. 9, pp. 2655–2675, May 2014, doi: 10.1007/S11269-014-0632-0/METRICS.
[22] Z. T. L. Liyan Tian and S. M. Quiring, "Developing a hybrid drought index: Precipitation Evapotranspiration Difference Condition Index," *Clim. Risk Manag.*, vol. 29, p. 100238, 2020, doi: https://doi.org/10.1016/j.crm.2020.100238.
[23] M. Jung *et al.*, "Recent decline in the global land evapotranspiration trend due to limited moisture supply," *Nat. 2010 4677318*, vol. 467, no. 7318, pp. 951–954, Oct. 2010, doi: 10.1038/nature09396.
[24] H. U. Bogachan Benli , Suleyman Kodal , Adem Ilbeyi, "Determination of evapotranspiration and basal crop coefficient of alfalfa with a weighing lysimeter," *Agric. Water Manag.*, vol. 81, no. 3, pp. 358–370, 2006, doi: https://doi.org/10.1016/j.agwat.2005.05.003.
[25] X. Jia, M. D. Dukes, J. M. Jacobs, and S. Irmak, "WEIGHING LYSIMETERS FOR EVAPOTRANSPIRATION RESEARCH IN A HUMID ENVIRONMENT," *Trans. ASABE*, vol. 49, no. 2, pp. 401–412, 2006, doi: 10.13031/2013.20414.
[26] F. R. Miranda, R. S. Gondim, and C. A. G. Costa, "Evapotranspiration and crop coefficients for tabasco pepper (Capsicum frutescens L.)," *Agric. Water Manag.*, vol. 82, no. 1–2, pp. 237–246, 2006, doi: https://doi.org/10.1016/j.agwat.2005.07.024.
[27] L.E. Williams and J. E. Ayars, "Water use of Thompson Seedless grapevines as affected by the application of gibberellic acid (GA3) and trunk girdling – practices to

increase berry size," *Agric. For. Meteorol.*, vol. 129, no. 1–2, pp. 85–94, 2005, doi: https://doi.org/10.1016/j.agrformet.2004.11.007.

[28] J. Amayreh and N. Al-Abed, "Developing crop coefficients for field-grown tomato (Lycopersicon esculentum Mill.) under drip irrigation with black plastic mulch," *Agric. Water Manag.*, vol. 73, no. 3, pp. 247–254, 2005, doi: https://doi.org/10.1016/j.agwat.2004.10.008.

[29] Dennis Baldocchi, "Assessing ecosystem carbon balance: Problems and prospects of the eddy covariance technique," Global Change Biology. Accessed: Mar. 06, 2025. [Online]. Available: https://www.researchgate.net/publication/51997481_Assessing_ecosystem_carbon_balance_Problems_and_prospects_of_the_eddy_covariance_technique

[30] Kimberly Novick, Ram Oren, Paul Stoy, and G. K. Jehn-Yih Juang, Mario Siqueira, "The relationship between reference canopy conductance and simplified hydraulic architecture," *Adv. Water Resour.*, vol. 32, no. 6, pp. 809–819, 2009, doi: https://doi.org/10.1016/j.advwatres.2009.02.004.

[31] H. Schume, H. Hager, and G. Jost, "Water and energy exchange above a mixed European Beech - Norway Spruce forest canopy: A comparison of eddy covariance against soil water depletion measurement," *Theor. Appl. Climatol.*, vol. 81, no. 1–2, pp. 87–100, Oct. 2005, doi: 10.1007/S00704-004-0086-Z/METRICS.

[32] Russell L. Scott, "Using watershed water balance to evaluate the accuracy of eddy covariance evaporation measurements for three semiarid ecosystems," *Agric. For. Meteorol.*, vol. 150, no. 2, pp. 219–225, 2010, doi: https://doi.org/10.1016/j.agrformet.2009.11.002.

[33] M. W. Zhigang Sun, Qinxue Wang, Bunkei Matsushita, Takehiko Fukushima, Zhu Ouyang, "A New Method to Define the VI-Ts Diagram Using Subpixel Vegetation and Soil Information: A Case Study over a Semiarid Agricultural Region in the North China Plain," *Sensors*, vol. 8, no. 10, pp. 6260–6279, 2008, doi: https://doi.org/10.3390/s8106260.

[34] S. D. W. Kell B Wilson, Paul J Hanson, Mulholland Patrick J, Dennis D Baldocchi, "A comparison of methods for determining forest evapotranspiration and its components: sap-flow, soil water budget, eddy covariance and catchment water balance," *Agric. For. Meteorol.*, vol. 106, no. 2, pp. 153–168, 2001, doi: https://doi.org/10.1016/S0168-1923(00)00199-4.

[35] Ian Watson, "Hydrology An Environmental Approach," *Routledge*, p. 722, 1995, doi: https://doi.org/10.1201/9780203751442.

[36] V. Pandey, P. K. Pandey, and A. P. Mahanta, "CALIBRATION AND PERFORMANCE VERIFICATION OF HARGREAVES SAMANI EQUATION IN A HUMID REGION," *Irrig. Drain.*, vol. 63, no. 5, pp. 659–667, Dec. 2014, doi: 10.1002/IRD.1874.

[37] P. W. &Christopher M. Hossein Tabari, Parisa Hosseinzadehtalaei, "Validation and calibration of solar radiation equations for estimating daily reference evapotranspiration at cool semi-arid and arid locations," *Hydrol. Sci. J.*, vol. 61, no. 3, pp. 610–619, 2016, doi: https://doi.org/10.1080/02626667.2014.947293.

[38] W. Brutsaert, "Hydrology: An Introduction," *Cornell Univ. New York*, Aug. 2005, doi: 10.1017/CBO9780511808470.

[39] G. H. Hargreaves and Z. A. Samani, "Reference Crop Evapotranspiration from Temperature," *Appl. Eng. Agric.*, vol. 1, no. 2, pp. 96–99, 1985, doi: 10.13031/2013.26773.

[40] J. Dalton, "Experimental essays, on the constitution of mixed gases; on the force of steam or vapour from water and other liquids in different temperatures, both in a

Torricellian vacuum and in air; on evaporation; and on the expansion of elastic fluids by heat," *Mem. Lit. Philos. Soc. Manchester*, vol. 5, no. 2, pp. 535--602, 1798, [Online]. Available: https://www.biodiversitylibrary.org/part/308525

[41] A. Meyer, "Ueber einige Zusammenhänge zwischen Klima und Boden in Europa," *ETH Zürich*, 1926, doi: https://doi.org/10.3929/ethz-a-000092038.

[42] Howard Latimer Penman, "Natural evaporation from open water, bare soil and grass," *Proc. R. Soc. L.*, vol. 193, pp. 120–145, 1948, doi: https://doi.org/10.1098/rspa.1948.0037.

[43] V. . Romanenko, "Computation of the Autumn Soil Moisture Using a Universal Relationship for a Large Area," *Ukr. Hydrometeorol. Res. Inst.*, 1961, [Online]. Available: https://www.scirp.org/reference/referencespapers?referenceid=2151471

[44] D. G. Yu Feng , Ningbo Cui , Lu Zhao , Xiaotao Hu, "Comparison of ELM, GANN, WNN and empirical models for estimating reference evapotranspiration in humid region of Southwest China," *J. Hydrol.*, vol. 536, pp. 376–383, 2016, doi: https://doi.org/10.1016/j.jhydrol.2016.02.053.

[45] J. C. Xiaoying Liu, Xu, Chunying, Xiuli Zhong, Yuzhong Li , Xiaohuan Yuan, "Comparison of 16 models for reference crop evapotranspiration against weighing lysimeter measurement," *Agric. Water Manag.*, vol. 184, pp. 145–155, 2017, doi: https://doi.org/10.1016/j.agwat.2017.01.017.

[46] K. Djaman *et al.*, "Evaluation of the Penman-Monteith and other 34 reference evapotranspiration equations under limited data in a semiarid dry climate," *Theor. Appl. Climatol.*, vol. 137, no. 1–2, pp. 729–743, Jul. 2019, doi: 10.1007/S00704-018-2624-0/METRICS.

[47] Y. Yin, S. Wu, D. Zheng, and Q. Yang, "Radiation calibration of FAO56 Penman–Monteith model to estimate reference crop evapotranspiration in China," *Agric. Water Manag.*, vol. 95, no. 1, pp. 77–84, 2008, doi: https://doi.org/10.1016/j.agwat.2007.09.002.

[48] P. Droogers and R. G. Allen, "Estimating reference evapotranspiration under inaccurate data conditions," *Irrig. Drain. Syst.*, vol. 16, no. 1, pp. 33–45, Feb. 2002, doi: 10.1023/A:1015508322413/METRICS.

[49] B. L. Moussa Bruno Kafando, Mahamadou Koïta, Mathieu Le Coz, Ousmane Roland Yonaba, Tazen Fowe, Cheick Oumar Zouré, Moussa Diagne Faye, "Use of Multidisciplinary Approaches for Groundwater Recharge Mechanism Characterization in Basement Aquifers: Case of Sanon Experimental Catchment in Burkina Faso," *Water*, vol. 13, no. 22, p. 3216, 2021, doi: https://doi.org/10.3390/w13223216.

[50] L. A. Mounirou *et al.*, "Multi-scale analysis of runoff from a statistical perspective in a small Sahelian catchment under semi-arid climate," *Arab. J. Geosci.*, vol. 13, no. 4, pp. 1–16, Feb. 2020, doi: 10.1007/S12517-020-5141-2/METRICS.

[51] J. J. L. Jalal Shiri, Ozgur Kisi, Gorka Landeras, "Daily reference evapotranspiration modeling by using genetic programming approach in the Basque Country (Northern Spain)," *J. Hydrol.*, vol. 414–415, no. 2, pp. 302–316, 2012, doi: 10.1016/j.jhydrol.2011.11.004.

[52] Hamma Yacouba, Harouna Karambiri, Pierre Queloz, Lawani Adjadi Mounirou, Fowé Tazen, Mahamadou Koïta, Angelbert Chabi Biaou, "Future climate or land use? Attribution of changes in surface runoff in a typical Sahelian landscape," *Comptes Rendus. Géoscience, Geo-hydrological Data Model.*, vol. 355, no. 1, pp. 411–438, 2023, [Online]. Available: https://comptes-rendus.academie-sciences.fr/geoscience/articles/10.5802/crgeos.179/

[53] J. L. Monteith, "Evaporation and environment," Symposia of the Society for

Experimental Biology. Accessed: Mar. 06, 2025. [Online]. Available: https://repository.rothamsted.ac.uk/item/8v5v7/evaporation-and-environment

[54] J. Wright, "Derivation of alfalfa and grass reference evapotranspiration," *Agric. Food Sci.*, 1996.

[55] John D. Valiantzas, "Simplified versions for the Penman evaporation equation using routine weather data," *J. Hydrol.*, vol. 331, no. 3–4, pp. 690–702, 2006, doi: https://doi.org/10.1016/j.jhydrol.2006.06.012.

[56] John D. Valiantzas, "Simplified forms for the standardized FAO-56 Penman–Monteith reference evapotranspiration using limited weather data," *J. Hydrol.*, vol. 505, pp. 13–23, 2013, doi: https://doi.org/10.1016/j.jhydrol.2013.09.005.

[57] A. R. Pereira, N. A. V. Nova, A. S. Pereira, and V. Barbieri, "A model for the class A pan coefficient," *Agric. For. Meteorol.*, vol. 76, no. 2, pp. 75–82, 1995, doi: https://doi.org/10.1016/0168-1923(94)02224-8.

[58] V. P. Singh, "Hydrologic Systems: Watershed Modeling," *Prentice Hall*, p. 448, 1989, Accessed: Mar. 06, 2025. [Online]. Available: https://books.google.com/books/about/Hydrologic_Systems_Watershed_modeling.html?id=QbUPAQAAIAAJ

[59] W. D. C. Harry F. Blaney, "Determining water requirements in irrigated areas from climatological and irrigation data," *Determ. WATER Requir. Irrig. AREAS*, 1950, [Online]. Available: https://dn790000.ca.archive.org/0/items/determiningwater96blan/determiningwater96blan.pdf

[60] H. F. Blaney and W. D. Criddle, "Determining Consumptive Use and Irrigation Water Requirements," *US Dep. Agric.*, 1962, [Online]. Available: https://nmwrri.nmsu.edu/footer_pages/nm-wrri-library-database-files/wrri-library-pdfs/wrrilibrary5/005314.pdf

[61] M. A. Josilva M. Muniandy, Zulkifli Yusop, "Evaluation of reference evapotranspiration models and determination of crop coefficient for Momordica charantia and Capsicum annuum," *Agric. Water Manag.*, vol. 169, pp. 77–89, 2016, doi: https://doi.org/10.1016/j.agwat.2016.02.019.

[62] S. Trajkovic, "Hargreaves versus Penman-Monteith under Humid Conditions," *J. Irrig. Drain. Eng.*, vol. 133, no. 1, pp. 38–42, Feb. 2007, doi: 10.1061/(ASCE)0733-9437(2007)133:1(38).

[63] D. D. R. P. DI Dr. Roman Neunteufel, Laurent Richard MSc and K. M. und E. H. unter der Mitarbeit von Stefan Tuschel, "Wasserverbrauch und Wasserbedarf," *Habilitation*, 1967, [Online]. Available: https://info.bml.gv.at/dam/jcr:00070937-0320-4544-b6a4-320325dcfd86/Wasserverbrauch Wasserbedarf Literaturstudie.pdf

[64] J. E. O. Ugyen Dorji and M. S. Seidenkrantz, "Water balance in the complex mountainous terrain of Bhutan and linkages to land use," *J. Hydrol. Reg. Stud.*, vol. 7, pp. 55–68, 2016, doi: https://doi.org/10.1016/j.ejrh.2016.05.001.

[65] W. B. and G. W. Robertson, "ESTIMATION OF LATENT EVAPORATION FROM SIMPLE WEATHER OBSERVATIONS," *Can. J. Plant Sci.*, vol. 45, no. 3, 1965, doi: https://doi.org/10.4141/cjps65-051.

[66] M. Ahooghalandari, M. Khiadani, and M. E. Jahromi, "Developing Equations for Estimating Reference Evapotranspiration in Australia," *Water Resour. Manag.*, vol. 30, no. 11, pp. 3815–3828, Sep. 2016, doi: 10.1007/S11269-016-1386-7/METRICS.

[67] G. Ravazzani, C. Corbari, S. Morella, P. Gianoli, and M. Mancini, "Modified Hargreaves-Samani Equation for the Assessment of Reference Evapotranspiration in Alpine River Basins," *J. Irrig. Drain. Eng.*, vol. 138, no. 7, pp. 592–599, Dec. 2011, doi: 10.1061/(ASCE)IR.1943-4774.0000453.

[68] Antonio Berti, Tardivo, Gianmarco, Alessandro Chiaudan and M. B. Francesco Rech, "Assessing reference evapotranspiration by the Hargreaves method in north-eastern Italy," *Agric. Water Manag.*, vol. 140, pp. 20–25, 2014, doi: https://doi.org/10.1016/j.agwat.2014.03.015.
[69] P. Lobit, L. López Pérez, and J. P. Lhomme, "Retrieving air humidity, global solar radiation, and reference evapotranspiration from daily temperatures: development and validation of new methods for Mexico. Part II: radiation," *Theor. Appl. Climatol.*, vol. 133, no. 3–4, pp. 799–810, Aug. 2018, doi: 10.1007/S00704-017-2212-8/METRICS.
[70] Pengcheng Tang; Bing Xu; Zhanyi Gao; Heping Li; Xiaoyu Gao; Chaozi Wang, "Estimating reference crop evapotranspiration with elevation based on an improved HS model," *Hydrol. Res.*, vol. 50, no. 1, pp. 187–199, 2019, doi: https://doi.org/10.2166/nh.2018.022.
[71] M. M. Heydari and M. Heydari, "Calibration of Hargreaves–Samani equation for estimating reference evapotranspiration in semiarid and arid regions," *Arch. Agron. Soil Sci.*, vol. 60, no. 5, pp. 695–713, May 2014, doi: 10.1080/03650340.2013.808740.
[72] Rachid Hadria, Tarik Benabdelouhab and A. S. Hayat Lionboui, "Comparative assessment of different reference evapotranspiration models towards a fit calibration for arid and semi-arid areas," *J. Arid Environ.*, vol. 184, p. 104318, 2021, doi: https://doi.org/10.1016/j.jaridenv.2020.104318.
[73] Z. Samani, "Estimating Solar Radiation and Evapotranspiration Using Minimum Climatological Data," *J. Irrig. Drain. Eng.*, vol. 126, no. 4, pp. 265–267, Jul. 2000, doi: 10.1061/(ASCE)0733-9437(2000)126:4(265).
[74] G. . Makkink, "Testing the Penman Formula by Means of Lysimeters," *J. Inst. Water Eng.*, vol. 11, pp. 277–288, 1957, [Online]. Available: https://www.scirp.org/reference/referencespapers?referenceid=2386218
[75] Søren Hansen, "Estimation of Potential and Actual Evapotranspiration: Paper presented at the Nordic Hydrological Conference (Nyborg, Denmark, August - 1984)," *Hydrol. Res.*, vol. 15, no. 4–5, pp. 205–212, 1984, doi: https://doi.org/10.2166/nh.1984.0017.
[76] R. J. Taylor, C. H. B. Priestley, "On the assessment of surface heat flux and evaporation using large-scale parameters," *Mon. Weather Rev.*, pp. 81–92, 1972, doi: https://doi.org/10.1175/1520-0493(1972)100<0081:OTAOSH>2.3.CO;2.
[77] G. H. Hargreaves, "Moisture Availability and Crop Production," *Trans. ASAE*, vol. 18, no. 5, pp. 980–0984, 1975, doi: 10.13031/2013.36722.
[78] W. Abtew, "EVAPOTRANSPIRATION MEASUREMENTS AND MODELING FOR THREE WETLAND SYSTEMS IN SOUTH FLORIDA1," *JAWRA J. Am. Water Resour. Assoc.*, vol. 32, no. 3, pp. 465–473, Jun. 1996, doi: 10.1111/J.1752-1688.1996.TB04044.X.
[79] S. Irmak, A. Irmak, R. G. Allen, and J. W. Jones, "Solar and Net Radiation-Based Equations to Estimate Reference Evapotranspiration in Humid Climates," *J. Irrig. Drain. Eng.*, vol. 129, no. 5, pp. 336–347, Oct. 2003, doi: 10.1061/(ASCE)0733-9437(2003)129:5(336).
[80] Ludovic Oudin, Frédéric Hervieu, Claude Michel, Charles Perrin, Vazken Andréassian, and C. L. François Anctil, "Which potential evapotranspiration input for a lumped rainfall–runoff model?: Part 2—Towards a simple and efficient potential evapotranspiration model for rainfall–runoff modelling," *J. Hydrol.*, vol. 303, no. 1–4, pp. 290–306, 2005, doi: https://doi.org/10.1016/j.jhydrol.2004.08.026.
[81] M. E. Jensen and H. R. Haise, "Estimating Evapotranspiration from Solar Radiation," *J. Irrig. Drain. Div.*, vol. 89, no. 4, pp. 15–41, Dec. 1963, doi: 10.1061/JRCEA4.0000287.

[82] L. Turc, "Water requirements assessment of irrigation, potential evapotranspiration: Simplified and updated climatic formula," *Ann. Agron.*, vol. 12, pp. 13–49, 1961, [Online]. Available: https://www.scirp.org/reference/referencespapers?referenceid=926529

[83] S. T. S. Kolakovic, "Wind-adjusted Turc equation for estimating reference evapotranspiration at humid European locations," *Hydrol. Res.*, vol. 40, no. 1, pp. 45–52, 2009, doi: https://doi.org/10.2166/nh.2009.002b.

[84] O. Kisi, "Comparison of Different Empirical Methods for Estimating Daily Reference Evapotranspiration in Mediterranean Climate," *J. Irrig. Drain. Eng.*, vol. 140, no. 1, p. 04013002, Aug. 2013, doi: 10.1061/(ASCE)IR.1943-4774.0000664.

[85] S. Akhavan, E. Kanani, and H. Dehghanisanij, "Assessment of different reference evapotranspiration models to estimate the actual evapotranspiration of corn (Zea mays L.) in a semiarid region (case study, Karaj, Iran)," *Theor. Appl. Climatol.*, vol. 137, no. 1–2, pp. 1403–1419, Jul. 2019, doi: 10.1007/S00704-018-2634-Y/METRICS.

[86] J. M. Caprio, "The Solar Thermal Unit Concept in Problems Related to Plant Development and Potential Evapotranspiration," *Phenol. Seas. Model.*, pp. 353–364, 1974, doi: 10.1007/978-3-642-51863-8_29.

[87] C. Jones, "crop growth models," *Manag. Farm Irrig. Syst.*, 1990, [Online]. Available: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/crop-models#:~:text=and crop management.-,Crop models are mathematical algorithms that capture the quantitative information,scenarios in a few minutes.

[88] S. Alexandris, P. Kerkides, and A. Liakatas, "Daily reference evapotranspiration estimates by the 'Copais' approach," *Agric. Water Manag.*, vol. 82, no. 3, pp. 371–386, 2006, doi: https://doi.org/10.1016/j.agwat.2005.08.001.

[89] L. Castañeda and P. Rao, "COMPARISON OF METHODS FOR ESTIMATING REFERENCE EVAPOTRANSPIRATION IN SOUTHERN CALIFORNIA," *Environ. Sci.*, 2005.

[90] J. L. McGuinness and E. F. Borone, "A Comparison of Lysimeter-Derived Potential Evapotranspiration With Computed Values," *Tech. Bull.*, p. 171893, 1972, doi: 10.22004/ag.econ.171893.

[91] M. A. John C. Stephens, "Discussion of "Estimating Evaporation from Insolation," *J. Hydraul. Div.*, vol. 91, no. 5, 1965, doi: https://doi.org/10.1061/JYCEAJ.0001310.

[92] J. Stephens and E. Stewart, "A COMPARISON OF PROCEDURES FOR COMPUTING EVAPORATION AND EVAPOTRANSPIRATION (i)," *Fort Lauderdle*, 1963.

[93] M. Lurie and N. Michailoff, "Evaporation from Free Water Surface," *Ind. Eng. Chem.*, vol. 28, no. 3, pp. 345–349, Mar. 1936, doi: 10.1021/IE50315A019/ASSET/IE50315A019.FP.PNG_V03.

[94] M. Gangopadhyaya, "Measurement and Estimation of Evaporation and Evapotranspiration - World Meteorological Organization. Commission for Instruments and Methods of Observation. Working Group on Evaporation Measurement, M. Gangopadhyaya - Google Books," Secretariat of the World Meteorological Organization. Accessed: Mar. 06, 2025. [Online]. Available: https://books.google.com.pk/books/about/Measurement_and_Estimation_of_Evaporatio.html?id=J2vizwEACAAJ&redir_esc=y

[95] H. Brockamp, B. and Wenner, "Verdunstungsmessungen auf den Steiner See bei Munster," *Dtsch. gewässerkundliche Mitteilungen*, pp. 149–154, 1963, [Online]. Available: http://scirp.org/reference/referencespapers?referenceid=2151472

[96] W. Mahringer, "Verdunstungsstudien am Neusiedler See," *Arch. für Meteorol. Geophys. und Bioklimatologie Ser. B*, vol. 18, no. 1, pp. 1–20, Mar. 1970, doi:

10.1007/BF02245865/METRICS.
[97] W. H. PEARSALL, “Vegetation and Hydrology,” *Nature*, vol. 199, no. 316, 1963, doi: https://doi.org/10.1038/199316a0.
[98] F. Albrecht, “Die Methoden zur Bestimmung der Verdunstung der natürlichen Erdoberfläche,” *Arch. für Meteorol. Geophys. und Bioklimatologie Ser. B*, vol. 2, no. 1–2, pp. 1–38, Jun. 1950, doi: 10.1007/BF02242718/METRICS.
[99] W. Trabert, “Neue Beobachtungenûber Verdampfungsgeschwindigkeiten,” *Meteorol. Zeitschrift*, pp. 261–263, 1896, [Online]. Available: https://www.scirp.org/reference/referencespapers?referenceid=2151466
[100] S. T. VARGA-HASZONITS ZOLTÁN, LANTOS ZSUZSA, KALOCSAI RENÁTÓ, “A PÁROLGÁS FOGALMA, FORMÁI ÉS MEGHATÁROZÁSUK,” *Acta Agron. Óváriensis*, vol. 60, 1973, [Online]. Available: http://epa.oszk.hu/03100/03114/00025/pdf/EPA03114_acta_agronomica_ovariensis_2019_ksz_047-071.pdf
[101] P. S. Kashyap and R. K. Panda, “Evaluation of evapotranspiration estimation methods and development of crop-coefficients for potato crop in a sub-humid region,” *Agric. Water Manag.*, vol. 50, no. 1, pp. 9–25, 2001, doi: https://doi.org/10.1016/S0378-3774(01)00102-0.
[102] A. O.-B. Gorka Landeras and J. J. López, “Comparison of artificial neural network models and empirical and semi-empirical equations for daily reference evapotranspiration estimation in the Basque Country (Northern Spain),” *Agric. Water Manag.*, vol. 95, no. 5, pp. 553–565, 2008, doi: https://doi.org/10.1016/j.agwat.2007.12.011.
[103] A. A. Sabziparvar, H. Tabari, A. Aeini, and M. Ghafouri, “Evaluation of class a pan coefficient models for estimation of reference crop evapotranspiration in cold semi-arid and warm arid climates,” *Water Resour. Manag.*, vol. 24, no. 5, pp. 909–920, Jul. 2010, doi: 10.1007/S11269-009-9478-2/METRICS.
[104] T. Y. Hossein DehghaniSanij and V. Rasiah, “Assessment of evapotranspiration estimation models for use in semi-arid environments,” *Agric. Water Manag.*, vol. 64, no. 2, pp. 91–106, 2004, doi: https://doi.org/10.1016/S0378-3774(03)00200-2.
[105] A. B. I. A. N. Proutsos, “Comparative evaluation of 24 reference evapotranspiration equations applied on an evergreen-broadleaved forest,” *Hydrol. Res.*, vol. 49, no. 4, pp. 1028–1041, 2018, doi: https://doi.org/10.2166/nh.2017.232.
[106] S. I. Koffi Djaman, Komlan Koudahe, Christopher Oluwakunmi Akinbile, “Evaluation of Eleven Reference Evapotranspiration Models in Semiarid Conditions,” *J. Water Resour. Prot.*, vol. 9, no. 12, 2017, doi: 10.4236/jwarp.2017.912094.
[107] S. Gebhart, K. Radoglou, G. Chalivopoulos, and A. Matzarakis, “Evaluation of Potential Evapotranspiration in Central Macedonia by EmPEst,” pp. 451–456, 2013, doi: 10.1007/978-3-642-29172-2_64.
[108] J. Lu, G. Sun, S. G. McNulty, and D. M. Amatya, “A COMPARISON OF SIX POTENTIAL EVAPOTRANSPIRATION METHODS FOR REGIONAL USE IN THE SOUTHEASTERN UNITED STATES1,” *JAWRA J. Am. Water Resour. Assoc.*, vol. 41, no. 3, pp. 621–633, Jun. 2005, doi: 10.1111/J.1752-1688.2005.TB03759.X.
[109] D. M. Amatya, R. W. Skaggs, and J. D. Gregory, “Comparison of Methods for Estimating REF-ET,” *J. Irrig. Drain. Eng.*, vol. 121, no. 6, pp. 427–435, Nov. 1995, doi: 10.1061/(ASCE)0733-9437(1995)121:6(427).
[110] Koffi Djaman, Balde, Alpha B., Sow, Abdoulaye, Bertrand Muller, Suat Irmak , Mamadou K. N’Diaye, Baboucarr Manneh and K. S. Yonnelle D. Moukoumbi,

Koichi Futakuchi, "Evaluation of sixteen reference evapotranspiration methods under sahelian conditions in the Senegal River Valley," *J. Hydrol. Reg. Stud.*, vol. 3, pp. 139–159, 2015, doi: https://doi.org/10.1016/j.ejrh.2015.02.002.

[111] Z. X. Xinyi Song, Fan Lu, Weihua Xiao, Kui Zhu, Yuyan Zhou, "Performance of 12 reference evapotranspiration estimation methods compared with the Penman–Monteith method and the potential influences in northeast China," *Meteorol. Appl.*, 2018, doi: https://doi.org/10.1002/met.1739.

[112] M. E.-R. Ahmed Elbeltagi, Aman Srivastava, Abdullah Hassan Al-Saeedi, Ali Raza, Ismail Abd-Elaty, "Forecasting Long-Series Daily Reference Evapotranspiration Based on Best Subset Regression and Machine Learning in Egypt," *Water*, vol. 15, no. 6, p. 1149, 2023, doi: https://doi.org/10.3390/w15061149.

[113] E. Mirzania, M. H. Kashani, G. Golmohammadi, O. R. Ibrahim, and M. Saroughi, "Hybrid COOT-ANN: a novel optimization algorithm for prediction of daily crop reference evapotranspiration in Australia," *Theor. Appl. Climatol.*, vol. 154, no. 1–2, pp. 201–218, Oct. 2023, doi: 10.1007/S00704-023-04552-8/METRICS.

[114] Ho-Jun Kim, Sewwandhi Chandrasekara, and T. K. Hyun-Han Kwon, Carlos Lima, "A novel multi-scale parameter estimation approach to the Hargreaves-Samani equation for estimation of Penman-Monteith reference evapotranspiration," *Agric. Water Manag.*, vol. 275, p. 108038, 2023, doi: https://doi.org/10.1016/j.agwat.2022.108038.

[115] F. Di Nunno and F. Granata, "Future trends of reference evapotranspiration in Sicily based on CORDEX data and Machine Learning algorithms," *Agric. Water Manag.*, vol. 280, p. 108232, 2023, doi: https://doi.org/10.1016/j.agwat.2023.108232.

[116] R. K. Gupta and H. S. Chauhan, "Stochastic Modeling of Irrigation Requirements," *J. Irrig. Drain. Eng.*, vol. 112, no. 1, pp. 65–76, Feb. 1986, doi: 10.1061/(ASCE)0733-9437(1986)112:1(65).

[117] G. Landeras, A. Ortiz-Barredo, and J. J. López, "Forecasting Weekly Evapotranspiration with ARIMA and Artificial Neural Network Models," *J. Irrig. Drain. Eng.*, vol. 135, no. 3, pp. 323–334, Jan. 2009, doi: 10.1061/(ASCE)IR.1943-4774.0000008.

[118] A. E. Rhenals and R. L. Bras, "The irrigation scheduling problem and evapotranspiration uncertainty," *Water Resour. Res.*, vol. 17, no. 5, pp. 1328–1338, Oct. 1981, doi: 10.1029/WR017I005P01328.

[119] L. E. de O. A. W. B. Alves, G. de S. Rolim, "REFERENCE EVAPOTRANSPIRATION FORECASTING BY ARTIFICIAL NEURAL NETWORKS," *Sci. Pap. Soil Water Eng.*, vol. 37, no. 6, 2017, doi: https://doi.org/10.1590/1809-4430-Eng.Agric.v37n6p1116-1125/2017.

[120] A. Gensler, J. Henze, B. Sick, and N. Raabe, "Deep Learning for solar power forecasting - An approach using AutoEncoder and LSTM Neural Networks," *2016 IEEE Int. Conf. Syst. Man, Cybern. SMC 2016 - Conf. Proc.*, pp. 2858–2865, Feb. 2017, doi: 10.1109/SMC.2016.7844673.

[121] Milan Gocić, Motamedi Shervin and M. A. Shahaboddin Shamshirband ,Dalibor Petković, Sudheer Ch, Roslan Hashim, "Soft computing approaches for forecasting reference evapotranspiration," *Comput. Electron. Agric.*, vol. 113, pp. 164–173, 2015, doi: https://doi.org/10.1016/j.compag.2015.02.010.

[122] F. Granata, R. Gargano, and G. de Marinis, "Artificial intelligence based approaches to evaluate actual evapotranspiration in wetlands," *Sci. Total Environ.*, vol. 703, p. 135653, 2020, doi: https://doi.org/10.1016/j.scitotenv.2019.135653.

[123] Y. Luo *et al.*, "Medium range daily reference evapotranspiration forecasting by using ann and public weather forecasts," *Water Resour. Manag.*, vol. 29, no. 10, pp. 3863–

3876, Aug. 2015, doi: 10.1007/S11269-015-1033-8/METRICS.

[124] G. F. Seydou Traore , Yufeng Luo, "Deployment of artificial neural network for short-term forecasting of evapotranspiration using public weather forecast restricted messages," *Agric. Water Manag.*, vol. 163, pp. 363–379, 2016, doi: https://doi.org/10.1016/j.agwat.2015.10.009.

[125] J. Y. Jianfeng Zhang, Yan Zhu, Xiaoping Zhang, Ming Ye, "Developing a Long Short-Term Memory (LSTM) based model for predicting water table depth in agricultural areas," *J. Hydrol.*, vol. 561, pp. 918–929, 2018, doi: https://doi.org/10.1016/j.jhydrol.2018.04.065.

[126] T. E. Hassan Afzaal, Aitazaz A. Farooque, Farhat Abbas, Bishnu Acharya, "Computation of Evapotranspiration with Artificial Intelligence for Precision Water Resource Management," *Appl. Sci.*, vol. 10, no. 5, p. 1621, 2020, doi: https://doi.org/10.3390/app10051621.

[127] S. Cao *et al.*, "Efficient and effective sparse LSTM on FPGA with bank-balanced sparsity," *FPGA 2019 - Proc. 2019 ACM/SIGDA Int. Symp. Field-Programmable Gate Arrays*, pp. 63–72, Feb. 2019, doi: 10.1145/3289602.3293898.

[128] M. K. Alaa Sagheer, "Time series forecasting of petroleum production using deep LSTM recurrent networks," *Neurocomputing*, vol. 323, pp. 203–213, 2019, doi: https://doi.org/10.1016/j.neucom.2018.09.082.

[129] S. Trajkovic, B. Todorovic, and M. Stankovic, "Forecasting of Reference Evapotranspiration by Artificial Neural Networks," *J. Irrig. Drain. Eng.*, vol. 129, no. 6, pp. 454–457, Dec. 2003, doi: 10.1061/(ASCE)0733-9437(2003)129:6(454).

[130] M. M. Alfonso F. Torres, Wynn R. Walker, "Forecasting daily potential evapotranspiration using machine learning and limited climatic data," *Agric. Water Manag.*, vol. 98, no. 4, pp. 553–562, 2011, doi: https://doi.org/10.1016/j.agwat.2010.10.012.

[131] M. Karbasi, "Forecasting of Multi-Step Ahead Reference Evapotranspiration Using Wavelet- Gaussian Process Regression Model," *Water Resour. Manag.*, vol. 32, no. 3, pp. 1035–1052, Feb. 2018, doi: 10.1007/S11269-017-1853-9/METRICS.

[132] A. Ashrafzadeh, O. Kişi, P. Aghelpour, S. M. Biazar, and M. A. Masouleh, "Comparative Study of Time Series Models, Support Vector Machines, and GMDH in Forecasting Long-Term Evapotranspiration Rates in Northern Iran," *J. Irrig. Drain. Eng.*, vol. 146, no. 6, p. 04020010, Mar. 2020, doi: 10.1061/(ASCE)IR.1943-4774.0001471.

[133] L. B. Ferreira and F. F. da Cunha, "Multi-step ahead forecasting of daily reference evapotranspiration using deep learning," *Comput. Electron. Agric.*, vol. 178, p. 105728, 2020, doi: https://doi.org/10.1016/j.compag.2020.105728.

[134] Vahid Nourani and J. A. Gozen Elkiran, "Multi-step ahead modeling of reference evapotranspiration using a multi-model approach," *J. Hydrol.*, vol. 581, p. 124434, 2020, doi: https://doi.org/10.1016/j.jhydrol.2019.124434.

[135] L. S. P. Jiabing Cai, Yu Liu, Tingwu Lei, "Estimating reference evapotranspiration with the FAO Penman–Monteith equation using daily weather forecast messages," *Agric. For. Meteorol.*, vol. 145, no. 1–2, pp. 22–35, 2007, doi: https://doi.org/10.1016/j.agrformet.2007.04.012.

[136] G. B. Hanoi Medina, Di Tian, Puneet Srivastava, Anna Pelosi, Chirico, "Medium-range reference evapotranspiration forecasts for the contiguous United States based on multi-model numerical weather predictions," *J. Hydrol.*, vol. 562, pp. 502–517, 2018, doi: https://doi.org/10.1016/j.jhydrol.2018.05.029.

[137] B. N. Kushan C. Perera, Andrew W. Western and B. George, "Forecasting daily reference evapotranspiration for Australia using numerical weather prediction

outputs," *Agric. For. Meteorol.*, vol. 194, pp. 50–63, 2014, doi: https://doi.org/10.1016/j.agrformet.2014.03.014.

[138] G. B. C. A. Pelosi, H. Medina, P. Villani , G. D'Urso, "Probabilistic forecasting of reference evapotranspiration with a limited area ensemble prediction system," *Agric. Water Manag.*, vol. 178, pp. 106–118, 2016, doi: https://doi.org/10.1016/j.agwat.2016.09.015.

[139] Q. Z. Yufeng Luo , Xiaomin Chang , Shizhang Peng, Shahbaz Khan, Weiguang Wang and X. Cai, "Short-term forecasting of daily reference evapotranspiration using the Hargreaves–Samani model and temperature forecasts," *Agric. Water Manag.*, vol. 136, pp. 42–51, 2014, doi: https://doi.org/10.1016/j.agwat.2014.01.006.

[140] M. A. A.-S. Phon Sheng Hou, Lokman Mohd Fadzil, Selvakumar Manickam, "Vector Autoregression Model-Based Forecasting of Reference Evapotranspiration in Malaysia," *Sustainability*, vol. 15, no. 4, p. 3675, 2023, doi: https://doi.org/10.3390/su15043675.

[141] E. I. F. F. Lucas Borges Ferreira, Fernando França da Cunha, Rubens Alves de Oliveira, "Estimation of reference evapotranspiration in Brazil with limited meteorological data using ANN and SVM – A new approach," *J. Hydrol.*, vol. 572, pp. 556–570, 2019, doi: https://doi.org/10.1016/j.jhydrol.2019.03.028.

[142] M. T. Sevim Seda Yamaç, "Estimation of daily potato crop evapotranspiration using three different machine learning algorithms and four scenarios of available meteorological data," *Mlad. Todorovic*, vol. 228, p. 105875, 2020, doi: https://doi.org/10.1016/j.agwat.2019.105875.

[143] Z. Chen, Z. Zhu, H. Jiang, and S. Sun, "Estimating daily reference evapotranspiration based on limited meteorological data using deep learning and classical machine learning methods," *J. Hydrol.*, vol. 591, p. 125286, 2020, doi: https://doi.org/10.1016/j.jhydrol.2020.125286.

[144] M. S. Babak Mohammadi, "Modeling daily reference evapotranspiration via a novel approach based on support vector regression coupled with whale optimization algorithm," *Agric. Water Manag.*, vol. 237, p. 106145, 2020, doi: https://doi.org/10.1016/j.agwat.2020.106145.

[145] S. Mehdizadeh, J. Behmanesh, and K. Khalili, "Using MARS, SVM, GEP and empirical equations for estimation of monthly mean reference evapotranspiration," *Comput. Electron. Agric.*, vol. 139, pp. 103–114, 2017, doi: https://doi.org/10.1016/j.compag.2017.05.002.

[146] M. A. M. Mohamed A. Yassin, A.A. Alazba, "Artificial neural networks versus gene expression programming for estimating reference evapotranspiration in arid climate," *Agric. Water Manag.*, vol. 163, pp. 110–124, 2016, doi: https://doi.org/10.1016/j.agwat.2015.09.009.

[147] H. C. , Sheng Wang , Jinjiao Lian, Yuzhong Peng, Baoqing Hu, "Generalized reference evapotranspiration models with limited climatic data based on random forest and gene expression programming in Guangxi, China," *Agric. Water Manag.*, vol. 221, pp. 220–230, 2019, doi: https://doi.org/10.1016/j.agwat.2019.03.027.

[148] P. C. Wissam Abdallah, Nassib Abdallah, Jean-Marie Marion, Mohamad Oueidat, "A vector autoregressive methodology for short-term weather forecasting: tests for Lebanon," *SN Appl. Sci.*, vol. 2, no. 1555, 2020, doi: https://doi.org/10.1007/s42452-020-03292-y.

[149] Jatin Bedi, "Transfer learning augmented enhanced memory network models for reference evapotranspiration estimation," *Knowledge-Based Syst.*, vol. 237, p. 107717, 2022, doi: https://doi.org/10.1016/j.knosys.2021.107717.

[150] P. Aghelpour and R. Norooz-Valashedi, "Predicting daily reference

evapotranspiration rates in a humid region, comparison of seven various data-based predictor models," *Stoch. Environ. Res. Risk Assess.*, vol. 36, no. 12, pp. 4133–4155, Dec. 2022, doi: 10.1007/S00477-022-02249-4/METRICS.
[151] A. M. Masoud Karbasi, Mehdi Jamei, Mumtaz Ali and Z. M. Yaseen, "Forecasting weekly reference evapotranspiration using Auto Encoder Decoder Bidirectional LSTM model hybridized with a Boruta-CatBoost input optimizer," *Comput. Electron. Agric.*, vol. 198, p. 107121, 2022, doi: https://doi.org/10.1016/j.compag.2022.107121.
[152] R. Ballesteros, J. F. Ortega, and M. Á. Moreno, "FORETo: New software for reference evapotranspiration forecasting," *J. Arid Environ.*, vol. 124, pp. 128–141, 2016, doi: https://doi.org/10.1016/j.jaridenv.2015.08.006.
[153] W. W. Yang Yang , Yuanlai Cui, Yufeng Luo , Xinwei Lyu , Seydou Traore, Shahbaz Khan, "Short-term forecasting of daily reference evapotranspiration using the Penman-Monteith model and public weather forecasts," *Agric. Water Manag.*, vol. 177, pp. 329–339, 2016, doi: https://doi.org/10.1016/j.agwat.2016.08.020.
[154] R. G. Allen, A. J. Clemmens, C. M. Burt, K. Solomon, and T. O'Halloran, "Prediction Accuracy for Projectwide Evapotranspiration Using Crop Coefficients and Reference Evapotranspiration," *J. Irrig. Drain. Eng.*, vol. 131, no. 1, pp. 24–36, Feb. 2005, doi: 10.1061/(ASCE)0733-9437(2005)131:1(24).
[155] A. Rahimi Khoob, "Comparative study of Hargreaves's and artificial neural network's methodologies in estimating reference evapotranspiration in a semiarid environment," *Irrig. Sci.*, vol. 26, no. 3, pp. 253–259, Mar. 2008, doi: 10.1007/S00271-007-0090-Z/METRICS.
[156] S. A. T. Miguel A. Mariño, John C. Tracy, "Forecasting of reference crop evapotranspiration," *Agric. Water Manag.*, vol. 24, no. 3, pp. 63–187, 1993, doi: https://doi.org/10.1016/0378-3774(93)90022-3.
[157] D. A. K. Fernando and A. W. Jayawardena, "Runoff Forecasting Using RBF Networks with OLS Algorithm," *J. Hydrol. Eng.*, vol. 3, no. 3, pp. 203–209, Jul. 1998, doi: 10.1061/(ASCE)1084-0699(1998)3:3(203).
[158] MO Zhi, "Forecast of crop evapotranspiration," *ICID Bull.*, vol. 43, no. 1, 1994, [Online]. Available: https://www.oieau.fr/eaudoc/system/files/documents/5/29850/29850_doc.pdf
[159] K. D. Papa Malick Ndiaye, Ansoumana Bodian, Lamine Diop, Abdoulaye Deme, Alain Dezetter, "Evaluation and Calibration of Alternative Methods for Estimating Reference Evapotranspiration in the Senegal River Basin," *Hydrology*, vol. 7, no. 2, p. 24, 2020, doi: https://doi.org/10.3390/hydrology7020024.
[160] J. M. R.-C. D. Vanella, D.S. Intrigliolo, S. Consoli, G. Longo-Minnolo, G. Lizzio, R.C. Dumitrache, E. Mateescu, J. Deelstra, "Comparing the use of past and forecast weather data for estimating reference evapotranspiration," *Agric. For. Meteorol.*, vol. 295, p. 108196, 2020, doi: https://doi.org/10.1016/j.agrformet.2020.108196.
[161] A. A. M. H. W.G.M. Bastiaanssen, M. Menenti, R.A. Feddes, "A remote sensing surface energy balance algorithm for land (SEBAL). 1. Formulation," *J. Hydrol.*, vol. 212–213, pp. 198–212, 1998, doi: https://doi.org/10.1016/S0022-1694(98)00253-4.
[162] R. G. Allen *et al.*, "Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration (METRIC)—Applications," *J. Irrig. Drain. Eng.*, vol. 133, no. 4, pp. 395–406, Aug. 2007, doi: 10.1061/(ASCE)0733-9437(2007)133:4(395).
[163] Q. Mu, F. A. Heinsch, M. Zhao, and Steven W. Running, "Development of a global evapotranspiration algorithm based on MODIS and global meteorology data," *Remote Sens. Environ.*, vol. 3, no. 4, pp. 519–536, 2007, doi: https://doi.org/10.1016/j.rse.2007.04.015.
[164] J. J. D.P. Roy, L. Boschetti, C.O. Justice, "The collection 5 MODIS burned area

product — Global evaluation by comparison with the MODIS active fire product," *Remote Sens. Environ.*, vol. 112, no. 9, pp. 3690–3707, 2008, doi: https://doi.org/10.1016/j.rse.2008.05.013.

[165] G. B. Chirico, A. Pelosi, C. De Michele, S. Falanga Bolognesi, and G. D'Urso, "Forecasting potential evapotranspiration by combining numerical weather predictions and visible and near-infrared satellite images: an application in southern Italy," *J. Agric. Sci.*, vol. 156, no. 5, pp. 702–710, Jul. 2018, doi: 10.1017/S0021859618000084.

[166] M. N. Dilini Delgoda, Hector Malano, Syed K. Saleem,Halgamuge, "Irrigation control based on model predictive control (MPC): Formulation of theory and validation using weather forecast data and AQUACROP model," *Environ. Model. Softw.*, vol. 78, pp. 40–53, 2016, doi: https://doi.org/10.1016/j.envsoft.2015.12.012.

[167] G. Ben Hamouda, D. Zaccaria, K. Bali, R. L. Snyder, and F. Ventura, "Evaluation of Forecast Reference Evapotranspiration for Different Microclimate Regions in California to Enable Prospective Irrigation Scheduling," *J. Irrig. Drain. Eng.*, vol. 148, no. 1, p. 04021061, Oct. 2021, doi: 10.1061/(ASCE)IR.1943-4774.0001632.

[168] I. J. Lorite, J. M. Ramírez-Cuesta, M. Cruz-Blanco, and C. Santos, "Using weather forecast data for irrigation scheduling under semi-arid conditions," *Irrig. Sci.*, vol. 33, no. 6, pp. 411–427, Nov. 2015, doi: 10.1007/S00271-015-0478-0/METRICS.

[169] F. S. Melton et al, "Satellite Irrigation Management Support With the Terrestrial Observation and Prediction System: A Framework for Integration of Satellite and Surface Observations to Support Improvements in Agricultural Water Resource Management," *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, vol. 5, no. 6, pp. 1709–1721, 2012, doi: 10.1109/JSTARS.2012.2214474.