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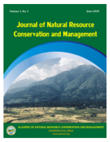

T-Min-based geometrical similarity model for prediction of evapotranspiration demand of Eucalyptus under waterlogged sodic soil conditions

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ABSTRACT

The ET demands of growing plants and trees are required for calculating groundwater draft due to plantation over a long period. The traits of high water demand of large growing trees are useful for selection as bio-drainage trees for reclamation and management of waterlogged salt-affected soils. High water-demanding trees are also useful for seepage interception. Researchers are still looking for a practical method of estimation of ET of tall growing trees suitable for bio-drainage and seepage interception over a long period using the most commonly available weather parameters data. Analytical modeling of ET using weather and tree parameters may avoid the associated complexity of direct ET measurement. Eucalyptus is the most commonly used tree species for bio-drainage due to its higher ET demand and tolerance to waterlogging and salt buildup. ET of the eucalyptus depends on interrelated weather parameters and its height. A geometrical similarity (GS) between minimum temperature T_{min}) and ETthe of the eucalyptus plant was observed. A Tmin-based GS Model was hypothesized. Calculated ET values of eucalyptus by the Singh & Verma model were used for developing a based GS model and predicting ET values of eucalyptus for 10 years. Characteristic constants (C_{Tmin}) of the GS Model were worked out for different months over the maximum height attainment life span of the eucalyptus. ET values predicted by the GS Model were compared with the calculated values of ET by the Singh and Verma model. The overall average % deviation of predicted ET by the Tmin-based GS Model compared to the analytically calculated ET values was only 5.93%. The developed Tmin-based GS Model is a simple method for estimation of ET of eucalyptus trees for field application and has good field applicability.

Keywords: Bio-drainage, evapo-transpiration, geometrical similarity model, internal drainage, waterlogging

INTRODUCTION

Understanding of evaporation of water from soil and plant surfaces and transpiration demand is essential for the water management of crops and trees. Surface evaporation and transpirational water demand depend on weather parameters such as maximum-minimum temperature, maximum-minimum humidity, sunshine hours, wind velocity, soil moisture status, types of crops, and stage and salinity or sodicity status of the soils. Direct measurement of evapotranspiration (ET) of the crops is comparatively easier yet time-consuming. Measurements of ET of growing trees become impossible and excessively time-consuming. ET for seasonal and short-duration crops is much easier compared to long-duration perennial crops, plantations, and trees (Neeraj and Suman, 2012). Water is applied to the crops or plantations through irrigation to maximize optimum economic growth. ET data are required for research and management of agricultural and forest lands, hydrologic cycle, natural groundwater withdrawal, irrigation, and water resource management. Internal drainage or subsurface drainage is essentially required to reclaim waterlogged salt-affected soils. For undulating lands with poor fertility status bio-drainage is recommended for controlling the water table and salt regime of the soils. Plenty of research works related to direct or indirect measurement of ET demands of short-duration crops (cereals, pulses, vegetables, and oil seeds) are reported in the literature from time to time (Tripathi, 2004, Tyagi *et al.*, 2000). Lysimeters weighing or non-weighing types both provide precise measurements of the actual ET of crops or small plantations (Xu and Chen, 2005; Valipour, 2012a, b; Valipour, 2015a, b, c). Many types of lysimeters are available in the market and have been used for direct measurement of ET of short-duration crops. Good precision could be also achieved by imaging techniques (Hart *et al.*, 2009; Rahimi *et al.*, 2015). Eucalyptus has high ET demand and tolerance to salinity, sodicity, and waterlogging hence recommended to biodrain waterlogged salt-affected soils most economically (Zahid and Nawaz, 2007; Forrester *et al.*, 2010; Ram *et al.*, 2011, Dagar *et al.*, 2016). ET of growing trees in lysimeters had been measured by researchers only for a short duration due to the limitations of the size of lysimeters. Eucalyptus tree plantations are also popular in many countries for meeting their timber demands.

The main eucalyptus growing countries over the globe are China (170 Mha) (Liu *et al.*, 2008) India (2.5 Mha) (ICFRE, 2010), and Brazil (3.7 M ha) (Stape *et al.*, 2001; Stape, 2002). South Africa has the largest area under eucalyptus plantations of about half a million hectares in the African continent (Teketay, 2003). Besides its intended uses, it may give in large amounts of timber, fuel, and fodder besides improving the environmental quality of the region in a short life span. The common economic life span of eucalyptus is about 5-7 years with normal species and 4-5 years with cloned species eucalyptus in the Indian subcontinent (Verma *et al.*, 2014).

Sap flow measurement using thermal probes and infrared gas analyzers, the most modern instruments are being used to measure water extractions by the large trees in the fields. Such instruments have associated limitations. Many times readings are quite misleading with errors of more than 100%, depending on the type of instrument, methods, tree girth, size, and number of trees used for ET estimation. Available methods require complex and extremely costly instrumental devices having limited use suitability only for specific research purposes. Modeling of ET is the easiest way of estimating ET demands of seasonal crops or growing long-duration trees (Khoshhal and Mokarram, 2012; Sen *et al.*, 2019; Singh & Verma, 2019; Singh *et al.* 2022; Singh *et al.* 2022). Large numbers of models are available for the estimation of ET of short-duration crops under varying climatic conditions. The most common and widely used model for estimating reference crop ET is FAO Penman-Monteith (Valipour and Eslamian, 2014). This model requires too many weather parameters. Keeping the difficulties in the collection of required weather data empirical methods such as mass transfer, radiation, temperature, and pan evaporation-based methods were developed for estimating reference crop ET with limited data (Valipour, 2015d; 2014b, c, d, e, f, g). Many new approaches have also been tried for testing and comparing the results with earlier available models (Valipour, 2014).

Eucalyptus has been used as a bio-draining plant for reclaiming waterlogged salt-affected soils over the globe (Gafri, 1994; Greenwood *et al.*, 1985). ET of the growing eucalyptus trees is dependent on the weather-air-soil-water environment. Daily weather parameters such as maximum temperature (Tmax), minimum temperature (Tmin), maximum and minimum relative humidity (RH7hr and RH14hr), wind velocity (Vwind), sunshine hour (SShr), and pan evaporation (Epan) affect the ET of plant in of a region. If one observes closely he may find that these parameters are closely correlated with each other and affect the physiological responses of plants. A slight to moderate change in one weather parameter would cause changes in other weather parameters. These changes may be quick with some parameters and delayed with others thereby evolving a new equilibrium and weather-dependent process. Instead of all available weather parameters, a single weather parameter-based model is useful for better understanding the concepts and field applications. As an example, a change in incoming solar radiation due to seasonal variations or cloudiness would result in a change in air temperature causing an increase or decrease in the rate of water loss from wet or water surfaces further regulating the evaporation rate. There exists a new equilibrium among weather parameters always. Physiological responses of plants/trees are dependent on their genetic traits, local environment, nutrient availability, soil types, soil moisture status, aeration, and physico-chemical properties of soil. Assuming a hypothesis that weather parameters are interrelated with each other, a single weather parameter can be used as an index for relating or correlating physiological responses of the plants under given conditions of soil water-aeration nutrient status and physicochemical properties of soil. The moisture content of the soil and shallow water table conditions also affect physiological activities and responses. ET is the rate of water demand of the plants/trees/crops and water losses from the surfaces of soil and plants due to evaporation. Meeting out ET of the crops with a minimum soil moisture deficit regime would lead to the optimum yield. Therefore the physiological responses are a function of genetic traits, weather parameters, soil water-aeration nutrient status, and physico-chemical properties of soil. For a specific location, specific genetic material, specific soil medium, and nutrient status the water uptake would become a function of a single weather parameter and crop stage i.e. total chlorophyll content of the plants. Developing weather parameters-based analytical ET models for growing long-duration tree species may be a very tedious job. No such model is available yet in the literature. One can easily understand that for a specific month, the average climatic conditions remain unchanged forever. Average weather conditions i.e. all weather parameters during a specific month remain unaltered (in a range) for all practical purposes for growing trees. Thus an increase or decrease in any weather parameter during a specific month over any period would be highly correlated with other parameters. Tmin (minimum temperature) is recorded at each weather observatory which coincides with the time of maximum humidity. Therefore Tmin becomes a governing weather parameter and ET of eucalyptus a function of Tmin. Therefore a well-interrelated single weather parameter with other weather parameters can be correlated with the stage (age) of the tree and ET. In the present study, a simple geometrical similarity (GM) model is developed for relating the average monthly ET of eucalyptus with the average Tmin of the area for a specific month. The calculated values of ET by the GS Model were compared with the analytically calculated values of ET of eucalyptus for validating the model.

MATERIALS AND METHODS

Height-Based ET Model for Eucalyptus

Singh *et al.* (2016) developed an analytical model for plant height considering a hypothesis for the rate of increase in height of eucalyptus plant with age as under.

1. The rate of increase in eucalyptus plant height is proportional to the effective height (H_m-H) of a plant at a given time which can be mathematically expressed as below.

$$\frac{dH}{dT} \propto (H_m - H) \tag{1}$$

Where,

H = Plant height at a given time, T

T = Age of plant

H_m = Expected average maximum height of eucalyptus in the region

2. The rate of increase in plant height is proportional to power from age function which can be mathematically written as below.

$$\frac{dH}{dT} \propto T^{\mu} \tag{2}$$

Where

μ= Characteristic constant

A governing equation for explaining eucalyptus height with time by combining Eqn. (1) and (2) can be written as below.

$$\frac{dH}{dT} = \lambda (H_m - H) T^{\mu} \tag{3}$$

Finally, a eucalyptus plant height model as a function of time was derived which is given below.

$$H_T = H_m - (H_m - H_s) e^{-\alpha T^{\beta}} \tag{4}$$

Where

$\alpha = \dfrac{\lambda}{\beta}$ and $\beta = \mu+1$, and λ are constant.

For the plants with the least expanding canopy cover laterally, it was further hypothesized that the rate of change of ET concerning plant height (H) is proportional to plant height (H) and canopy area (A) which can be expressed as below.

$$\frac{dET}{dH} \propto H\,A \tag{5}$$

Where

$$A = \eta\, H^{\theta} \tag{6}$$

η and θ = constants

The following governing equation for ET was derived by combining Eqn. (5) and (6).

$$\frac{d\,ET}{dH} = \zeta\,\eta\,H^{\theta+1} \tag{7}$$

Where,

ζ= Proportionality constant.

The following height-dependent ET formula was derived by solving governing Eqn. (7).

$$ET = \xi\, H^{\Psi} \tag{8}$$

Where,

$$\xi = \frac{\zeta\eta}{\psi}, \text{ and } \psi = \theta + 2$$

After substituting Eqn. (4) into Eqn. (8) The ET model can be written as below.

$$ET = \xi \left(H_m - (H_m - H_s)e^{-\alpha\, T^{\beta}}\right)^{\psi} \tag{9}$$

Tmin-Based Geometric Similarity Model

Two curves are said to be geometrically similar if there exists a relationship between corresponding variables. The ratio of output and associated input parameters is known as the characteristic constant of the model. The desired output can be calculated by multiplying it with the variable input parameter as below.

$$Output = C_{ch} \times Input\ parameter \tag{10}$$

Where,

C_{ch} = Characteristic constant of the model which is calculated as below.

$$C_{E_{pan}} = \frac{ET}{T_{\min}} \tag{11}$$

Study Area

The experimental area is located in Sharda Sahayak Canal Command reach of Kashrawan village of district Raibareli, U.P., India. The site lies between $26^{0}30^{\prime}18.90^{\prime\prime}$ N latitudes and $81^{0}\,6^{\prime}\,40.18^{\prime\prime}$ E longitudes at an elevation of 110 m above the mean sea level. The area suffers from high sodicity (pH>10.2) and severe waterlogging (water table < 0.50 m below ground level) having flat topography with an average slope of 1.5 % in the direction of the East. The area is mainly canal irrigated and represents a semi-arid-sub-tropical climate, characterized by hot summers and cool winters. The average annual rainfall of the area is 990 mm. Most of the rainfall occurs during the four months of June to September. Ten years average T_{min} varies between 7.34 to 26.01 °C.

Sharda Sahayak Canal System

Sharda Sahayak Canal System takes off water from the right bank of the lower Sharada Barrage supplying irrigation water to 2.0 M ha through a total length of the branch, secondary, and tertiary canal of 8704 km. A vast patch on either side of the canal is waterlogged coupled with sodicity in different reaches. The area suffers from severe waterlogging with water table ranges of 0.00 m to 1.5 m below ground surface throughout the year. Surface ponding in the area is observed after heavy downpour. Surface drainage networks of the area are least effective during the peak rainy season due to heavy weed infestations and blockage by the farmers. The bottom width of the canal is 46 m and the depth is 2.2 m with a side slope of 1:2. Canal discharge at full supply level is 170 m^3/s.

Soil Types, Water Table, and Salt Status

The soil textural classes were observed to be loam up to 30 cm, clay from 30 to 60 cm, and sandy clay loam from 60 to 120 cm soil depth. Soil pH were 10.5, 10.3, 9.78, 9.43, 8.83 and 8.72; and EC were 2.60, 2.10, 1.02, 0.80, 0.54 and 0.55 dS/m at 00 to 15, 15 to 30, 30 to 45, 45 to 60, 60 to 90 and 90 to 120 depth, respectively. The soil pH and EC is high toward surfaces and decreases with soil depths. Heavy loads of salts Na_2CO_3 and $NaHCO_3$ are washed away during the initial phase of the rainy season.

Biodrainage belt

A drainage belt was established using a tractor-mounted auger. The diameter of the auger hole was

30 cm and the depth of the hole was 60 cm from the soil surface. Input mixture of 5 kg gypsum, 5 kg farm yard manure, and 10 kg canal silt was filled in holes. After filling the mixture holes one-year-old eucalyptus sapling (*Eucalyptus camaldulensis*) was planted. Irrigation eucalypts were done manually during the summer season. The bio-drainage belt was established over an area of 1.20 ha (400 m x 30 m) along the Sharda Sahayak Canal. The spacing between row to row and plant to plant was 1.5 m x 1.5 m.

Installation of Lysimeters

For direct measurement of ET of growing eucalyptus plants, four metallic non-weighing type lysimeters of 1.0 m diameter and 2 m depth were installed inside the bio-drainage belt. Plant heights and ET data were recorded at regular intervals of time. Constant water table depths were maintained inside and outside the lysimeters by applying water to the plant daily. The amount of water required to maintain a constant water level inside the lysimeter as that outside of the lysimeter was considered as the ET demands of the eucalyptus plant. The plant height of the eucalyptus was measured every month and ET daily for three years.

Application of models

The optimized values height model constants, H_s, H_m, α, and β were worked out by fitting three years of plant height-age data in Eqn. (4). Optimized characteristic constants, α and β of Eqn. (4) were worked out as $3.0\text{x}10^{-04}$ and 2.1289, respectively. Eucalyptus plant heights against age (time) were calculated using Eqn. (4) for 10 years (Fig. 1). The maximum average eucalyptus height under waterlogged sodic conditions was calculated as 17.473 m against 10 years of age. Plant height and ET data measured in lysimeters for three years were used to assess optimized values of the characteristic constants of Eqn. (9). The monthly optimized values ξ and ψ are presented in Table 1. Using optimized values of constants ξ and ψ and corresponding eucalyptus heights monthly ET were calculated by Eqn. (9).

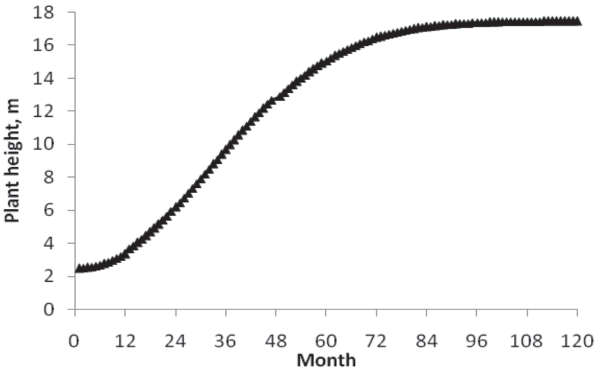

Fig. 1. Estimated plant heights up to 10 years

Application of Geometrical Similarity (GS) Model

Characteristics constants of the GS Model were worked out by using Eqn. (11). Monthly average value of T_{min} using 10 years of weather data was calculated. Using average monthly T_{min} data for years 2004, 2008, and 2013 ET of eucalyptus plants was calculated using Eqn. (10).

Percent Deviation

Percent deviation of predicted ET values by Tmin-based GS Model with corresponding observed (analytically calculated) ET values were calculated as below.

$$\%deviation = \frac{observed\ ET - predicted\ ET}{observed\ ET} \times 100 \quad (13)$$

Table 1. Monthly evapotranspiration model constants and correlation parameters

Month	Parameter		Month	Parameter	
	ξ	ψ		ξ	ψ
January	0.219812	2.116743	July	0.780679	1.693496
February	0.297069	2.164935	August	0.435737	1.830358
March	0.690200	1.886300	September	0.697042	1.611874
April	0.976481	1.801711	October	0.801228	1.640237
May	1.111126	1.799062	November	0.216200	2.084700
June	0.880176	1.816281	December	0.149345	2.190541

Note: ξ= constant, ψ = exponent

RESULTS AND DISCUSSION

Existence of Geometrical Similarity

Variations in monthly minimum temperature (T_{min}) shown in Fig. 2 and ET variations of a sample year shown in Fig. 3, Fig. 2, and Fig. 3 show peaks with increasing order of the months initially and receding thereafter with order of the month. Therefore there exists a geometrical similarity between T_{min} and ET of the eucalyptus. Hence proposed Tmin-based GS Model (Eqn. 10) remains applicable.

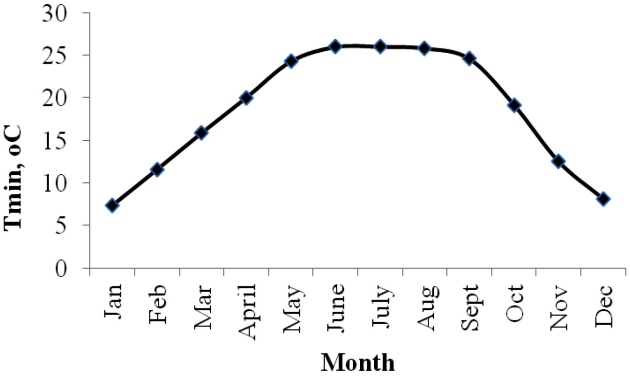

Fig. 2. Monthly variation of ten-year average T_{min}

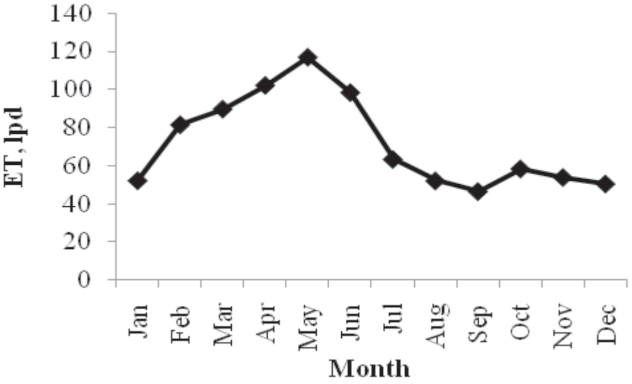

Fig. 3. Monthly variation of ten-year average observed ET

Characteristics Constants

The characteristics constants based on T_{min} data for different months over 10 years are presented in Table 2 and variations are shown in Fig. 4. Yearly variations of C_{Tmin} are shown in Fig. 5. It can be seen from Table 2 and Fig. 4 & 5 that the variation of characteristic constants has a valley shape. The characteristic constants are low for high ET periods during the rainy season due to high relative humidity and during winter due to reduced solar radiation and low temperature. Table 2 and Fig. 5 show that the characteristic constant for specific months increases with age and reaches a plateau at an age of seven to eight years. The values of RH_{7hr} ranged from 52.80% (April) to 87.87% (August) and T_{min} ranged from 7.34 °C (January) to 26.01 °C (July). The characteristic constant C_{Tmin} during the first year reached values in the range of 0.1151 to 0.5058 and during the 10th year ranged from 2.8474 to 12.7362.

Observed and Estimated ET

The calculated values of ET by the Singh & Verma Model are shown in Fig. 6 and that predicted by based G S Model is shown in Fig. 7. The predicted ET values by the Tmin-based GS Model ranged from 1.79-6.47, 3.70-15.42, 12.35-34.68, 31.86-83.31, 50.68-128.76, 61.64-163.55, 67.26-183.50, 70.65-192.40, 70.24-195.57 and 70.43-196.47 and ET predicted by Singh and Verma Model ranged 1.51-6.28, 3.12-14.96, 10.42-39.91, 26.87-80.81, 49.42-124.89, 69.02-158.64, 67.09-177.99, 69.16-186.62, 69.84-189.69 and 70.03-190.57 lpd/plant for 1, 2, 3, 4, 5, 6, 7, 8 and 9 years age respectively. The corresponding percent deviations of predicted ET by

Table 2. Monthly values of C_{Tmin} (=ET/ T_{min}) for 10 years

Month	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Jan	0.5058	0.4253	1.4204	3.6629	6.7368	9.545	11.3784	12.2795	12.6285	12.7362
Feb	0.1868	0.4289	1.4605	3.7354	6.7895	9.5219	11.2703	12.1151	12.435	12.5319
Mar	0.2501	0.5531	1.5932	3.5165	5.798	7.658	8.7888	9.3161	9.5108	9.5687
April	0.2663	0.6041	1.6389	3.4052	5.3723	6.9188	7.8262	8.2389	8.3883	8.4317
May	0.2586	0.6161	1.6437	3.3282	5.1437	6.5337	7.3307	7.6861	7.8126	7.8488
June	0.2036	0.5111	1.3521	2.6887	4.0924	5.1427	5.7323	5.9906	6.0806	6.106
July	0.1676	0.4094	0.9957	1.8469	2.6846	3.2832	3.6084	3.7476	3.7949	3.8083
Aug	0.1151	0.3107	0.7946	1.5122	2.2239	2.7307	3.0038	3.1185	3.1572	3.1677
Sept	0.1626	0.3977	0.8921	1.5390	2.1273	2.5229	2.7279	2.812	2.8397	2.8474
Oct	0.2636	0.6644	1.4801	2.5234	3.4534	4.0671	4.3798	4.5055	4.5462	4.5567
Nov	0.1962	0.6415	1.7267	3.3124	4.8421	5.8888	6.4262	6.6417	6.7105	6.729
Dec	0.2603	0.9054	2.488	4.8009	7.01164	8.5139	9.2713	9.5685	9.6623	9.687

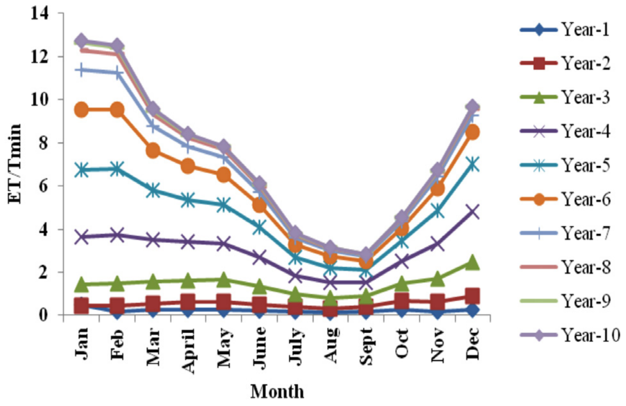

Fig. 4. Variation of C_{Tmin} (=ET/ T_{min}) for ten years

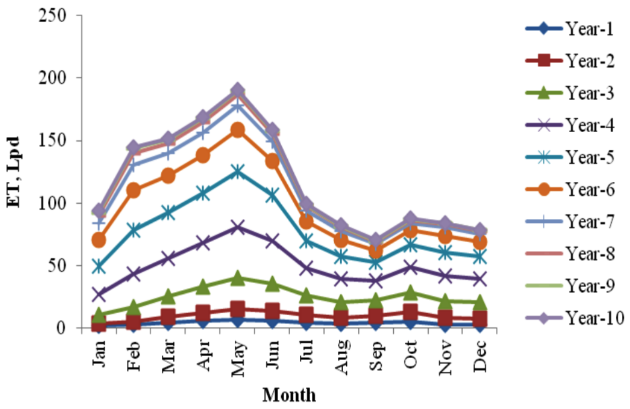

Fig. 6. Predicted ET by Singh & Verma Model

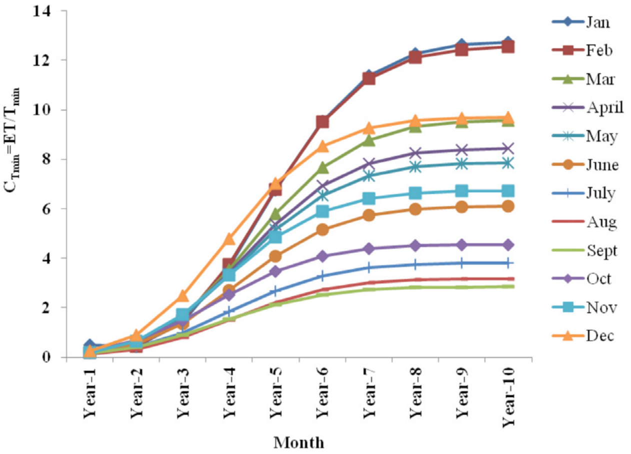

Fig. 5. Variation of monthly C_{Tmin} (=ET/ T_{min}) with age

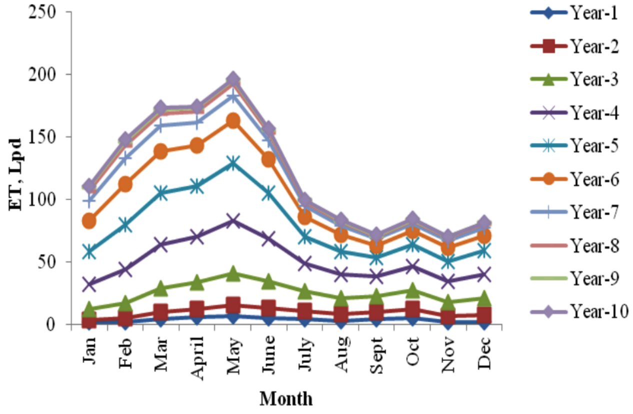

Fig. 7. Predicted ET by Tmin-based GS Model

Table 3. Estimated daily ET of eucalyptus for 10 years by Singh & Verma model

Month	ET, L/Plant/day									
	1-Yr	2-Yr	3-Yr	4-Yr	5-Yr	6-Yr	7-Yr	8-Yr	9-Yr	10-Yr
Jan	1.51	3.12	10.42	26.87	49.42	70.02	83.47	90.08	92.64	93.43
Feb	2.16	4.96	16.89	43.20	78.52	110.12	130.34	140.11	143.81	144.93
Mar	3.97	8.78	25.29	55.82	91.92	121.56	139.51	147.88	150.97	151.89
April	5.33	12.09	32.80	68.15	107.52	138.47	156.63	164.89	167.88	168.75
May	6.28	14.96	39.91	80.81	124.89	158.64	177.99	186.62	189.69	190.57
June	5.29	13.28	35.13	69.86	106.33	133.62	148.94	155.65	157.99	158.65
July	4.36	10.65	25.90	48.04	69.83	85.40	93.86	97.48	98.71	99.06
Aug	2.97	8.02	20.51	39.03	57.40	70.48	77.53	80.49	81.49	81.76
Sept	4.00	9.78	21.94	37.85	52.32	62.05	67.09	69.16	69.84	70.03
Oct	5.05	12.73	28.36	48.35	66.17	77.93	83.92	86.33	87.11	87.31
Nov	2.45	8.01	21.56	41.36	60.46	73.53	80.24	82.93	83.79	84.02
Dec	2.11	7.34	20.17	38.92	56.88	69.02	75.16	77.57	78.33	78.53
Range	1.51- 6.28	3.12- 14.96	10.42- 39.91	26.87- 80.81	49.42- 124.89	69.02- 158.64	67.09- 177.99	69.16- 186.62	69.84- 189.69	70.03- 190.57

T_{min} based G.S. Model compared to the ET predicted by Singh and Verma Model ranged -18.52- -18.59, -2.12- -2.32, -14.11- -14.16, -3.31- -3.38, -3.03- -3.11, -1.27- 1.32, -0.92- -1.03, -2.02- -2.12, -2.14- -2.25, 3.53-3.56, 16.17- 16.23 and -3.32- -3.55% with average deviations of -18.55, -2.32, -14.14, -3.35, -3.09, 1.28. -1.00, -2.07, -2.16, 3.54, 16.20, and -3.51% for 1, 2, 3, 4, 5, 6, 7, 8, and 9 years age respectively.

Table 4. Estimated daily ET of eucalyptus for 10 years by Tmin-based GS Model

Month	ET, L/Plant/day									
	1-Yr	2-Yr	3-Yr	4-Yr	5-Yr	6-Yr	7-Yr	8-Yr	9-Yr	10-Yr
Jan	1.79	3.70	12.35	31.86	58.59	83.01	98.96	106.79	109.83	110.76
Feb	2.21	5.07	17.25	44.12	80.19	112.46	133.11	143.08	146.86	148.01
Mar	4.53	10.02	28.87	63.72	104.92	138.76	159.25	168.80	172.33	173.38
April	5.51	12.49	33.90	70.43	111.12	143.10	161.87	170.41	173.50	174.40
May	6.47	15.42	41.15	83.31	128.76	163.55	183.50	192.40	195.57	196.47
June	5.22	13.11	34.68	68.97	104.97	131.91	147.03	153.66	155.97	156.62
July	4.40	10.76	26.16	48.53	70.54	86.26	94.81	98.47	99.71	100.06
Aug	3.03	8.19	20.93	39.84	58.59	71.94	79.14	82.16	83.18	83.45
Sept	4.09	9.99	22.41	38.66	53.45	63.38	68.53	70.65	71.34	71.54
Oct	4.87	12.28	27.36	46.64	63.83	75.18	80.95	83.28	84.03	84.22
Nov	2.05	6.71	18.07	34.67	50.68	61.64	67.26	69.52	70.24	70.43
Dec	2.18	7.60	20.88	40.30	58.89	71.46	77.82	80.31	81.10	81.31
Range	1.79- 6.47	3.70- 15.42	12.35- 34.68	31.86- 83.31	50.68- 128.76	61.64- 163.55	67.26- 183.50	70.65- 192.40	70.24- 195.57	70.43- 196.47

Table 5. Percent deviations of predicted ET by GS Model with Singh and Verma (2016) for 2004

Age	Jan	Feb	Mar	Apr	May	June	July	August	Sept	Oct.	Nov.	Dec
1-Yr	-18.54	-2.31	-14.11	-3.38	-3.03	1.32	-0.92	-2.02	-2.25	3.56	16.33	-3.32
2-Yr	-18.59	-2.22	-14.12	-3.31	-3.07	1.28	-1.03	-2.12	-2.15	3.53	16.23	-3.54
3-Yr	-18.52	-2.13	-14.16	-3.35	-3.11	1.28	-1.00	-2.05	-2.14	3.53	16.19	-3.52
4-Yr	-18.57	-2.13	-14.15	-3.35	-3.09	1.27	-1.02	-2.08	-2.14	3.54	16.18	-3.55
5-Yr	-18.56	-2.13	-14.14	-3.35	-3.10	1.28	-1.02	-2.07	-2.16	3.54	16.18	-3.53
6-Yr	-18.55	-2.12	-14.15	-3.34	-3.10	1.28	-1.01	-2.07	-2.14	3.53	16.17	-3.54
7-Yr	-18.56	-2.13	-14.15	-3.35	-3.10	1.28	-1.01	-2.08	-2.15	3.54	16.18	-3.54
8-Yr	-18.55	-2.12	-14.15	-3.35	-3.10	1.28	-1.02	-2.07	-2.15	3.53	16.17	-3.53
9-Yr	-18.56	-2.12	-14.15	-3.35	-3.10	1.28	-1.01	-2.07	-2.15	3.54	16.17	-3.54
10-Yr	-18.55	-2.13	-14.15	-3.35	-3.10	1.28	-1.01	-2.07	-2.16	3.54	16.17	-3.54
Range	-18.52	-2.12	-14.11	-3.31	-3.03	1.27	-0.92	-2.02	-2.14	3.53	16.17	-3.32
	-18.59	-2.32	-14.16	-3.38	-3.11	1.32	-1.03	-2.12	-2.25	3.56	16.23	-3.55
Avg.	-18.55	-2.32	-14.14	-3.35	-3.09	1.28	-1.00	-2.07	-2.16	3.54	16.20	-3.51

The percent deviations of predicted ET by the based GS Model were comparatively higher for November, January, and March consistently. A correction factor if necessary can be introduced for these months while predicting ET by the based GS Model.

The percent deviation of predicted ET by the based GS Model ranged from -1.00 to -18.55%. The overall average % deviation of the ET values predicted from the Tmin-based GS Model is only 5.93%. Overall average per cent deviations is much below 10% hence recommended for field application.

CONCLUSION

The ET demands of a growing tree or plants are required for designing a water application system for the soil or drainage rate of an area. Long-term ET data for growing trees are generally not available. The problem of canal irrigated areas is waterlogging and salt buildup in the root zone. Biodrainage is recommended for reclaiming waterlogged and salt-affected waterlogged areas with undulating terrain not suitable for agriculture or land having poor water transmission characteristics. It is also recommended for seepage interception along canals and reclamation of agricultural lands affected by waterlogging coupled with sodicity. Eucalyptus is the most suitable drainage plant globally due to its tolerance to sodicity, salinity, and waterlogging besides its adaptability to adoption under varying climatic conditions. Long-term ET data is essentially required for the planning and design of drainage. Measurement of ET of growing eucalyptus trees over a long period is a difficult task. Modeling of ET may avoid such associated complexity of direct ET measurement. ET of a tree or plant is dependent on its age and weather parameters. Weather parameters are interrelated with each other and are closely related to ET. A geometrical similarity was observed between the growing eucalyptus tree and average monthly weather parameters and consequently, a geometrical similarity model was hypothesized for the ET of the growing tree. A eucalyptus height-based model for ET was used for the estimation of ET of different months for 10 years. The characteristic constants of the GS Model for different months over 10 years were worked out using 10 years' average pan evaporation data. Predicted values of ET by the based GS Model were quite close to the ET values predicted by the Singh and Verma Model. The percent deviation of predicted ET by the based GS Model ranged from -1.00 to -18.55%. The overall average % deviation of the ET values predicted from the Tmin-based GS Model is only 5.93%. Overall average per cent deviations is much below 6% hence recommended for field application. The based GS Model has great field applicability for ET estimation of growing eucalyptus trees because of its simplicity and dependence on a single weather parameter. The GS Model could be also responsive under changing climatic conditions at other locations. T_{min} data performed well in predicting ET values. The Tmin-based GS Model is a simple model performing well in predicting ET values of growing eucalyptus trees.

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