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Research Article

Pan evaporation based geometrical similarity model for prediction of evapotranspiration

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ABSTRACT

The evapotranspiration (ET) demands of growing trees or plants are required for designing groundwater drafts due to plantation over a long period. The principle of high water extractive demand of growing trees could be useful for designing biodrainage systems for reclamation and managing waterlogged salt-affected soils as well as seepage interception. The search for a practical method of estimation of tall growing ET trees suitable for biodrainage over a long period of time using simple weather parameters is still going on. Modeling of ET based on weather parameters and tree parameters may avoid the associated complexity of direct ET measurement. Eucalyptus is the most commonly used tree species for bio-drainage. ET of the eucalyptus is dependent on interrelated weather parameters and the age of the tree. A geometrical similarity (GS) between weather parameters (E_{pan}) and ET of plants was observed, and an E_{pan}-based GS Model was hypothesized. Modeled ET values of eucalyptus by an analytical model of Singh & Verma were used for developing E_{pan} based GS model and predicting ET values for 10 years. Monthly characteristic constants (C_{Epan}) of GS Model were worked out. ET values predicted by GS Model for the year 2004, 2008 and 2013 were compared with the modeled values of ET by Singh and Verma model for different months. Overall average percent deviation of predicted ET values by E_{pan}-based GS Model was only 12.49% compared to the analytically modeled ET values. Average per cent deviations of ET values by the E_{pan}-based GS Model were .07, 21.3 and 8.11% for 2004, 2008 and 2013, respectively. The proposed model is a simple method for the estimation of ET of eucalyptus trees for field application.

Keywords: Biodrainage, evapotranspiration, geometrical similarity, subsurface drainage, waterlogging

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INTRODUCTION

Water management for crops and trees requires understanding of evapotranspiration. Measurement and modelling of ET for short-duration crops are easier compared to the long-duration perennial crops, plantations and trees (Neeraj & Suman, 2012). Through irrigation, crops or plantations are supplied water externally for optimum economic growth. ET data is required for research and management of agricultural and forest meteorology, hydrologic cycle, irrigation and water resource management. A lot of research works on the measurement of ET demand of short-duration crops (cereals, pulses and oil seeds) are reported in the literature (Tripathi, 2004; Tyagi et al., 2000). Lysiemeter study provides precise measurement of actual evapotranspiration (Xu & Chen, 2005; Valipour, 2012a, b; Valipour, 2015a, b, c). Different types of lysimeters have been used to directly measure ET of crops of short duration. Similar precision could be achieved by imaging techniques (Hart et al., 2009; Rahimi et al., 2015). Due to high evapotranspiration (ET) demand and tolerance to salinity, sodicity and waterlogging, eucalyptus is recommended to biodrain waterlogged salt-affected areas (Zahid & Nawaz, 2007; Ram et al., 2011). Measurements of ET of growing trees have also been tried by researchers for short periods only as the long-term measurement of tall growing trees in lysimeters is quite difficult.

The major eucalyptus growing countries 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). In Africa, South Africa has the largest area under Eucalyptus plantations of about half a million hectares (Teketay, 2003). It may give in return large amount of timber, fuel and fodder besides improving environment in a short life span. The common economic life span of eucalyptus in the Indian subcontinent is about five to seven years with normal species and four to five years with cloned species (Verma et al., 2014).

Modern instruments such as sap flow using thermal probes and infrared gas analyzers are being used to measure water extractions trees. These instruments have their limitations, and often readings may need to be more accurate with errors of more than 100%, depending on the type of instrument, methods, tree girth, size and number of trees used for estimation. These methods require complex and very costly instrumental devices and are generally suitable only for specific research purposes. Modeling of ET is the easiest way to correlate weather parameters with evapotranspirative demands of the crops/trees. Models are available for the estimation of ET of short-duration crops under varying climatic conditions. FAO Penman-Monteith has been widely used for estimating reference crop evapotranspiration (Valipour & Eslamian, 2014) but it requires too many parameters. Hence, empirical method such as mass transfer, radiation, temperature and pan evaporation-based method were developed for estimating reference crop evapotranspiration with limited data (Valipour, 2015d; 2014b, c, d, e, f, g). Some new approaches have also been tried for testing and comparing the results with the earlier model (Valipour, 2014h, i).

ET of the growing trees is dependent on weather-air-soil-water environment. Daily maximum temperature (T_{max}), daily minimum temperature (T_{min}), relative humidity (RH_{7hr} and RH_{14hr}), wind velocity (V_{wind}), sun shine hour (SS_{hr}) and pan evaporation (E_{pan}) are taken as parameters. These parameters are closely associated with each other. They affect the physiological responses of plants. Change in one weather parameter will change other weather parameters, some with quick and some with delayed response, thereby evolving a new equilibrium and weather-dependent process. A single weather parameter-based model is useful for better understanding the concepts and field applications. For example any change in solar radiation will cause a change in air temperature which will result in an increase or decrease in rate of water loss from wet or water surfaces, further regulating the evaporation rate. Always there exists a new equilibrium. The physiological response of plant/tree is dependent on its genetic characteristics, local environment, nutrient-soil water-aeration status and physico-chemical properties of soil. Assuming hypothesis that weather parameters are interrelated with each other. A single weather parameter can be considered as an index for correlating physiological responses of the plants under a given conditions of soil water-aeration nutrient status and physico-chemical properties of soil. Moisture status of soil and shallow water tables also affects physiological responses in a specification (waterlogging). ET rate measures crop, tree or plant water demand for optimum yield. Hence, the physiological response is a function of genetic tracts, weather parameters, soil water-aeration nutrient status, and soil physico-chemical properties. For given locations, given genetic material, in a given specific soil medium and nutrient status, water uptake become a function of single weather parameter and crop stage. Developing all weather parameters based ET model for growing tree species may be tedious job. Average climatic conditions of a specific month remain unchanged for ever. Average weather conditions during a specific month remain unaltered for all practical purposes for trees. Thus the increase in ET during a specific month over any period becomes a function of pan evapopration. Hence a single weather parameter that is well interrelated to other weather parameters can be correlated with the stage (age) of the tree and ET. A geometrical similarity model was developed for correlating average monthly pan evaporation with the monthly ET of eucalyptus.

MATERIALS AND METHODS

Height-based ET model for eucalyptus

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

The rate of increase in eucalyptus tree height is directly proportional to the effective height (H_m-H) of tree/plant at a specific time. Mathematically it can be expressed as:

$$\frac{dH}{dT} \propto (H_m - H) \qquad \text{... (1)}$$

Where, H = plant/tree height at a given time and T is time (age).

H_m = Average maximum height of eucalyptus in the region higher will be the increase in height rate.

Rate of increase in tree height is directly proportional to power form age function which can be mathematically written as:

$$\frac{dH}{dT} \propto \quad T^{\mu} \qquad \text{... (2)}$$

Where ì is the characteristic exponent. Combining equation (8) and (9) one will get.

A governing equation for explaining eucalyptus height with time can be written as below.

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

They developed a eucalyptus plant height model as a function of time given below.

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

Where

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

It was also hypothesized that the rate of ET change with respect to plant height is directly proportional to tree height (H) and canopy area (A).

$$\frac{d\ ET}{dH} \propto H\ A \qquad \text{... (5)}$$

Where

$$A = \eta H^{\theta} \qquad \text{... (6)}$$

Where, η and θ are constants.

Combining Eqn. (5) and (6) and introducing a proportionality constant following governing equation for ET can be obtained.

$$\frac{d\ ET}{dH} = \zeta\, \eta\, H^{\theta+1} \qquad \text{... (7)}$$

Where, ζ is proportionality constant.

Solving the above governing eqn (7) following height dependent ET formula.

$$ET = \xi H^{\psi} \qquad \text{...(8)}$$

Where,

$\xi = \dfrac{\zeta\eta}{\psi}$ and $\psi = \theta + 2$

Substituting Equation (4) in to equation (8) ET model was obtained as below.

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

Geometric similarity model

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

$$Output = C_{ch} \text{ x } input\ parameter \qquad \dots (10)$$

Where, C_{ch} is characteristic constant of the model. Characteristic constants of ET model is given below. Ev is the evaporation.

$$C_{E_{pan}} = \frac{ET}{E_{pan}} \qquad ...(11)$$

Study area

The location of study area is at Kashrawan village in Sharada Sahayak Canal Command of district Raibareli, U.P., India. Geographical coordinates lies between 26°30′18.90″N latitudes and 81°6′40.18″E longitudes at an elevation of 110 m above the mean sea level. The area having flat topography with averable slope of 1.5% in the direction of East. The area is canal irrigated and represents a semi-arid-sub-tropical climate, characterized by hot summers and a cool winter with mean annual rainfall of 990 mm. The most of the rainfall occur during June to Septembe. Ten year average pan evaporation varies between 55.83 cm to 243.13 cm.

Sharda Sahayak canal system

Sharda Sahayak Canal system supplies water to the area. It takes off water from the right bank of the lower Sharada Barrage supplying irrigation water to 2.0 million ha through a total length of the branch, secondary and tertiary canal of 8704 km. The capacity of canal is 650 m^3/s. A Large on either side of the canal is waterlogged coupled with sodicity in different reaches. Water table ranges from 0.00 m to 1.5 m throughout the year in the reaches suffering with severe waterlogging. The bottom width of canal is 46 m and depth is 2.2 m with side slope of 1:2. Canal discharge at full supply level is 170 m^3/s. 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, are depth. The soil pH and EC is high toward surfaces & decreases with soil depths.

Biodrainage belt

A biodrainage belt was established using tractor mounted auger and planting one year old eucalyptus saplings (*Eucalyptus camaldulensis*). The diameter of auger hole was 30 cm and depth of hole was 60 cm from soil surface. Input mixture of 5 kg gypsum, 5 kg farm yard manure and 10 kg canal silt was filled in holes. After filling mixture holes eucalyptus sapling were planted irrigation was done manually. The bio-drainage belt was established in an area of 1.20 ha (400m x 30m). Spacing between row and plants were 1.5 m x 1.5 m.

Installation of lysimeters

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 at regular interval of time were records. Constant water table depths inside the lysimeters and outside the lysimeters by applying water every day. The amount of water required to maintain water level was considered as the ET demands of the eucalyptus. Plant height of eucalyptus was measured on monthly basis and ET on daily basis for three years.

Application of models

Plant height and ET data were used to assess optimized values of the characteristic constants of Eqn. (9). The optimized values height model constants, H_s, H_m, α and α were worked out by fitting three years plant height-age data in Eqn. (4). The ET model constant ζ and ψ optimized using monthly ET and height data eqn (9).The maximum average eucalyptus height under waterlogged sodic conditions was calculated as 17.473 m at an age of 10 year. Optimized characteristic constants, α and β of Eqn. (4) were 3.0×10^{-04} and 2.1289, respectively. Eucalyptus height obtained from Eqn. (9) upto 10 year age is shown in Figure 1. Height based ET model's constants ζ and ψ for different months are presented in Table 1. Similarly ET were calculated using eqn (9).

Application of geometrical similarity (GS) model

Characteristics constants of GS model were worked out by using Eqn (11) and calculated values of ET and average Epan data. Using daily Epan data for year 2004, 2008 & 2013 ET values were calculated using eqn (10).

Percent deviation

Percent deviation of predicted ET values with corresponding observed ET values were calculated as below.

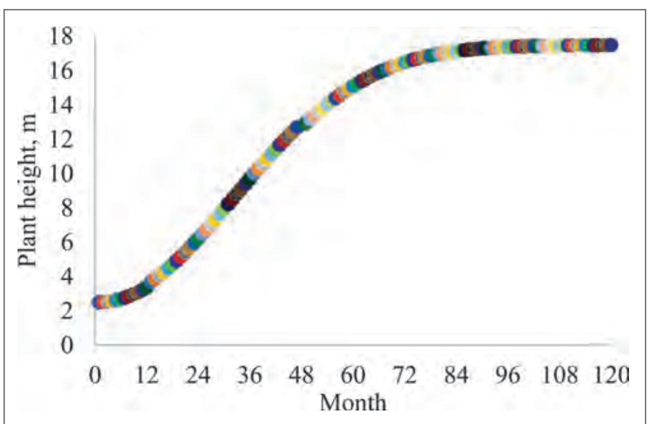


Figure 1: Estimated plant heights up to 10 years

Table 1: Monthly evapotranspiration model constants and correlation parameters

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

Note: ζ= constant, ψ = exponent

$$\%\ deviation = \frac{Observed\ ET - Predicted\ ET}{Observed\ ET} \times 100 \quad ...(13)$$

RESULTS AND DISCUSSION

Existence of geometrical similarity

Variations monthly pan evaporation (E_{pan}) shown in Figure 1 and ET variations of a sample year shown in Figure 2 and variations of observed ET values are shown in Figure 2. Show geometrical similarity There exists a geometrical similarity between E_{pan} and ET. Hence proposed model (Eqn 10) isapplicable.

Characteristics constants

The characteristics constants based on E_{pan} data for different months over a period of 10 years are presented in Table 2 and variations are shown in Figure 3. It can be seen from Table 2 and Figure 3 that the variation of characteristic constants has a valley shape. The characteristic constants are low for high ET period

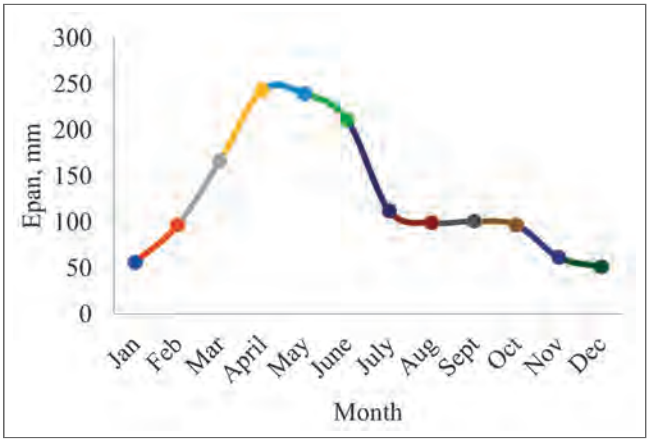


Figure 1: Monthly variation of ten year average pan evaporation

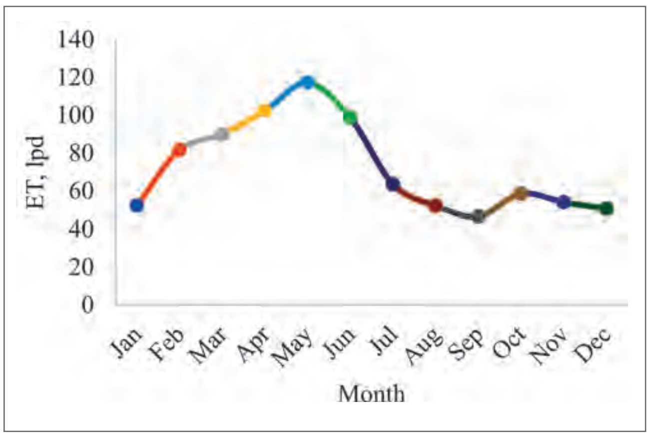


Figure 2: Monthly variation of ten year average observed ET

during rainy season due to high relative humidity and during winter

due to reduced solar radiation and low temperature. Table 2 and Figure 4 shows that the characteristic constant for specific months increases with age and reach a pleatue at an age of seven to eight years. The values of E_{pan} range from 0.0270 to 0.0413 during the first year and reached a value in the range of 1.4952 to 1.4719 during seventh and 1.6736 to 1.5379 during tenth of years of age.

Observed and estimated ET

The calculated values of ET with the help of characteristic constant based on 10 years average Epan data for year 2004, 2008 and 2013 and observed ET values are shown in Figure 5 to Figure 8. The predicted ET values with the help of C_{Epan} ranged 1.76 to 108.62, 2.22 to 149.18, 3.81 to 145.90, 5.14 to 162.62, 5.81 to 176.33, 4.51 to 135.36, 3.95 to 89.73,3.25 to 89.39, 4.68 to 81.88, 4.99 to 86.34, 2.56 to 87.71 and 2.25 to 83.82 lpd/plant for year 2004; 1.86 to 114.98, 2.79 to 186.97, 3.92 to 150.07, 5.75 to 181.92, 6.55 to198.67, 2.68 to 80.23, 2.52 to 57.28, 2.47 to 67.28, 4.84 to 84.77, 4.32 to 74.74, 2.14 to 73.43 and 1.40 to 52.14 lpd/plant for year

Table 2: Monthly values of C_{Epan} (=ET/ E_{pan}) for 10 years

Month	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year10
Jan	0.0270	0.0559	0.1867	0.4813	0.8853	1.2543	1.4952	1.6136	1.6595	1.6736
Feb	0.0224	0.0515	0.1753	0.4484	0.8149	1.1429	1.3528	1.4542	1.4926	1.5042
Mar	0.0239	0.0529	0.1525	0.3365	0.5541	0.7328	0.8410	0.8915	0.9101	0.9156
Apr	0.0219	0.0497	0.1349	0.2803	0.4422	0.5695	0.6442	0.6782	0.6905	0.6941
May	0.0263	0.0625	0.1668	0.3378	0.5221	0.6631	0.7440	0.7801	0.7929	0.7966
Jun	0.0251	0.0631	0.1668	0.3317	0.5049	0.6345	0.7073	0.7391	0.7502	0.7534
Jul	0.0390	0.0953	0.2318	0.4300	0.6250	0.7644	0.8401	0.8725	0.8835	0.8866
Aug	0.0300	0.0811	0.2074	0.3947	0.5805	0.7127	0.7840	0.8140	0.8241	0.8268
Sep	0.0398	0.0972	0.2180	0.3761	0.5200	0.6166	0.6667	0.6873	0.6941	0.6960
Oct	0.0524	0.1321	0.2943	0.5017	0.6866	0.8086	0.8708	0.8958	0.9039	0.9059
Nov	0.0400	0.1309	0.3522	0.6757	0.9877	1.2012	1.3109	1.3548	1.3688	1.3726
Dec	0.0413	0.1437	0.3950	0.7622	1.1139	1.3517	1.4719	1.5191	1.5340	1.5379

Figure 3: Variation of C_{Epan} (=ET/ E_{pan}) for ten years

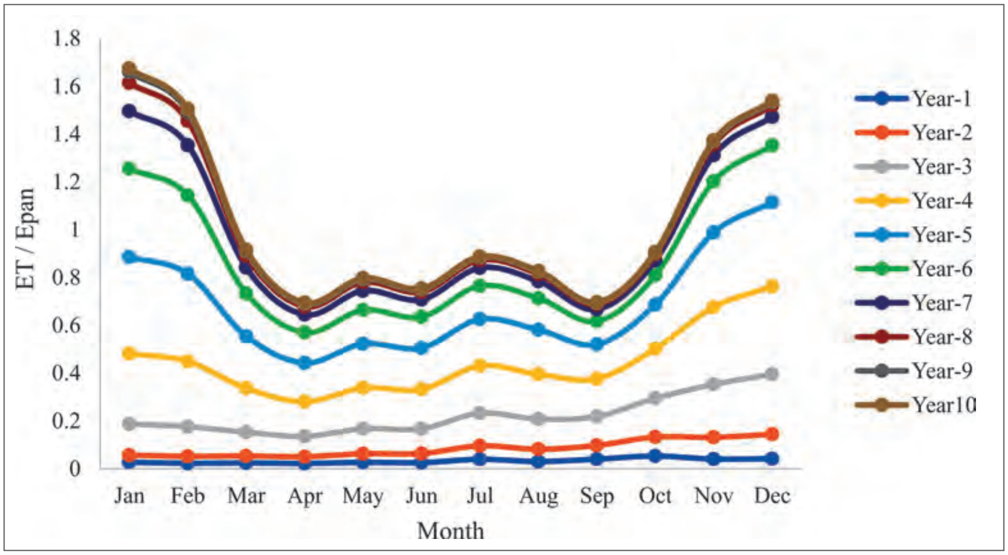
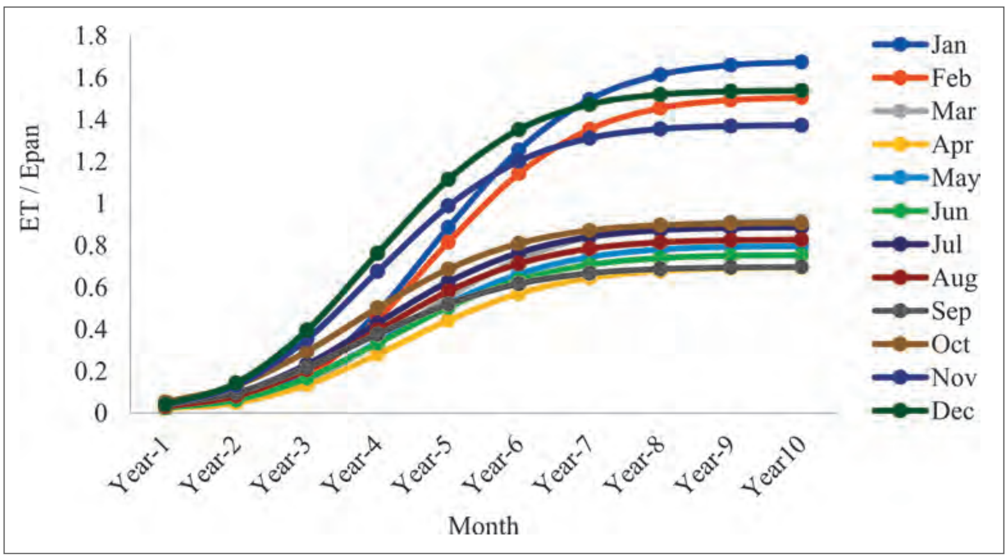


Figure 4: Variation of monthly C_{Epan} (=ET/ E_{pan}) with age.



2008 and 1.26 to 78.24, 2.10 to 140.67,4.13 to 157.87, 5.52 to 174.88, 7.23 to 219.32, 6.07 to 181.39, 4.77 to 108.39, 2.69 to 74.12, 3.61 to 63.19, 5.11 to 88.28, 2.34 to 80.32 and 1.97 to 73.24 lpd/plant for year 2013 for the respective months of January to December over a period of 10 years.

The percent deviation of predicted ET values from C_{Epan} with observed ET values ranged -16.92 to +14.68 % with average % deviation of 8.07 for year 2004, -23.06 to +49.43 % with average % deviation of 21.80 for year 2008 and -15.09 to +16.26 % with average % deviation of 8.11 for year 2013; respectively. Overall average % deviation of the ET values predicted from C_{Epan} is 12.66 which marginally higher than the ET observed.

CONCLUSION

The ET demands of the growing tree or plants are required for designing water application systems to the soil or biodrainage 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 build up in the root zone. Biodrainage is recommended

Table 3: Percent deviations of predicted ET by GS Model with Singh and Verma (2016) for 2004

Jan	Feb	Mar	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
-16.56	-2.78	4.03	3.56	7.48	14.74	9.40	-9.43	-17.00	1.19	-4.49	-6.64
-16.35	-3.02	3.99	3.64	7.49	14.68	9.39	-9.35	-16.87	1.10	-4.37	-6.68
-16.22	-2.96	3.95	3.63	7.47	14.69	9.42	-9.36	-16.91	1.13	-4.41	-6.74
-16.26	-2.94	3.94	3.62	7.47	14.69	9.43	-9.33	-16.91	1.12	-4.40	-6.73
-16.25	-2.93	3.94	3.63	7.47	14.68	9.42	-9.34	-16.92	1.12	-4.07	-6.73
-16.25	-2.93	3.94	3.63	7.47	14.68	9.43	-9.34	-16.92	1.12	-4.39	-6.74
-16.26	-2.93	3.94	3.63	7.47	14.68	9.42	-9.34	-16.92	1.12	-4.39	-6.73
-16.25	-2.93	3.94	3.63	7.48	14.68	9.42	-9.34	-16.92	1.11	-4.39	-6.73
-16.26	-2.93	3.94	3.63	7.48	14.68	9.42	-9.34	-16.92	1.11	-4.39	-6.73
-16.26	-2.93	3.89	3.63	7.47	14.68	9.42	-9.33	-16.92	1.11	-4.39	-6.74

Table 4: Percent deviations of predicted ET by GS Model with Singh and Verma (2016) for 2008

Jan	Feb	Mar	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
-23.18	-29.17	1.26	-7.88	-4.30	49.34	42.20	16.84	-21.00	14.46	12.65	33.65
-23.08	-29.03	1.25	-7.78	-4.28	49.40	42.16	16.83	-21.06	14.38	12.61	33.65
-23.03	-29.01	1.19	-7.80	-4.26	49.42	42.16	16.87	-21.06	14.39	12.62	33.61
-23.07	-29.00	1.20	-7.81	-4.26	49.43	42.17	16.88	-21.03	14.40	12.60	33.61
-23.07	-29.01	1.20	-7.80	-4.25	49.43	42.17	16.88	-21.04	14.40	12.86	33.61
-23.06	-29.01	1.20	-7.81	-4.25	49.42	42.18	16.87	-21.05	14.40	12.59	33.61
-23.06	-29.01	1.20	-7.80	-4.25	49.43	42.18	16.87	-21.05	14.39	12.60	33.61
-23.07	-29.01	1.20	-7.81	-4.25	49.42	42.18	16.87	-21.04	14.40	12.60	33.61
-23.07	-29.01	1.20	-7.80	-4.25	49.43	42.18	16.87	-21.05	14.40	12.60	33.61
-23.07	-29.01	1.15	-7.80	-4.25	49.43	42.18	16.88	-21.05	14.40	12.60	33.60

Table 5: Percent deviations of predicted ET by GS Model with Singh and Verma (2016) for 2013

Jan	Feb	Mar	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
16.56	2.78	-4.03	-3.56	-15.13	-14.74	-9.40	9.43	9.75	-1.19	4.49	6.64
16.35	3.02	-3.99	-3.64	-15.11	-14.68	-9.39	9.35	9.71	-1.10	4.37	6.40
16.22	2.96	-3.95	-3.63	-15.08	-14.69	-9.42	9.36	9.75	-1.13	4.41	6.45
16.26	2.94	-3.94	-3.62	-15.08	-14.69	-9.43	9.35	9.78	-1.12	4.40	6.73
16.25	2.94	-3.94	-3.63	-15.09	-14.68	-9.42	9.34	9.77	-1.12	4.68	6.73
16.25	2.93	-3.94	-3.63	-15.08	-14.68	-9.43	9.34	9.77	-1.12	4.39	6.74
16.26	2.94	-3.94	-3.63	-15.09	-14.68	-9.42	9.34	9.76	-1.12	4.40	6.75
16.25	2.93	-3.94	-3.63	-15.09	-14.68	-9.42	9.34	9.76	-1.11	4.40	6.74
16.26	2.93	-3.94	-3.63	-15.09	-14.68	-9.42	9.34	9.77	-1.11	4.39	6.74
16.26	2.94	-3.99	-3.63	-15.09	-14.68	-9.42	9.34	9.77	-1.11	4.40	6.74

Figure 5: Predicted values of ET for year 2004.

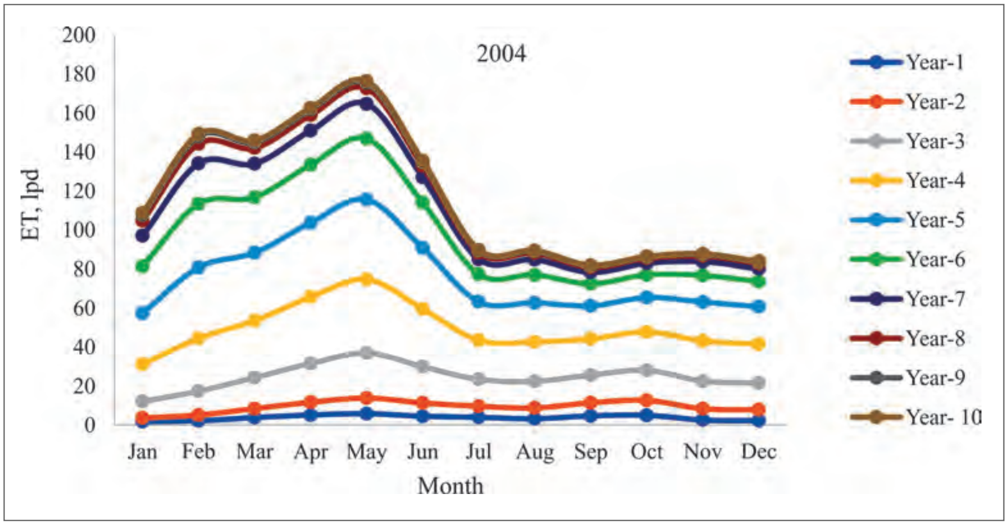


Figure 6: Predicted values of ET for year 2008.

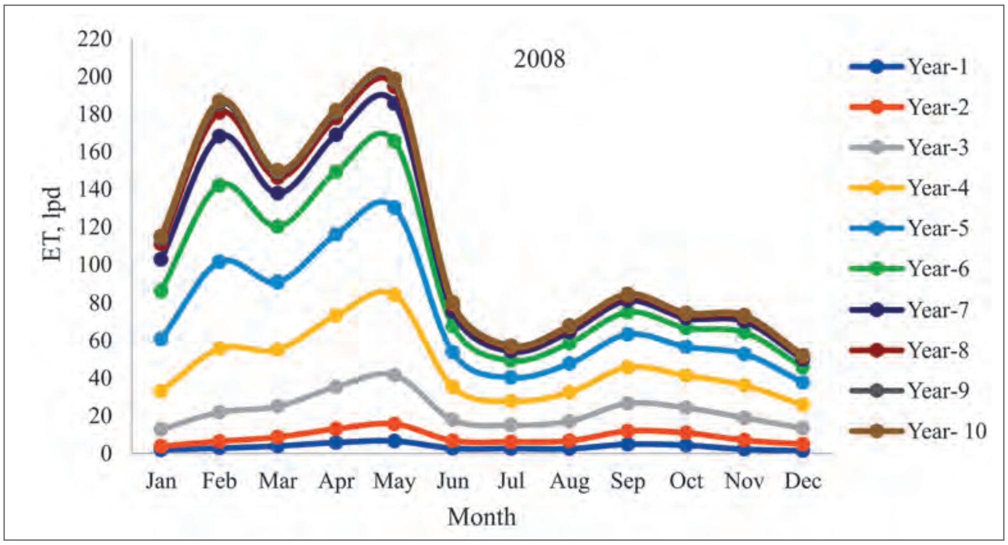


Figure 7: Predicted values of ET for year 2013.

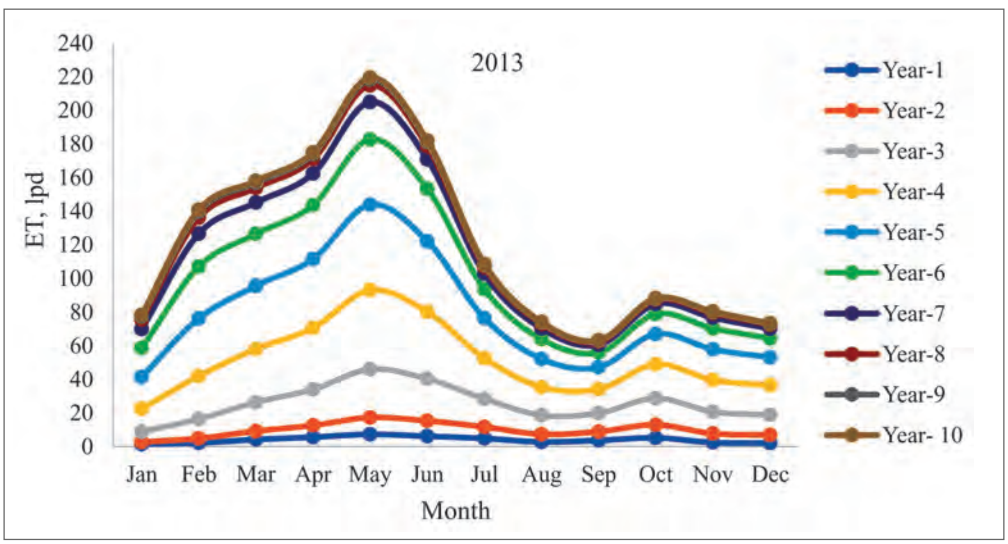
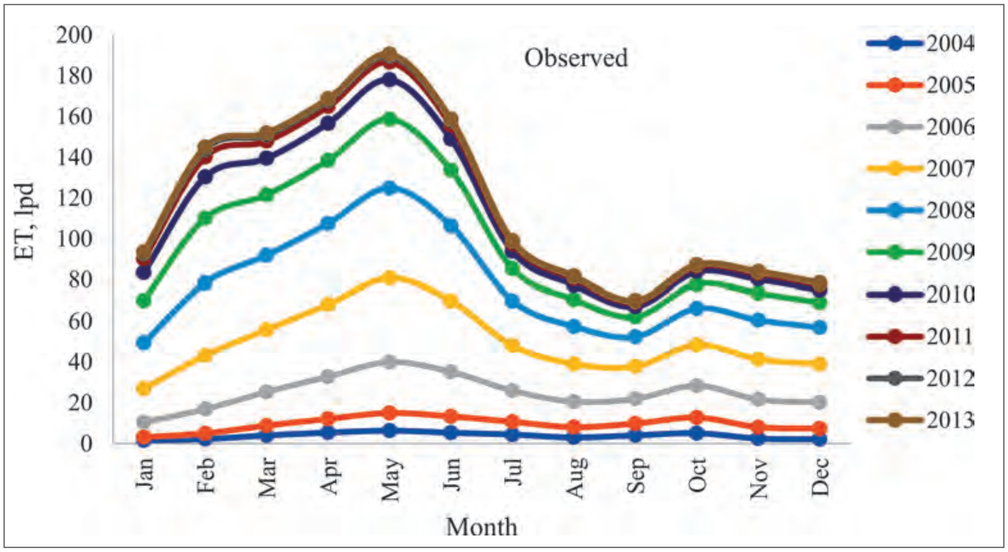


Figure 8: Predicted values of ET for year 2013.



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 canal and reclamation of agricultural lands affected by waterlogging coupled with sodicity. Eucalyptus is the most suitable biodrainage 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 planning and design of biodrainage. Measurement of ET of growing eucalyptus tree over a long period is difficult task. Modeling of ET may avoid such associated complexity of direct ET measurement. ET of tree or plant is dependent on its age and weather parameters. Weather parameters are interrelated with each other and are closely related with ET. A geometrical similarity was observed between growing eucalyptus tree and average monthly weather parameters and consequently a geometrical similarity model was hypothesized for ET of growing tree. A eucalyptus height based model for ET was used for estimation of ET of different month for a period of 10 years. The characteristic constants of GS Model for different months over a period of 10 years were worked out using ten years average pan evaporation data. Predicted values of ET with the use of GS Model for year 2004, 2008 and 2013 were compared with the modeled values of ET of different months. Average % deviations of predicted ET values by Epan based GS Model ranged 1.12-16.92, 1.21-49.42 and 1.12-16.29% with corresponding average deviations of 8.07, 21.3 and 8.11% for the year of 2004, 2008 and 2013, respectively with overall percent deviation of 12.49%. Epan-based GS Model has great field applicability of ET estimation of growing eucalyptus because of its simplicity and dependence on the single weather parameter of pan evaporation. The GS Model could also be responsive under changing climatic conditions at other locations. Epan data performed well in predicting ET values. The Epan-based geometrical similarity model is a simple model performing well in predicting ET values of growing eucalyptus trees.

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