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Analysis of Trend in Reference Evapotranspiration in TG Halli and other Sub Watersheds of Cauvery Basin in Karnataka, India

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Abstract:
In this study ET_r is estimated using the globally accepted Food and Agriculture Organization (FAO) Penman Monteith method (FAO-56 PM) over the 8 weather stations located in the different regions of Cauvery basin. The trends in ET_0 were detected by using the Mann–Kendall (MK) test. Results showed that both statistically significant increasing and decreasing trends were observed monthly ET_0 and increasing trends were observed in annual ETr. In annual time scale, the strong positive trend in ET_0 over Cauvery basin of the magnitude of about 26.56 mm/year was observed. In monthly time scale there was greater number of increasing trends than that of the decreasing trends in most of the warm months. The strongest positive trend magnitude was found in august and the most negative trend magnitude was found in march.

Keywords: Cauvery basin, Evapotranspiration, FAO, Penman Monteith method, annual time scale, monthly time scale.

I. INTRODUCTION

Scientists have developed a number of meteorological procedures for estimating reference evapotranspiration (ET) over the past six decades. The Penman and the Penman Monteith equations represent the two most commonly used methods today. Both procedures have been subjected to modifications in an effort to improve the estimates of reference ET. Unfortunately, this proliferation of "modified" Penman and Penman-Monteith Equations has led to considerable confusion, particularly when using reference ET in operational irrigation management where the use of crop coefficients is required.

The scientific community has addressed this issue in recent years and has developed a standardized computation procedure for estimating reference ET that is based on the Penman-Monteith Equation [1]. This standardized computation procedure has been adopted by the research community, most manufacturers of weather stations and the public weather networks that disseminate reference ET data. Turf Managers should be aware that older weather stations manufactured by Rain Bird, Toro and other irrigation companies may still use the older, non-standardized procedures for estimating reference ET. These older procedures may produce reference ET values with a bias relative to the new standardized procedure. Turf Managers are encouraged to upgrade their weather stations and/or irrigation management software to provide reference ET computed using this new standardized procedure so they can more effectively utilize future research on irrigation scheduling and management. Many tests for the detection of significant trends in hydro climatologic time series can be classified as parametric and non-parametric methods [2],[3]. Parametric trend tests are more powerful than non-parametric ones, but they require data to be independent and normally distributed. In comparison, non-parametric trend tests require only that the data be independent and can tolerate outliers in the data. On the other hand, they are insensitive to the type of data distribution [4], [5]. The Mann-Kendall (MK) and Spearman's Rho (SR) tests are examples of non-parametric tests that are applied for the detection of trends in many studies [6], [7], [8], [9], [10]. A comparison of the power of the MK and SR tests and their results showed the same power in detecting monotonic trends [11], [12].

The objectives of the present study are:

1) To detect the monotonic linear trends in ETo time series using Mann- Kendall (MK) non- parametric test.

2) To estimate the slope of trend lines of ETo time series using Theil Sen's estimator method.

2. MATERIAL & METHODS

The study area selected is TG Halli watershed and sub watersheds of Cauvery basin in Karnataka State, India. Figure 1 shows the location map of study area.

The Cauvery basin extends over states of Tamil Nadu, Karnataka, Kerala and Union Territory of Puducherry draining an area of 81,155 Sq.km which is nearly 2.7% of the total geographical area of the country with a maximum length and width of about 560 km and 245 km. It lies between 75°27' to 79°54' east longitudes and 10°9' to 13°30' north latitudes. It is bounded by the Western Ghats on the west, by the Eastern Ghats on the east and the south and by the ridges separating it from Krishna basin and Pennar basin on the north. The Cauvery River is one of the major rivers of the peninsula. It rises at an elevation of 1,341 m at Talakaveri on the Brahmagiri range near Cherangala village of Kodagu district of Karnataka.

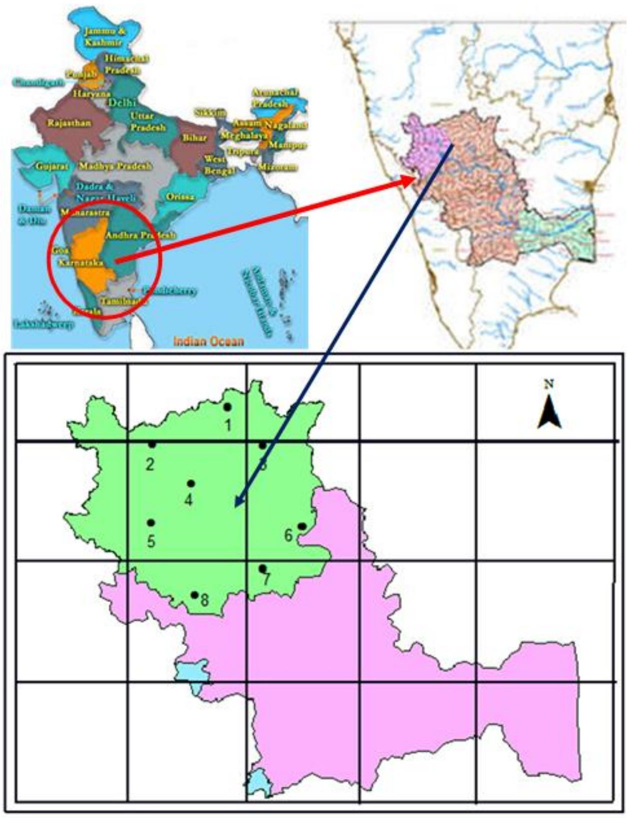

Figure.1. Location Map of Study Area

The location details of the stations considered for the present study is given in table1.

Table.1. geographic characteristics of the stations used in the study area.

No.	Location	Latitude	Longitude	Altitude in m
1	Kadaba amanikere	13°16'08"N	76°52'30"E	756
2	Madenur	12°57'27"N	76°15'00"E	915
3	Kalya	12°57'27"N	77°11'15"E	917
4	Seelanare	12°38'43"N	76°33'45"E	867
5	Tammadahalli	12°19'48"N	76°15'00"E	799
6	Kotekoppa	12°19'48"N	77°33'36"E	586
7	Gumballi	12°01'14"N	77°11'15"E	948
8	Berambadi	11°42'30"N	76°33'45"E	1148

The data used for the selected above stations were obtained from www.globalweather.tamu.edu for a span of 35 years. Table 2.a to 2.e give the statistical properties of annual daily values of maximum and minimum temperature, wind speed, solar radiation an mean relative humidity data such as minimum, lower quartile (Q1), median, upper quartile(Q3) and maximum value for each station. Figures 2.a to 2.e give the average annual daily values of maximum and minimum temperature, wind speed, solar radiation and mean relative humidity data of eight stations respectively.

Table.2. Statistical Properties of Annual Daily Maximum Temperature for 8 Stations In °C

St.#	Min	Q1	Median	Q3	Max
1	17.05	26.13	28.35	33.09	43.33
2	15.97	24.24	26.77	31.65	44.56
3	17.87	26.07	28.42	32.84	44.33
4	16.43	26.06	28.26	32.62	44.39
5	15.39	24.48	27.12	31.68	42.50
6	17.64	27.64	29.92	33.79	45.23
7	16.28	27.13	29.22	33.27	45.41
8	10.49	22.44	25.16	29.02	39.33

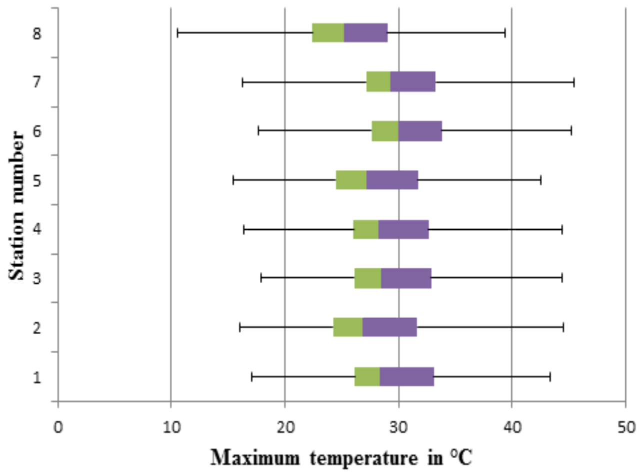

Figure.2. Annual Daily Maximum Temperature For 8 Stations

Table.3. Statistical Properties of Annual Daily Minimum Temperature For 8 Stations

#	Min	Q1	Median	Q3	Max
1	7.34	16.49	19.17	20.42	26.74
2	4.955	15.271	18.339	19.423	23.435
3	7.83	16.34	18.875	20.053	25.197
4	6.71	15.73	18.92	20.18	24.48
5	5.17	15.307	18.34	19.51	23.656
6	7.73	16.63	19.45	20.69	25.35
7	4.48	16.26	19.18	20.37	24.804
8	4.50	14.55	17.48	18.52	22.24

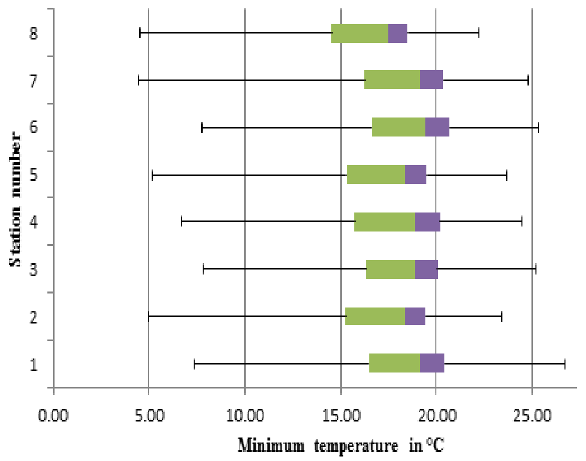

Figure.3. Annual Daily Minimum Temperature For 8 Stations

Table.4. Statistical Properties Of Annual Daiy Wind Speed For 8 Stations In M/Sec

St.	Min	Q1	Median	Q3	Max
1	0.62	2.10	2.65	3.24	6.73
2	0.55	1.90	2.42	3.11	8.06
3	0.47	1.99	2.57	3.21	7.46
4	0.51	2.09	2.60	3.33	7.78
5	0.48	1.73	2.32	3.00	8.27
6	0.48	1.78	2.33	3.02	6.18
7	0.47	1.57	1.98	2.57	5.27
8	0.38	1.30	1.81	2.38	6.74

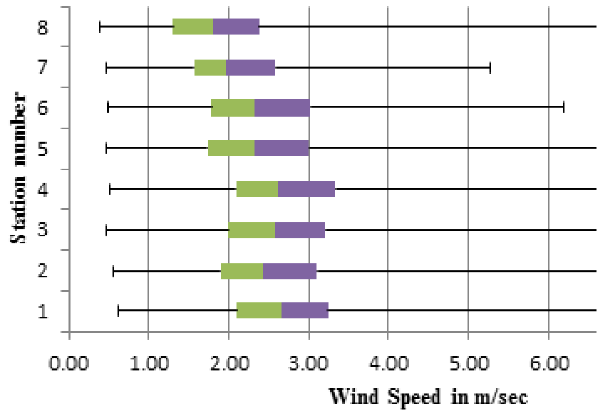

Figure.4. Annual Daily Wind Speed For 8 Stations In M/Sec

Table.5. statistical properties of annual daily relative humidity for 8 stations.

St.	Min	Q1	Median	Q3	Max
1	17.83	50.30	69.92	83.54	96.52
2	18.80	58.01	76.73	87.84	97.07
3	17.47	53.79	72.60	85.15	96.94
4	18.78	56.28	73.26	83.05	95.01
5	11.80	61.65	78.40	88.73	97.94
6	17.74	56.18	71.04	80.50	97.28
7	15.84	59.19	73.77	82.50	97.47
8	13.69	71.11	86.42	94.22	99.40

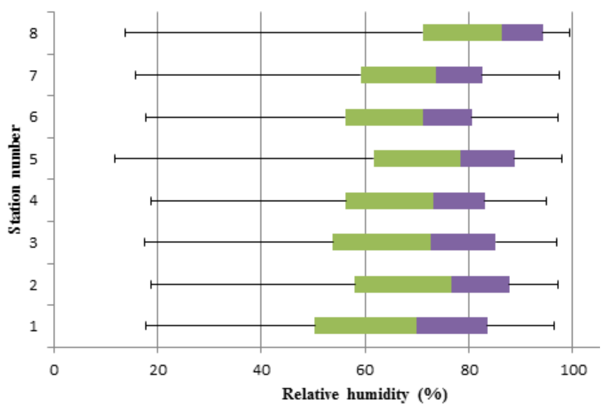

Figure. 5. Annual Daily Relative Humidity

Table.6. Statistical Properties Of Annual Daily Solar Radiation For 8 Stations In Mj/M^2/Day

St.	Min	Q1	Median	Q3	Max
1	0.72	13.69	19.86	22.44	27.97
2	0.72	12.28	19.23	22.23	28.15
3	0.72	12.53	19.12	22.07	27.99
4	0.81	16.82	20.90	23.24	28.00
5	0.72	13.28	19.98	22.82	28.45
6	0.68	16.23	20.64	23.04	27.93
7	0.72	16.69	20.89	23.30	27.95
8	0.72	9.07	16.63	21.47	28.20

Figure.6. Annual Daily Solar Radiation For 8 Stations In Mj/M^2/Day

3. METHODOLOGY

Penman-Monteith combination method is adopted as standard for reference evapotranspiration and reference crop as a hypothetical crop with an assumed height of 0.12 m having a surface resistance of 70 s m-1 and an albedo of 0.23 the FAO Penman-Monteith method was developed.

$$ET_r = \frac{0.408\Delta(R_n - S) + k\left(\frac{900}{T_a + 273}\right)V(e_s - e_a)}{\Delta + k(1 + 0.34V)} \qquad (1)$$

Where,

ET_r = reference crop evapotranspiration (mm/day),
Δ = slope of vapor pressure versus temperature curve
K = psychrometric constant (kPa^{o}C^{-1}),
v = wind speed at a 2 m height (m s^{-1}),

Rn = net radiation at crop surface (MJ m^{-2} d^{-1}),
G = soil heat flux density (MJ m^{-2} d^{-1}),
Ta = mean daily air temperature at 2 m height (°C), and
(es–ea)= saturation vapor pressure deficit (kPa).

The reference evapotranspiration, ETr, provides a standard to which:

- ✓ Evapotranspiration at different periods of the year or in other regions can be compared;
- ✓ Evapotranspiration of other crops can be related.

Mann Kendall test was originally introduced by Mann [13], and was then expanded by Kendall [14], This test is used to determine trends and their significance. This test also gives information about the starting point of the trend and sudden changes in the climate. One of the strong points of this test is its suitability for time series that do not fit into any specific statistical distribution. Another advantage of this test is that it is marginally influenced by outlier data which is seen in many time series. The Null Hypothesis of this test is that the data series does not follow a trend and is accidental, and the acceptance of the Alternative Hypothesis means that a trend does exist in the data series.

4. RESULTS

The annual daily ETr values computed are tabulated in table.3. Figure 3 & 4 shows the Box & Whisker plot of annual daily ETr values and Monthly mean daily ETr values for 8 stations in mm/month

Table.7. statistical properties of annual etr values (mm/day) for 8 stations

St	Min	Quartile 1	Median	Quartile 1	Max
1	0.2	3.3	4.4	5.7	10.2
2	0.2	2.8	4	5.1	9.1
3	0.2	3.1	4.3	5.5	9.6
4	0.3	3.6	4.5	5.7	9.6
5	0.1	2.8	4	5.1	9
6	0.2	3.7	4.6	5.7	9.1
7	0.2	3.6	4.4	5.5	8.7
8	0.2	2	3.2	4.2	7.5

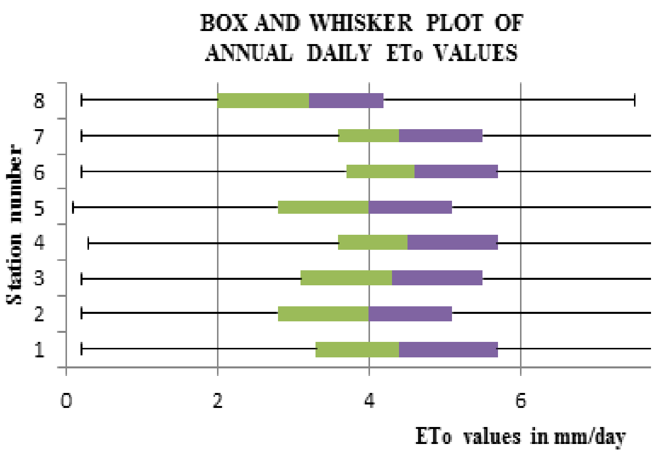

Figure.7. Annual Daily Eto Values For 8 Stations In Mm/Day

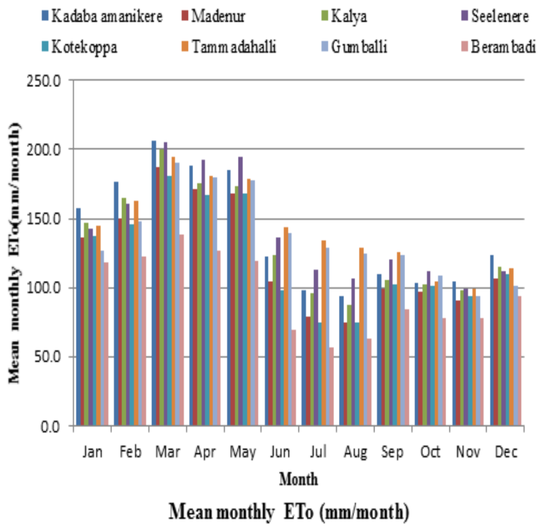

Figure.8. Monthly Mean Daily Eto Values For 8 Stations In Mm/Month

The trend of reference evapotranspiration and for 35 years is found using non-parametric Mann-Kendall test. Table 4 shows the ETo trend results in terms of Zc statistic of Mann-Kandall Method for all months and the year of 8 (The significance level alpha = 0.05).

Table.8.Trend Tests,Zc Statistic, Obtained Through The Mk Method For Eto For The Span Of 35 Years (1979-2013)

Month	Station name							
	Kadaba amanikere	Madenur	Kalya	Seelanare	Kotekoppa	Tammadahalli	Gumballi	Berambadi
J	0.21	0.19	0.14	0.138	0.22	0.11	0.20	0.21
F	0.27	0.09	0.22	0.092	0.27	0.12	0.12	0.29
M	0.04	0.03	0.01	-0.039	-0.10	-0.03	0.04	-0.02
A	-0.04	-0.02	0.07	-0.071	-0.02	-0.07	-0.07	0.19
M	-0.03	0.17	0.20	0.089	0.01	0.07	0.10	0.08
J	0.05	0.25	0.26	0.2	0.11	0.16	0.16	0.30
J	0.09	0.06	0.17	0.119	0.19	-0.07	0.12	0.20
A	0.50	0.49	0.50	0.39	0.25	0.27	0.20	0.57
S	0.20	0.03	0.17	0.034	0.05	-0.18	-0.04	0.16
O	-0.02	0.04	0.07	0.025	-0.05	-0.04	-0.08	0.03
N	0.12	0.08	0.11	0.02	0.13	0.03	0.09	0.35
D	0.24	0.21	0.13	0.173	0.16	0.18	0.13	0.32

From results It is observed that Zc shows the trend weather it is increasing or decreasing. In the months of Jan, Feb, May, June, Aug, Nov and Dec, all the stations exhibited Positive trend characteristics and in the months of Mar, Apr, Jul, Sep and Oct, all the stations exhibited either positive or negative trend characteristics. But Kalya is only the station showing positive trend in all the months. Fig shows the location of sites with increasing trends and decreasing trends at 5% singnificance level for the monthly ETo time series for the period of 1979-2013.

5. CONCLUSIONS

In this study, temporal trends in ETr data for 8 main stations were analyzed. The results showed that increasing and decreasing tends were found for monthly ETr. The results of monthly mean ETr values of average of 8 stations obtained by FAO56-PM method, the higher values of ETr are observed during the months of March, April and May (5.5 to 6.06 mm/day) whereas relatively lower values are obtained during the months of July, august and November (3.04 to 3.15mm/day). Mante Carlo test gives us a result which is p-values are nonnegative. so that it is concluded that the data used for calculation is homogeneous. Zc statistic obtained through MK method for ETr indicates that in all the months, all the stations (except Kalya) Exhibited either positive or negative trend characteristics. However, all the stations showed solely positive trend characteristics in Jan, Feb, May, June, Aug, Nov and Dec. Kalya is only the station showing positive trend in all the months. The multiple regression analysis indicates that wind speed was found to be the foremost dominant variable influencing the ETr in the study area in annual duration.

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