Variation of Reference Evapotranspiration and the Climatic Parameters in Humid tropics

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Abstract: The changes in the evapotranspiration have significant effect in the water resources management sector. In the changing climatic scenario it is important to look into the possibility of changes occurring in evapotranspiration. In this study the direction of trends of reference evapotranspiration (ETo) was explored in the humid tropics of Kerala. The variation in reference evapotranspiration is a good indicator of climate change since it combines almost all climate parameters like temperature, relative humidity, wind speed and solar radiation. Hence variations of these climatic parameters were also studied and compared with the ETo. Monthly climatic data of 7 meteorological stations, 6 maintained by Indian Meteorological Department (IMD) and one station maintained by Centre for Water Resources Development and Management (CWRDM) of Kerala for the period 1980 to 2011 were used for the analysis. Monthly evapotranspiration was calculated using modified Penmann- Montieth equation. It was found that the values of ETo in April and May for all the stations showed the maximum, ranging from 4.6 mm/day to 5.3 mm/day. In Northern Kerala, minimum value was found in the month of July and in southern region, in November ranging from 2.9 mm/day to 3.6 mm/day. This may be ascertaining to the fact that North East monsoon is more prominent in Southern Kerala. To identify the direction of the trend, Mann Kendall trend test, a non parametric statistical analysis was carried out using all meteorological parameters on monthly basis. Results showed a steady decrease in ETo in most of the stations. 57 % of stations gave reduced ETo in the month of January and April, and none in August. Non monsoon months (December to May) showed more variation than the monsoon months (June to November). Increasing trend was observed in two stations Kottayam and Punalur. The least affected station was Kochi in Central Kerala. A steady increasing trend in maximum temperature and relative humidity and decreasing trend in minimum temperature and in wind speed was observed in most of the months. In the case of maximum temperature, increasing trend existed in most stations except in the month of May in Alappuzha and Kottayam, which showed decreasing trend. Minimum temperature shows a decreasing trend in all of the stations except in Thiruvananthapuram, which showed increasing trend. An increase in trend of relative humidity was observed in all stations except in the month of January in Kottayam and June in Punalur, that showed declining trend. Almost all stations gave a declining wind speed. The regression analysis shows that ETo is highly correlated with wind speed and relative humidity and to a lesser extent to maximum and minimum temperature. These are some of the inferences drawn from this study.

Keywords: *reference evapotranspiration, climate parameters, trend Analysis, Mann Kendall*

1: Introduction

Climate change and its effect on water resources and hydrologic cycle is being studied recently. Various climate parameters were studied to get an indication of climate change. Rainfall and temperatures are commonly analysed. Evapotranspiration is another parameter which plays a main role in water cycle. Reference evapotranspiration (ETo) is of great importance as it combines all climatic parameters like maximum and minimum temperature, relative humidity, wind speed and sunshine hours. Evapotranspiration was found to show increasing trend in 14 stations out of 29 stations in Arabian Peninsula [1]. Trends in evapotranspiration in monthly, seasonal and annual time series was studied in humid climate of Serbia [2]. This study shows an increasing trend in majority of stations during summer season. In the contrary, in China a significant decreasing trend is found both in reference evapotranspiration and pan evaporation [3][4]. This is mainly caused by a significant decrease in net radiation and to a lesser extent by wind speed of the catchment. In another study trend and variation was analysed for evapotranspiration and related climate parameters [5]. Evapotranspiration was significantly and inversely correlated with precipitation and relative humidity and directly correlated to maximum an average temperature, vapour pressure deficit and

net radiation. In United States a comparative study of trends in precipitation, stream flow and evapotranspiration was studied [6]. An upward trend in precipitation over the last two decades of 20th century had a strong impact on stream flow and comparatively weaker impact on evapotranspiration. These studies indicate that spatial and temporal variation of evapotranspiration is location specific.

Kerala, the state lying between Western Ghats in East and Arabian Sea in the west is situated in the southern tip of India (8º18' and 12º48' N latitude and 74º52' and 77º22' E longitude). With an annual rainfall of 3000 mm, this state is enriched 44 small and medium rivers. The land is flatter in the western coast and becomes hilly in eastern region, classifying the state into three physiographic regions namely highland (altitude >76m), midland (<76m and > 7.6m) and lowland (<7.6m). Kerala is blessed with six months heavy rainfall in two monsoon seasons South-West (June to August) and North-East (September to November). The temperature reaches maximum (>32ºC) during March-May and lower temperature (<27ºC) in the month of December and January [7]. There are indications of variation in evapotranspiration and climate in Kerala as indicated in other parts of the world. In a study done in Kerala both reference evapotranspiration and pan evaporation are found to be show a decreasing trend in Calicut station of Northern Kerala for the years 1986 to 2010 [8]. Another report showed an increase in average and maximum temperature during the period 1998 to 2012 in Malur station of Northern Kerala [9]. This study with more meteorological stations may give a clearer picture of evapotranspiration and climatic parameters in Kerala.

2: Materials and methods

Monthly Climate data like maximum and minimum temperature, relative humidity, wind speed and sunshine hours were collected from Indian Meteorological Department (IMD) and Centre for Water Resources Development and Management (CWRDM), Kozhikode. Data from 7 meteorological stations for the period 1980 to 2011 were used for the analysis of long term variation of climatic parameters. Thiruvanathapuram (TVM), Punalur (PNL), Kottayam (KOT), Alappuzha (ALP), Kochi (KOC) and Kannur (KAN) were the stations maintained by IMD and Kozhikode (KOZ) by CWRDM, Kozhikode located as shown in fig 1. These data were used for calculating monthly evapotranspiration using Penman Montieth equation.

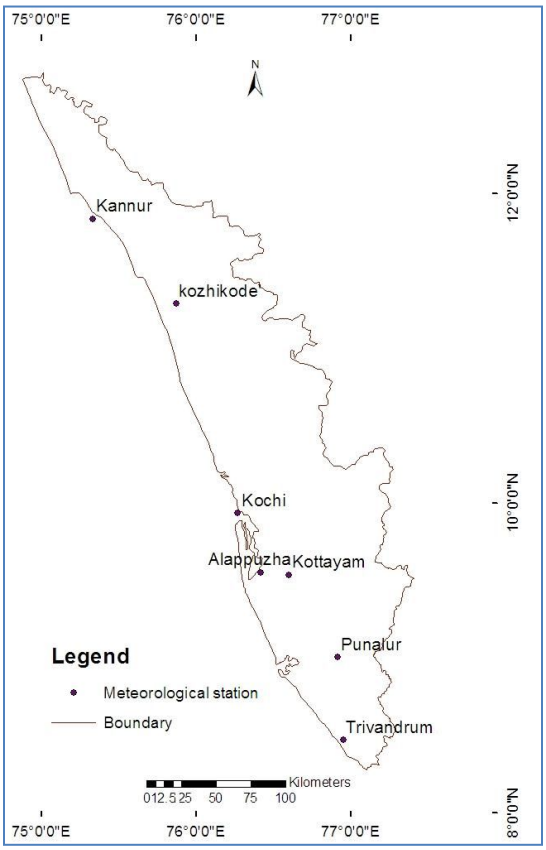


Fig. 1: Location map of Meteorological stations

The location details of meteorological stations are given in table 1. Out of the seven stations, two stations falls in lowland region, one in high land and others in midland region.

Table 1: Details of Meteorological Station

Station	Longitude	Latitude	Altitude (m)
Alappuzha	76.42	9.55	0
Kochi	76.27	9.93	4
Kannur	75.37	11.88	12
Trivandrum	76.95	8.47	20
Kottayam	76.60	9.53	25
Kozhikode	75.87	11.29	60
Punalur	76.92	9.00	159

2.1 Penmann montieth equation

Evapotranspiration was calculated by using FAO

Penmann Montieth method which is given by the following equation.

Where
ET_o reference evapotranspiration [mm day^{-1}], R_n net radiation at the crop surface [MJ m^{-2} day^{-1}], G soil heat flux density [MJ m^{-2} day^{-1}], T mean daily air temperature at 2 m height [°C], u_2 wind speed at 2 m height [m s^{-1}], e_s saturation vapour pressure [kPa], e_a actual vapour pressure [kPa], e_s - e_a saturation vapour pressure deficit [kPa], D slope vapour pressure curve [kPa $°C^{-1}$], g psychrometric constant [kPa $°C^{-1}$]. CROPWAT was used for calculating monthly evapotranspiration.

2.2: Mann Kendall trend test

Mann Kendall, a non parametric test for identifying trends in time series data is used for the study. Non parametric test compares the relative magnitudes of sample data rather than the data values themselves. The Mann Kendall test was run at 5% significance level. The null hypothesis of no trend was checked with alternative hypothesis of decreasing or increasing trend. Let x1, x2, ….. xn represent n data points where xj represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

Where

The variance of S is calculated by

The Z statistics is calculated as follows

The value of S illustrates the magnitude of increasing and decreasing trend depending upon positive and negative value respectively. But this has to be checked with the probability associated with S and number of data n to compute the significance of the trend. If the probability is lower than the significance level, then the null hypothesis was rejected. Addinsoft's xlstat 2013 was the software used for the Mann Kendall test.

3: Result

Monthly evapotranspiration was calculated for each stations using CROPWAT software. The highest value of ETo was occurred in summer months of April and March. The value of maximum ETo ranges from 5.30 mm/day in Kannur of Northern Kerala to 4.51 mm/day in Kottayam. The ETo was minimum in Monsoon months. The lowest value ranges from 2.91 mm/day in Kozhikode to 3.61 mm/day in Punalur. The lowest value was observed in July in the case of Northern Kerala and in November in Southern Kerala. This may be due to the fact that Northeast monsoon is more prominent in South Kerala. The variation of ETo throughout the year is minimal and is shown in fig 2.

Fig. 2: Variation of monthly average ETo

3.1: Trend in Evapotranspiration

Mann Kendall test was run at 5% significance level for estimating the trends in ETo for each month for all the 7 stations. ETo was observed to have a general decreasing trend. The declining trend was

Table 2: Kendalls tau (τ) in Mann Kendall test in each station (* p value is less than significance level 0.05)

Month	ALP	KOC	KAN	TVM	KOT	KOZ	PUN	Decreasing (increasing)
Jan	-0.46*	-0.08	-0.33*	-0.30*	0.35*	-0.42*	0.00	4(1)
Feb	-0.41*	0.07	0.09	-0.21	0.39*	-0.58*	-0.19	2(1)
Mar	-0.46*	-0.18	-0.01	-0.15	0.29*	-0.53*	-0.09	2(1)
Apr	-0.47*	0.00	0.11	-0.32*	-0.27*	-0.47*	-0.13	4(0)
May	-0.29*	-0.12	0.00	-0.19	-0.35	-0.35*	-0.02	3(0)
Jun	0.03	0.22	-0.15	0.19	0.12	-0.29*	0.39*	1(1)
Jul	-0.01	0.15	0.03	-0.07	-0.06	-0.38*	0.17	1(0)
Aug	0.16	0.18	0.00	0.08	-0.08	-0.19	0.40*	0(1)
Sep	-0.09	0.05	-0.13	-0.13	-0.07	-0.32*	0.09	1(0)
Oct	-0.17	-0.14	0.15	-0.07	-0.01	-0.26*	0.07	1(0)
Nov	-0.36*	0.00	-0.25	-0.28*	-0.05	-0.17	0.02	2(0)
Dec	-0.42*	0.03	-0.27	-0.20	0.24	-0.44*	0.01	2(0)
Decreasing (Increasing)	7(0)	0(0)	1(0)	3(0)	2(3)	10(0)	0(2)	

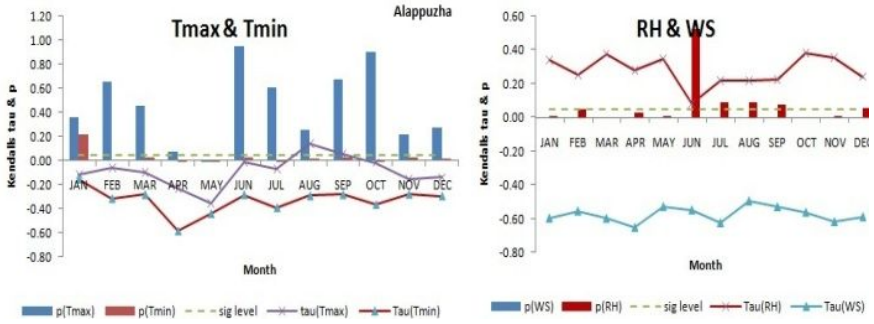
more in months of January and April and none in August. In Alappuzha and Kozhikode ETo was observed to be decreasing in most of the year. Reduced ETo are more prominent in summer months than compared to monsoon months as shown in Table 2. Increasing trend was observed in two stations Punalur and Kottayam.

3.2: Maximum and minimum temperature (Tmax, Tmin)

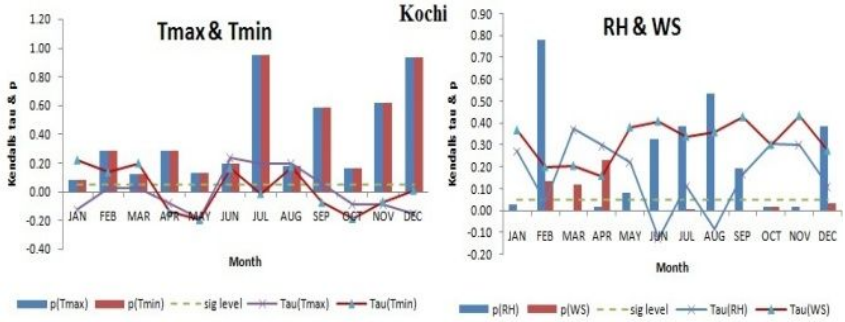
Trend test was done for the maximum and minimum temperature of each month for all stations. It was found that maximum temperature was inclined towards a general increasing trend, while minimum towards decreasing. Maximum temperature was observed to be increasing in most stations. Declining temperature was observed only in the month of May in Alappuzha and Kottayam. On the other hand minimum temperature was observed to be decreasing in the study period. Only in Trivandrum it was found to be increasing. The Kendalls statistics of all the stations are given in fig 3(a, b, c, d, e, f, g). This study reveals an increasing maximum temperature and decreasing minimum temperature. While checked with ETo and temperature, the months which showed decreasing ETo also showed decreasing temperature, in Alappuzha and Kozhikode.

3.3: Relative humidity (RH) and wind speed (WS)

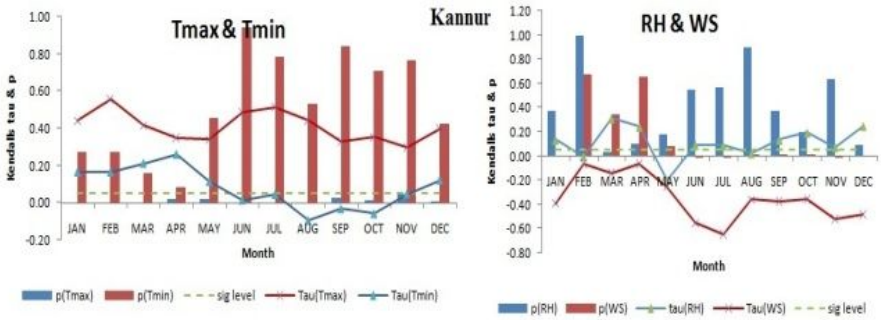
An increasing trend was observed in the case of relative humidity in almost all stations. Alternatively in the month of January in Kottayam and June in Punalur, a decreasing trend was observed. On the other hand wind speed was observed to have a decreasing trend in all stations except in Kochi. The Kendalls statistics of relative humidity and windspeed of all the stations were shown in fig 3(a,b,c,d,e,f,g). While comparing ETo, relative humidity and wind speed, the months which gave decreasing ETo also showed decreasing wind speed and increasing relative humidity.


Alappuzha
Tmax & Tmin
Kendalls tau & p
Month
p(Tmax)
p(Tmin)
sig level
tau(Tmax)
Tau(Tmin)
RH & WS
p(WS)
p(RH)
Tau(RH)
Tau(WS)

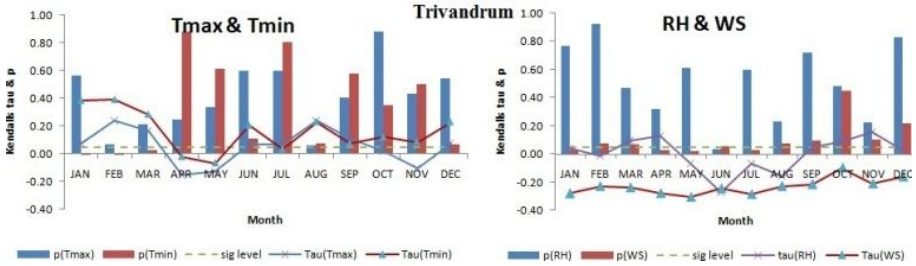
(a)


Kochi
Tmax & Tmin
Kendalls tau & p
Month
p(Tmax)
p(Tmin)
sig level
Tau(Tmax)
Tau(Tmin)
RH & WS
p(RH)
p(WS)
Tau(RH)
Tau(WS)

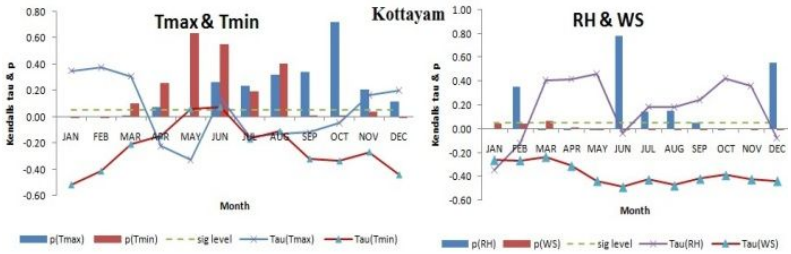
(b)


Kannur
Tmax & Tmin
Kendalls tau & p
Month
p(Tmax)
p(Tmin)
sig level
Tau(Tmax)
Tau(Tmin)
RH & WS
p(RH)
p(WS)
tau(RH)
Tau(WS)

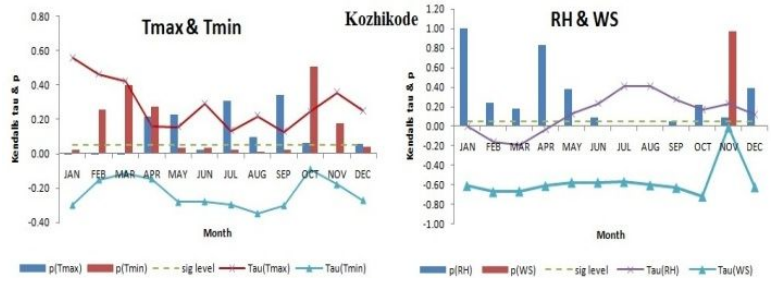
(c)


Trivandrum
Tmax & Tmin
Kendalls tau & p
Month
p(Tmax)
p(Tmin)
sig level
Tau(Tmax)
Tau(Tmin)
RH & WS
p(RH)
p(WS)
tau(RH)
Tau(WS)

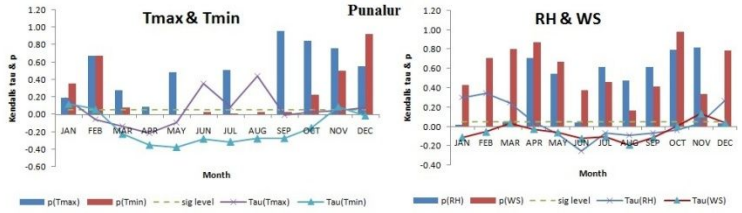
(d)



(e)



(f)



(g)

Fig.3: Kendalls statistics of maximum and minimum temperature relative humidity and wind speed of (a) Alappuzha, (b) Kochi (c) Kannur (d) Trivandrum (e) Kottayam (f) Kozhikode & (g) Punalur

3.4: Relation between ETo, Tmax, Tmin, RH and WS

The Mann Kendall test revealed that there is a decreasing trend in reference evapotranspiration, minimum temperature and wind speed. Alternatively an increasing trend was observed in maximum temperature and relative humidity. Also the factors which affect ETo are location specific. To understand the dominating factor that affects the variation in evapotranspiration, regression analysis was done using the climatic parameters and ETo. The ETo was highly correlated with wind speed and relative humidity and to a lesser extent to maximum and minimum temperature in regression analysis. Fig 8 shows regression analysis of various parameters with ETo of six stations for a particular month that showed variation in Mann Kendall test. The variations in maximum and minimum temperature were observed to have only slight effect on ETo. The wind speed was positively correlated with ETo and relative humidity negatively correlated as indicated by the Mann Kendall test. The regression coefficient is more in Kannur (R2=0.83) in case of Kannur. For the other stations the regession coefficient were Trivandrum 0.74, Kottayam 0.70, Alappuzha 0.62,Kozhikode 0.30 and Punalur 0.01. on the other hand ETo was highly negatively correlated (R2=0.69) by RH in Alappuzha. The regression coefficient of ETo and RH was 0.64, 0.34, 0.28, 0.24 and 0.13 in Punalur, Kannur, Kozhikode, Kottayam and Trivandrum. In Punalur, the only station in high land ETo was not much affected by wind speed, RH was rather the most influenced parameter here. Kannur, Kottayam and Kozhikode that falls in midland region with altitude ranging from 12m to 25m the most influenced parameter was wind speed then comes the RH. In Alappuzha and Kozhikode both wind speed and relative humidity plays similar role in the ETo analysis. Since trend was not detected in Kochi in

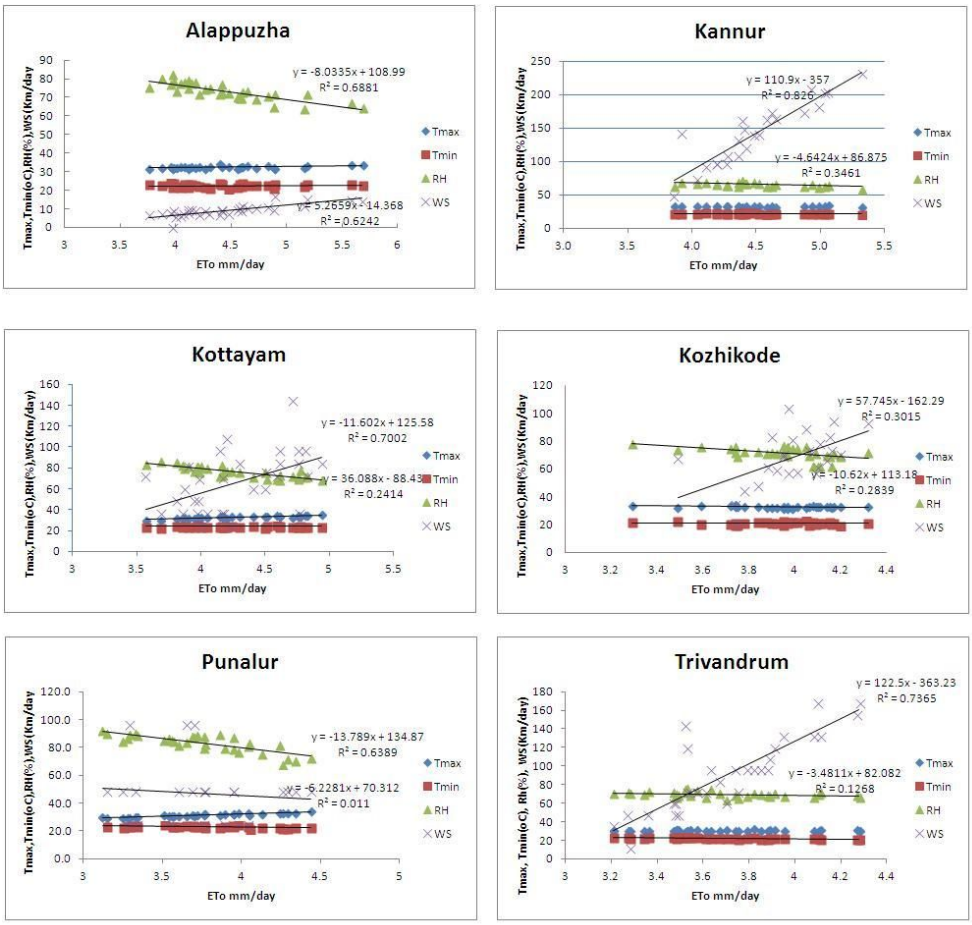


Fig.4: Regression analysis of ETo with the related climatic parameters for six stations

MannKendall test, the regression analysis was not done for the station. Since no significant trend was detected in Kochi, regression analysis was not done for that station.

3: Conclusion

The Mann Kendall test revealed a decreasing trend in ETo in most stations. 57 % of stations gave reduced ETo in the month of January and April, and none in August. Non monsoon months (December to May) showed more variation than the monsoon months (June to November). Increasing trend was observed in two stations Kottayam and Punalur. The decreasing ETo was observed in similar studies in the study area [9]. A steady increasing trend in maximum temperature and relative humidity and decreasing trend in minimum temperature and in wind speed was observed in most of the months. The regression analysis showed high correlation with relative humidity and wind speed. Whereas the temperature was only slightly correlated with ETo. And the amount of influence of RH and WS were location specific, though wind speed was found to be a major factor which influences ETo, followed by relative humidity. The influence of wind speed is more prominent in midland stations. In Punalur, the only station in highland the most influenced factor was relative humidity rather than wind speed. These are some of the inferences drawn from this study.

4: Acknowledgement

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