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Study of trends in weather parameters at Akola using moving average technique

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■ **ABSTRACT :** Climatic parameters (maximum temperature, minimum temperature, wind speed, bright sunshine hours, morning relative humidity, evening relative humidity and open pan evaporation) for 37 years (1971-2007) were collected from Agricultural Meteorological Observatory Dr. PDKV, Akola. Mean monthly climatic data for the period were used to determine reference evapotranspiration (ET_0) by FAO-56 Penman-Monteith method. The trends of change of these parameters were analyzed by working out seven years moving average and forming regression equations. The mean monthly maximum air temperature showed slightly decreasing trend for most of the months during the year except February, August and December. Whereas, there was unsteady variation in minimum air temperature and showed linear increasing trend during monsoon period. There was strong variation in wind speed and bright sunshine hours and showed continuous linear decreasing trend. However, mean monthly morning and evening relative humidity showed the linear increasing trend for most of the period of the year. The mean monthly pan evaporation also showed the decreasing trend throughout year. There was major variation in monthly reference evapotranspiration and showed linear decreasing trend for all the months of the year.

■ **KEY WORDS :** Moving averages, Reference evapotranspiration, Trend analysis

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The atmospheric phenomenon exhibited through rainfall, temperature, humidity, wind velocity, sunshine hours and wind direction etc. is weather. During the 20^{th} century greenhouse gases, especially CO_2, in the atmosphere increased markedly (Szasz, 2005). Climate change is recognized as a serious environmental issue (Easterling *et al.*, 1999 and Johnston, 2000). It has repeatedly affected much or all of the earth. Available evidences suggest that such changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies (Barrow *et al.*, 2000; Hulme *et al.*, 2002; Rajendra, 2004 and Marton, 2004 and 2005). Today, plenty of agriculture investigation focused on understanding the relation between mean climate change and crop production (Varallayay, 1992; Rajendra, 2004 and Jolanki, 2005). Hence, in studying the effect of climatic change on crop production, the changes in climatic variability and associated weather patterns should be included. Chattopadhyay and Hulme (1997) analysed evaporation time series data for different stations in India and for a country as a whole, for different season and found that future warming seems likely to lead in general to increase potential evapotranspiration.

Evapotranspiration is an important component of the hydrologic cycle. Evapotranspiration, which includes evaporation of water from land and water surface and transpiration by vegetation, continues to be of foremost importance in water resources planning and management. The concept of the reference evapotranspiration was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. As water is abundantly available at reference evapotranspiring surface, soil factors do not affect evapotranspiration. The only factors affecting reference evapotranspiration are climatic parameters. Consequently, ETo is a climatic parameter and can be computed from weather data. Few investigators however, studied the effect of climatic variability on water requirement of crop *i.e.* evapotranspiration need (Zhang and Cai, 2013; Doll, 2002; Feng *et al.*, 2012 and Tang *et al.*, 2011). There is a growing need to quantify the effect of climate change on evapotranspiration in different agro ecologies and agri-production environments. Similarly, various climate change scenarios need to be evaluated and the specific adoption strategies be evolved.

Keeping in view the importance and need of study of climate change with aim to evaluate variation of climatic parameters and so on change in atmospheric demand of water in terms of evapotranspiration, the study was carried out.

■ METHODOLOGY

The meteorological station namely Akola was selected for study which represents the Western Vidarbha. Akola is situated in subtropical zone (Agro climatic zone VII) at $20^0 40^/$ N latitude and $77^0 02^/$ E longitude at an altitude of 307.415 m above mean sea level. The average annual rainfall is 750 mm. Meteorological data *viz.*, maximum temperature (Tmax), minimum temperature (Tmin), morning relative humidity (RHI), evening relative humidity (RHII), wind speed (WS), bright sunshine hours (BSH) and pan evaporation (OPE) were collected from Agricultural Meteorological Observatory, Dr. PDKV, Akola for the period of 1971-2007 (37 years). Other parameters like geographic location *viz.*, latitude, longitude and altitude also obtained. Pan evaporation observations were taken with standard US Weather Bureau Class 'A' open pan.

Determination of reference evapotranspiration:

Monthly reference evapotranspiration for Akola was calculated using FAO-56 Penman-Monteith model (Allen *et al.*, 1998) expressed as:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T + 273}\right)\mu_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\mu_2)}$$

where, ET_o = Reference evapotranspiration (mm day^{-1}), Δ = Slope of saturation vapour pressure curve (kPa $^oC^{-1}$), T= Mean air temperature (^{o}C), γ= Psychometric constant (kPa $^oC^{-1}$), R_n= Net radiation at the crop surface (MJ m^{-2} day^{-1}), G= Soil heat flux density (MJ m^{-2} day^{-1}), u_2= Wind speed at 2.0 m height (ms^{-1}), e_a= Actual vapour pressure (kPa), e_s= Saturation vapour pressure (kPa), e_s- e_a= Saturation vapour pressure deficit (kPa).

Collected data of all weather parameters and ETo data were analyzed statistically for determining average, standard deviation, co-efficient of variation, skewness and kurtosis from which its variability was tested. The trends of these parameters were analyzed by using moving average technique and forming regression equation.

Moving average technique :

The moving average is a weighted mean of previous end data of weather parameters. For 7 months simple moving average of weather parameter is the mean of the previous 7 corresponding months. If those weather parameters are P_M, P_{M-1}, ..., P_{M-6}, then the formula is given as :

$$\text{Moving average} = (P_M + P_{M-1} + ... + P_{M-6})/7$$

When calculating successive values, a new value comes into the sum and old value drops out, meaning a full summation each time is given by :

$$MA_{month,\ i} = MA_{month,\ i-1} - (P_{M-n} / n) + (P_M / n)$$

■ RESULTS AND DISCUSSION

Monthly weather data of 37 years were used for analysis and the water demand of agronomical crops were also estimated in terms of reference evapotranspiration by using the standard method of Penman-Monteith. Particularly the study has examined the various statistical characteristics of the various meteorological parameters, estimated moving averages and established the graphs to analyze the trends of their changing patterns.

Maximum air temperature :

It is seen from Table 1 that the mean monthly maximum air temperature varied from 29.53 ^{0}C to 42.34 ^{0}C. Highest maximum air temperature was found during the month of May, whereas lowest maximum air temperature was found during the month of December. It was also found that co-efficient of variation ranged between 2.44 per cent to 4.74 per cent, which indicated the variations in maximum air temperature.

Seven years moving averages of monthly maximum air temperature were estimated and plotted month wise as shown in Fig.1. It was seen that the monthly maximum air temperature showed slightly decreasing trend for nearly all months, except February, August and

Table 1: Statistical characteristics of mean monthly maximum air temperature

Month	Mean, ^{o}C	Standard deviation, ^{o}C	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	29.81	1.17	3.92	-0.38	0.04
February	32.58	1.21	3.71	-0.08	-0.49
March	37.18	1.54	4.15	-0.10	-0.78
April	41.10	1.00	2.44	0.04	0.63
May	42.34	1.27	3.00	-0.35	-0.65
June	37.43	1.77	4.74	0.03	-0.65
July	32.20	1.23	3.83	0.21	-0.35
August	30.35	0.98	3.22	0.89	1.06
September	32.25	1.45	4.50	0.30	-0.31
October	33.53	1.52	4.52	0.37	-0.99
November	31.57	0.87	2.75	0.44	0.24
December	29.53	1.13	3.84	-0.27	0.86

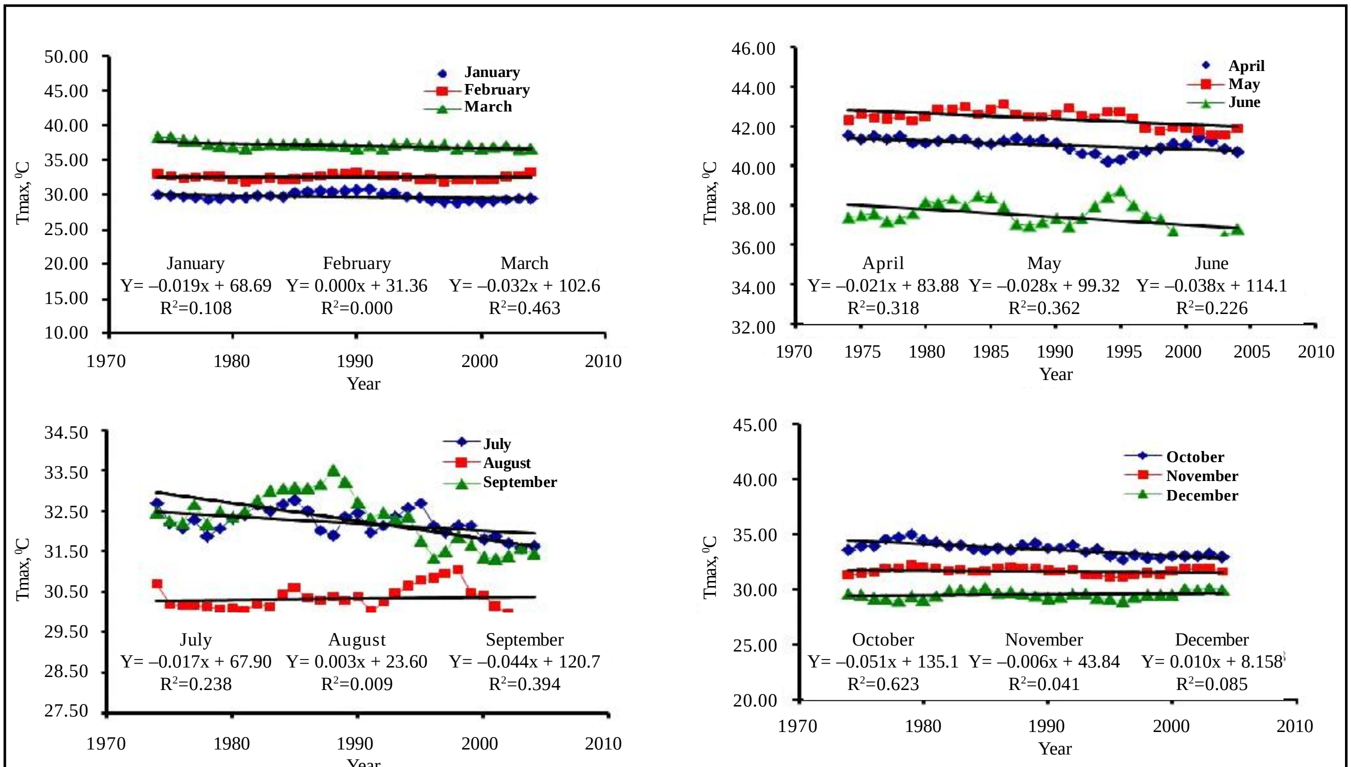

Fig. 1 : Seven years moving average trends in mean monthly maximum temperature

December. Rate of decrease was found to be low as 0.006 ^{0}C to 0.05 ^{0}C. It may be concluded that there was variation in mean monthly maximum air temperature and showed linear decreasing trend for most of the period of the year.

Minimum air temperature :

Table 2 shows that the mean monthly minimum air temperature varied from 11.38^0 C to 27.28^{0}C. The co-efficient of variation was found to be in the range of 2.71 to 33.71 per cent, with maximum standard deviation 3.99 and the series was mostly negatively skewed with relatively peaked distribution, as most of the kurtosis was positive.

Fig.2, shows that monthly minimum air temperature showed slightly decreasing linear trend for the months

Table 2 : Statistical characteristics of mean monthly minimum air temperature

Month	Mean, °C	Standard deviation, °C	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	11.38	2.54	22.30	-1.84	7.35
February	13.73	1.59	11.60	-0.65	0.23
March	18.15	1.22	6.73	-0.07	-0.50
April	23.44	1.35	5.75	-0.21	-0.41
May	27.28	0.98	3.60	-0.17	-1.06
June	25.60	0.86	3.37	0.16	0.46
July	23.66	0.64	2.71	-1.13	2.06
August	23.13	1.27	5.48	4.48	24.60
September	22.31	0.83	3.74	-1.85	4.08
October	18.65	1.15	6.14	0.11	1.18
November	14.12	2.55	18.07	0.13	-0.57
December	11.64	3.93	33.71	3.75	18.69

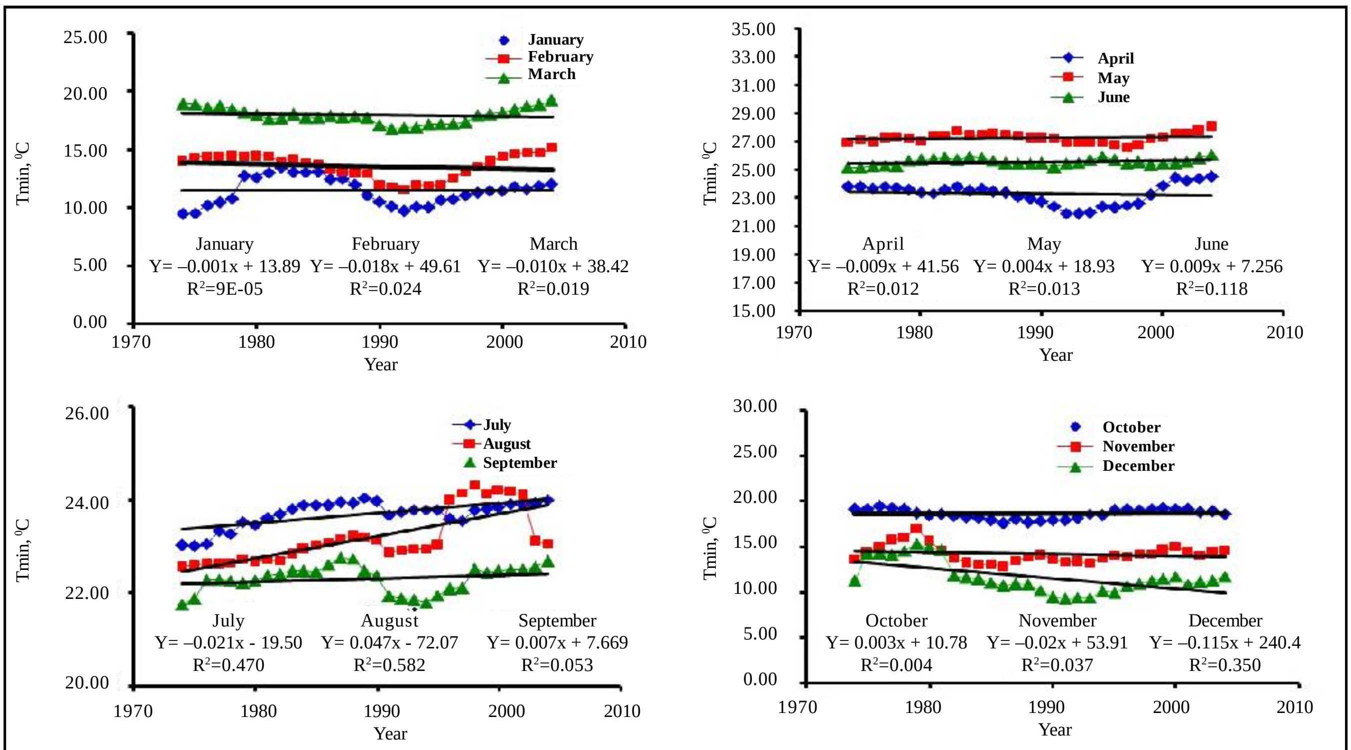

Fig. 2 : Seven years moving average trends in mean monthly minimum temperature

November to April with the maximum rate 0.115^{0}C during the month of December and slightly increasing trend for the months May to October with the maximum rate 0.047^{0}C. Co-efficients of determination (R^2) were found to be significant for the monsoon season and non-significant for the summer and winter season. It may be concluded from the analysis that there was unsteady variation in monthly minimum air temperature and found linear decreasing trend for winter and early summer, whereas linear increasing trend during monsoon and late summer season.

Wind speed :

Table 3 shows that the mean monthly wind speed

Table 3: Statistical characteristics of mean monthly wind speed

Month	Mean, km/hr	Standard deviation, km/hr	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	5.06	1.60	31.57	-0.32	0.32
February	5.97	1.88	31.45	1.29	4.41
March	6.62	1.49	22.44	-0.18	0.57
April	8.65	2.18	25.20	-1.83	5.06
May	13.79	2.53	18.37	0.20	0.38
June	14.53	2.61	17.98	0.11	-0.59
July	11.30	2.57	22.74	-0.61	0.14
August	10.65	2.53	23.77	-0.72	1.12
September	7.51	1.74	23.16	-0.84	1.48
October	4.26	1.21	28.37	-0.42	1.17
November	4.08	1.41	34.63	-0.24	0.18
December	4.11	1.42	34.54	-0.36	0.04

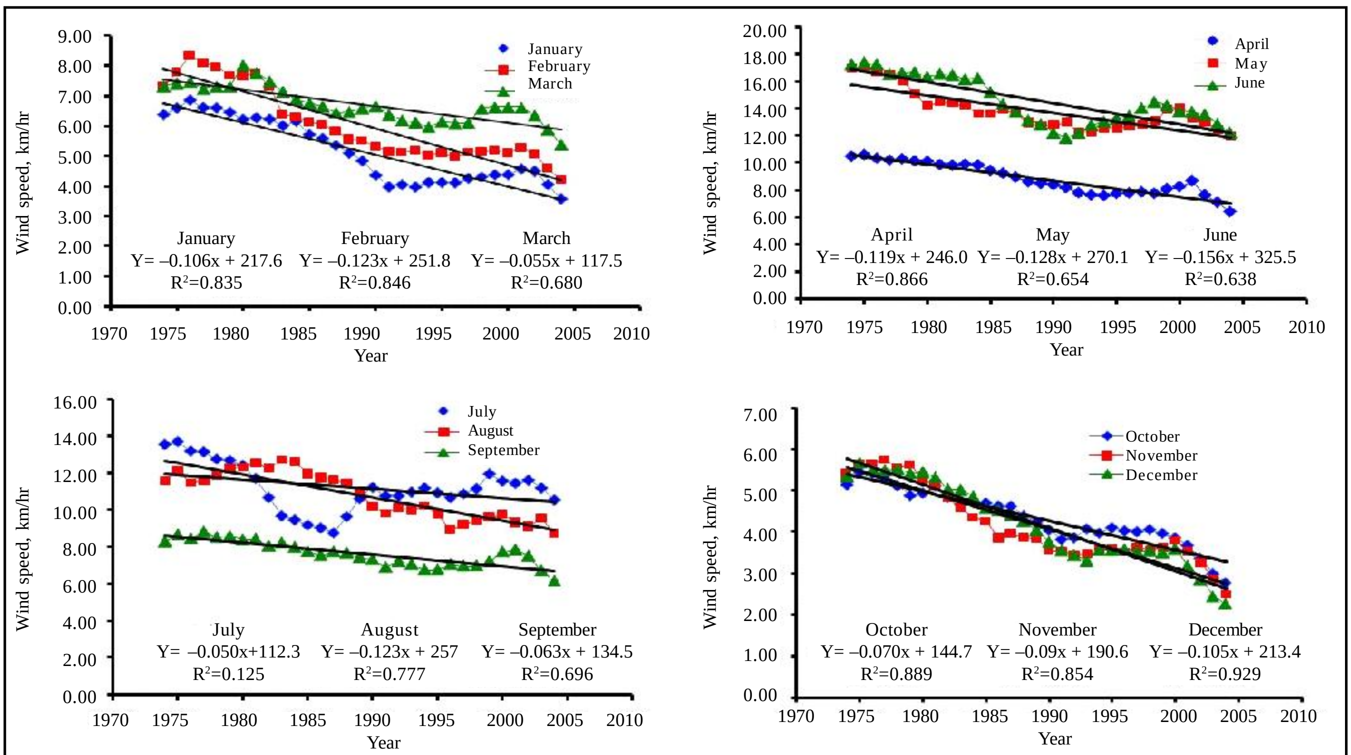

Fig. 3 : Seven years moving average trends in mean monthly wind speed

varied from 4.08 km/hr to 14.53 km/hr. The co-efficient of variation ranged between 17.98 to 34.63 per cent, which indicated high variation in wind speed and monthly wind speed series was mostly negatively skewed except during summer season and kurtosis was 5.06 showing relatively peaked distribution.

Fig. 3, shows that monthly wind speed showed decreasing linear trend for all the months and the rate of decrease was found to be in the range of 0.05 km/hr to 0.156 km/hr. The co-efficient of determination (R^2) were found to be statistically significant for almost all the month except the month of July.

Bright sunshine hours :

It is seen from Table 4 that the mean monthly bright sunshine hours varied from 4.3 hrs to 9.70 hrs. The co-

Table 4 : Statistical characteristics of mean monthly bright sunshine hours

Month	Mean, hrs	Standard deviation, hrs	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	8.62	0.82	9.55	-0.66	-0.28
February	9.18	0.72	7.80	-0.61	-0.31
March	9.39	0.95	10.09	0.63	3.03
April	9.70	0.80	8.25	-0.61	-0.13
May	9.66	0.89	9.25	-0.44	-0.44
June	7.05	1.37	19.44	0.09	-0.56
July	4.32	1.16	26.91	0.36	0.21
August	4.43	3.25	73.23	5.17	29.47
September	6.43	1.39	21.62	-0.75	0.29
October	8.26	0.92	11.19	0.35	-0.46
November	8.55	0.91	10.61	-0.72	0.56
December	8.59	0.95	11.09	-2.87	12.35

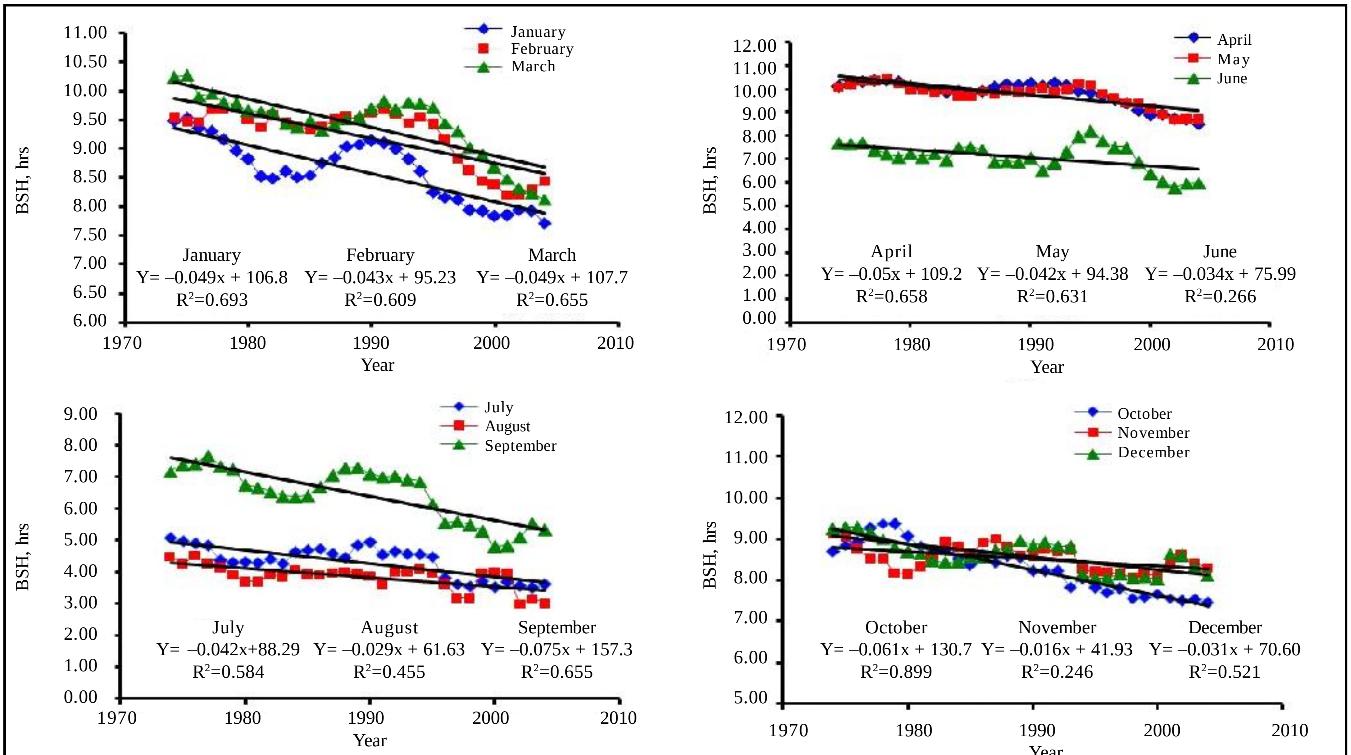

Fig. 4 : Seven years moving average trends in mean monthly bright sunshine hours

efficient of variation was in the range of 7.8 to 73.23 per cent, which indicated high variation in bright sunshine hours.

Fig. 4 shows that bright sunshine hours had linear decreasing trend for all the months and rate of decrease was found to be very low ranging between 0.016 hrs to 0.075 hrs. The co-efficients of determination (R^2) were found to be statistically significant for all the months.

Morning relative humidity :

It is seen from Table 5 that the mean monthly morning relative humidity varied from 36 per cent to 87 per cent. The co-efficient of variation ranged between 3 to 28 per cent, which indicated variation in morning relative humidity.

It is observed that the monthly morning relative humidity showed slightly increasing linear trend for almost

Table 5: Statistical characteristics of mean monthly morning relative humidity

Month	Mean, %	Standard deviation, %	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	68	10	14	-1	0
February	56	10	18	0	-1
March	42	12	28	1	1
April	36	7	20	0	0
May	46	7	15	0	0
June	70	6	9	-1	1
July	84	3	4	0	0
August	87	2	3	-1	0
September	85	5	6	-1	-1
October	77	9	12	-1	0
November	71	8	12	0	-1
December	71	9	12	0	0

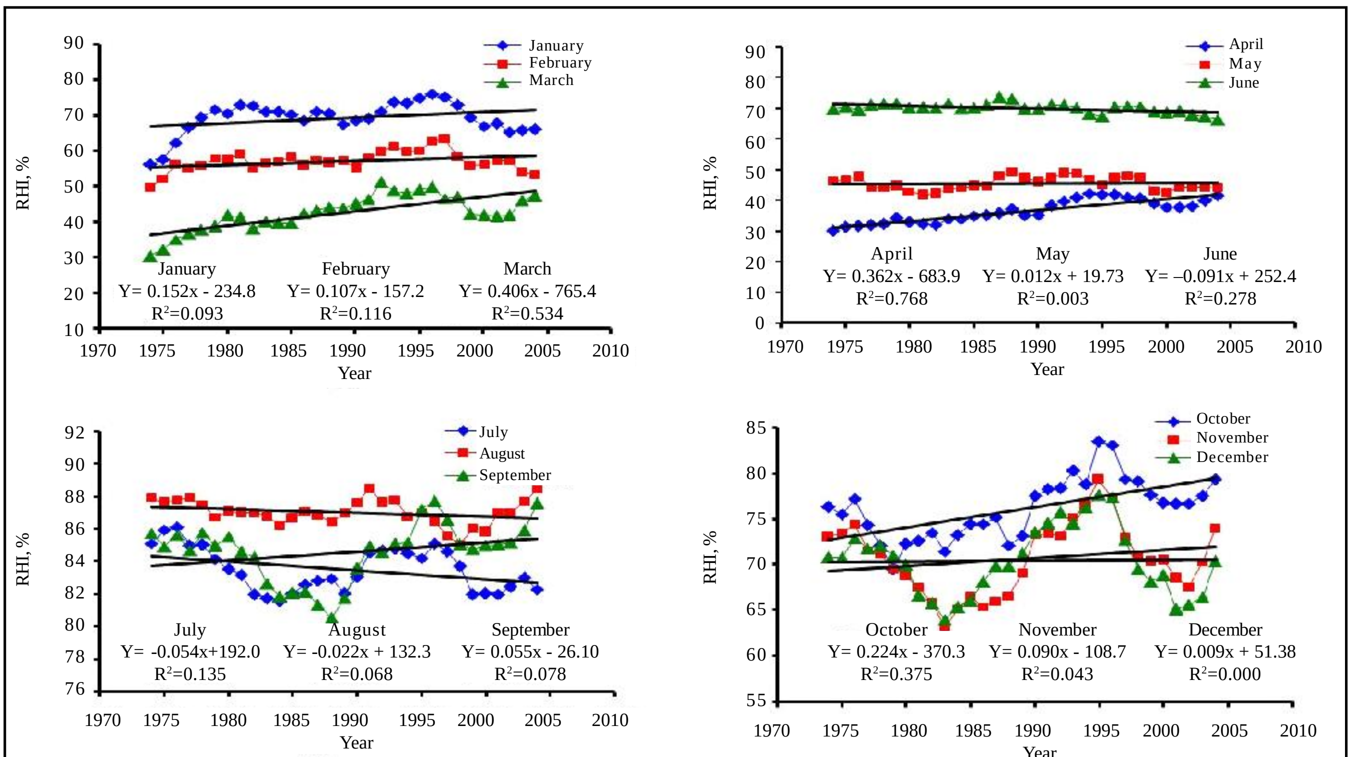

Fig. 5 : Seven years moving average trends in mean monthly morning relative humidity

all the months except for month of June, July and August. The maximum rate of increase was found to be 0.406 per cent. It may be concluded from analysis that there was variation in monthly morning relative humidity and showed linear increasing trend (Fig. 5).

Evening relative humidity :

Table 6 shows that mean monthly evening relative humidity had co-efficient of variation ranged between 8 and 37 per cent, which indicated high variation. Monthly evening relative humidity series was totally positively skewed whereas kurtosis was found to be 15.

It was observed that monthly evening relative humidity showed increasing trend for all the months and the maximum rate of increase was found to be 0.262 per cent. The co-efficients of determination (R^2) were

Table 6 : Statistical characteristics of mean monthly evening relative humidity

Month	Mean, %	Standard deviation, %	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	29	7	23	0	1
February	22	6	25	0	-1
March	17	6	33	1	0
April	14	4	27	0	0
May	18	4	24	1	0
June	41	6	15	1	0
July	61	6	9	0	0
August	69	5	8	0	1
September	57	10	17	0	-1
October	39	10	26	0	-1
November	31	7	24	1	1
December	30	8	26	3	15

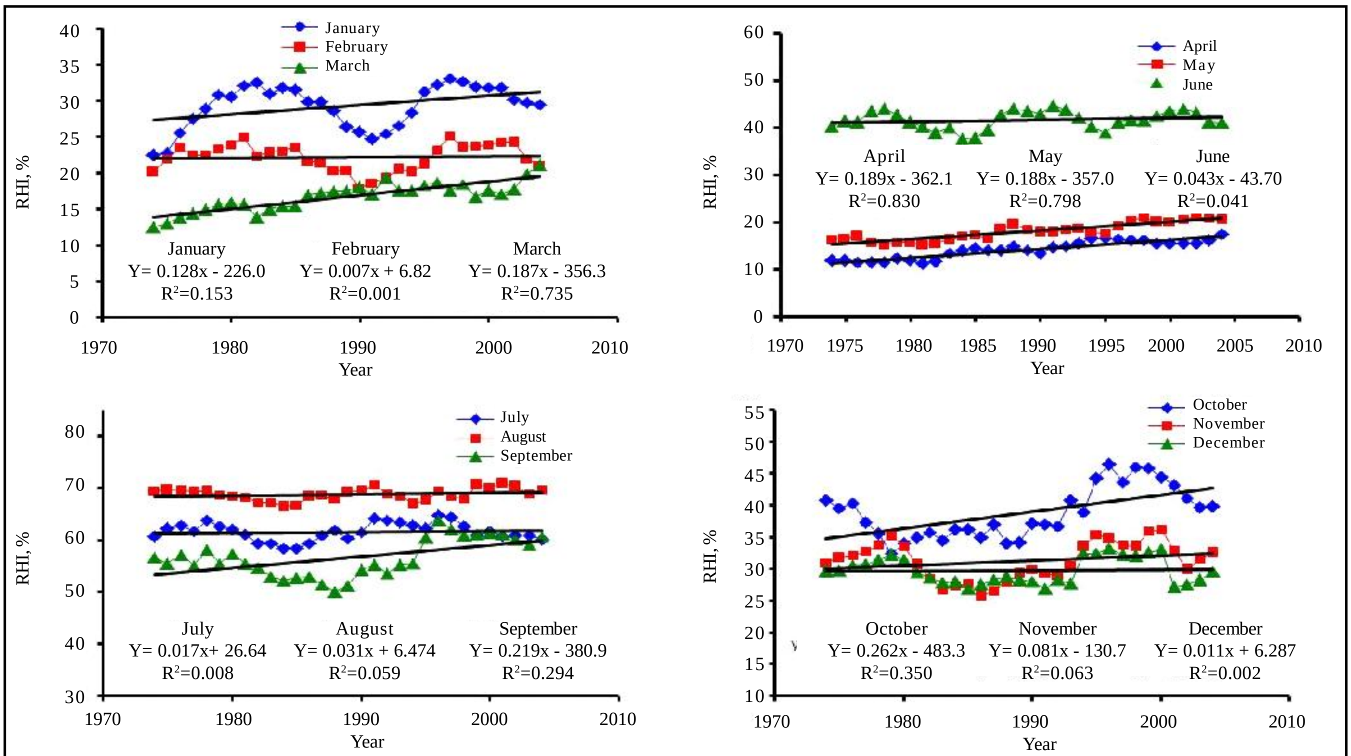

Fig. 6 : Seven years moving average trends in mean monthly evening relative humidity

found to be statistically significant for summer season and non-significant for winter and monsoon season (Fig. 6).

Pan evaporation :

It is seen from Table 7 that the mean monthly pan evaporation varied from 4.19 mm to 16.30 mm. It was also found that the co-efficient of variation ranged between 13.39 to 23.28 per cent, which indicated high variation in pan evaporation. Table also indicated that monthly pan evaporation series mostly positively skewed whereas kurtosis was found to be -0.86 to 8.61.

It is seen from Fig. 7 that there was strong variation in monthly pan evaporation and showed decreasing trend

Table 7: Statistical characteristics of mean monthly pan evaporation

Month	Mean, mm	Standard deviation, mm	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	4.76	0.88	18.56	1.28	2.58
February	6.67	0.94	14.11	0.49	0.19
March	9.88	2.30	23.28	2.19	8.61
April	13.24	1.77	13.39	0.09	-0.28
May	16.30	2.43	14.90	-0.02	-0.39
June	10.83	2.42	22.31	0.01	-0.86
July	5.59	1.22	21.90	0.70	0.19
August	4.36	0.87	20.02	1.19	2.02
September	4.87	1.02	20.99	0.81	1.21
October	5.20	1.12	21.43	0.84	0.90
November	4.82	0.79	16.38	0.61	0.13
December	4.19	0.80	19.03	0.24	1.43

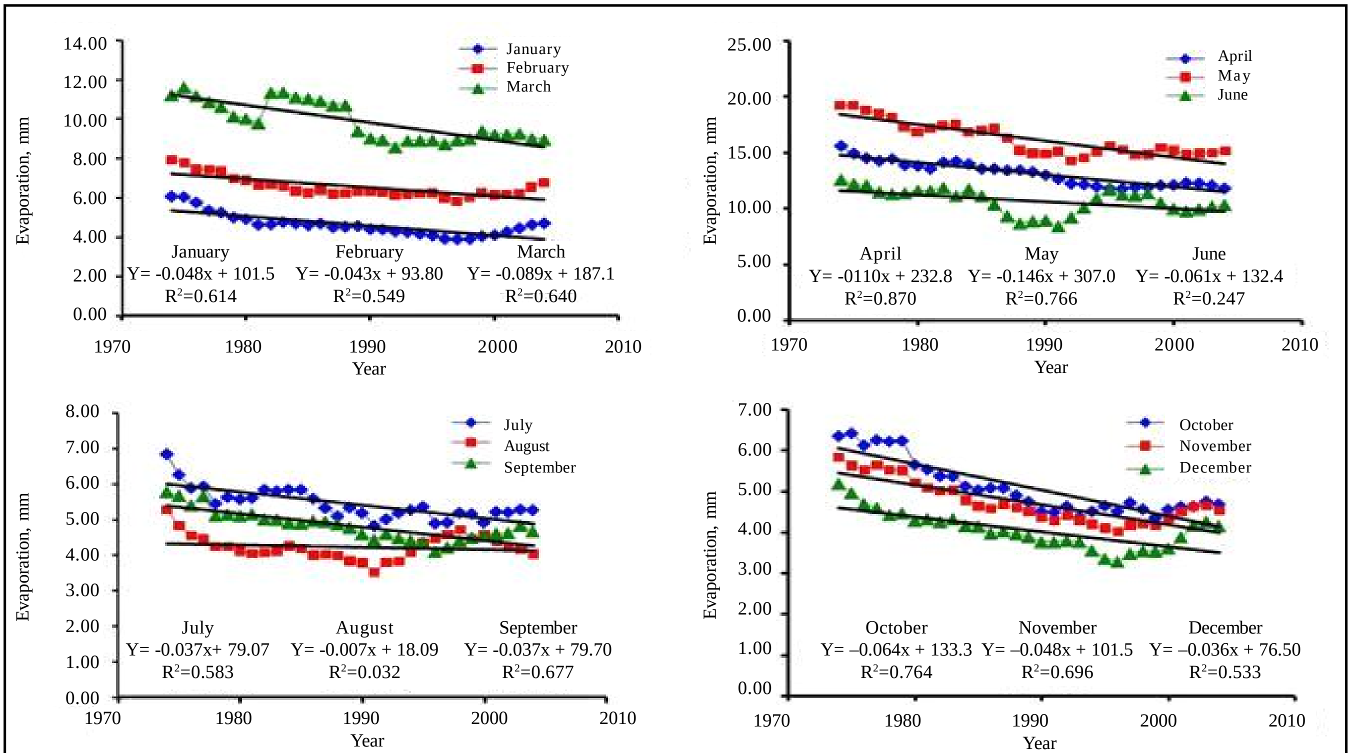

Fig. 7 : Seven years moving average trends in mean monthly evaporation

for all the months. The maximum rate of decrease was found to be very low as 0.146 mm. The co-efficient of determination were found to be statistically significant for almost all the months except the month of August.

Reference evapotranspiration :

It is seen from Table 8 that the mean monthly reference evapotranspiration varied from 3.26 mm/day to 10.25 mm/day. The highest reference evapotranspiration was found during the month of May whereas, lowest was found during month of December. The co-efficient of variation ranged between 11.27 to 14.66 per cent, which indicated high variations in monthly reference evapotranspiration. Table 8 also indicated that monthly

Table 8 : Statistical characteristics of mean monthly reference evapotranspiration

Month	Mean, mm/ day	Standard deviation, mm/day	Co-efficient of variation, %	Co-efficient of skewness	Co-efficient of kurtosis
January	3.63	0.53	14.65	0.02	0.67
February	4.68	0.58	12.49	0.02	0.81
March	6.12	0.75	12.26	0.00	0.91
April	7.99	1.15	14.43	-1.64	4.08
May	10.25	1.25	12.23	-0.25	-0.27
June	7.66	1.12	14.66	-0.03	-0.96
July	4.79	0.70	14.65	0.78	0.06
August	4.02	0.45	11.27	0.56	0.01
September	4.57	0.71	15.50	0.04	-0.80
October	4.32	0.49	11.36	0.39	0.09
November	3.70	0.44	11.84	-0.46	-0.02
December	3.26	0.46	14.24	-0.04	0.81

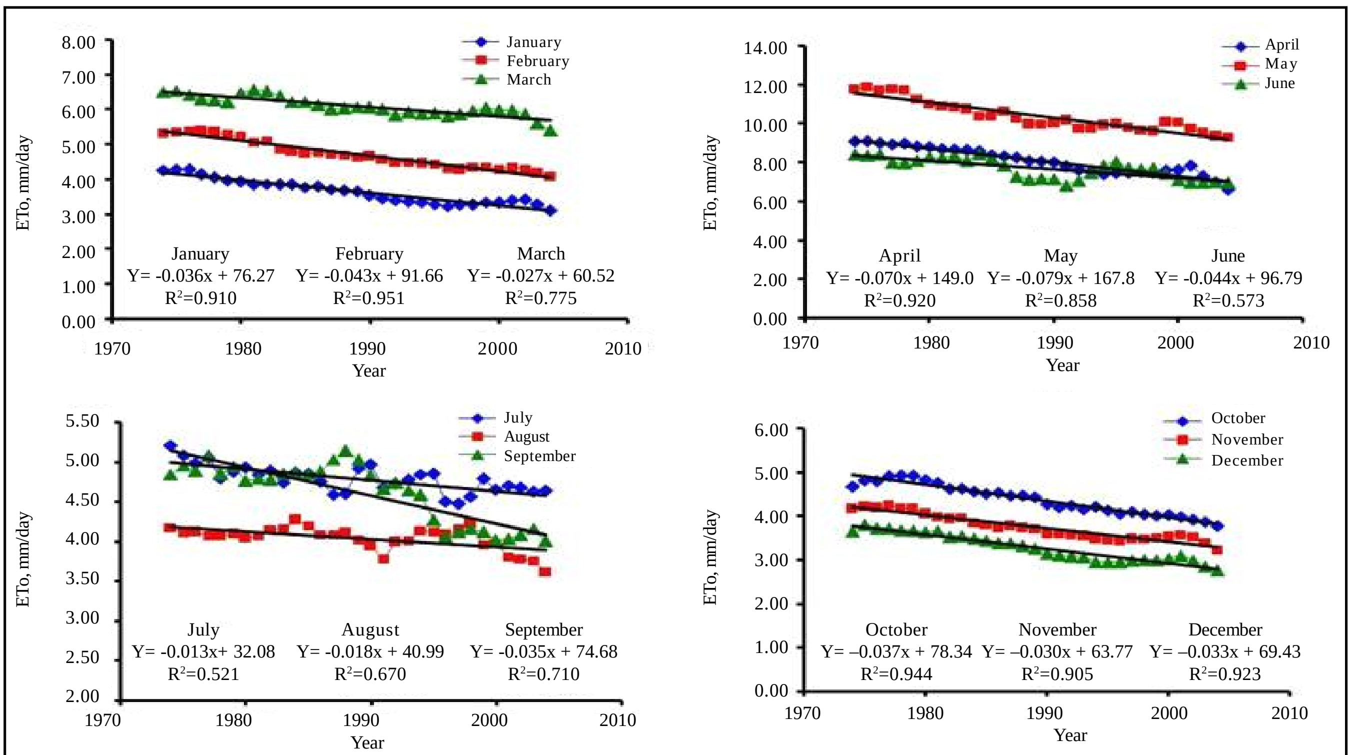

Fig. 8 : Seven years moving average trends in mean monthly evapotranspiration

reference evapotranspiration series mostly positively skewed, whereas kurtosis was found to be maximum 0.91.

From Fig. 8, it is observed that the monthly reference evapotranspiration showed nearly decreasing trend for all the month and the maximum rate of decrease was found to be very low as 0.08 mm/day. The co-efficients of determination (R^2) were found to be statistically significant for all the months of the year.

It may be concluded from analysis that there was slight variation in monthly reference evapotranspiration and showed slightly decreasing trend for all months of the year.

Conclusion :

Unsteady variations in monthly maximum and minimum air temperature were observed. Maximum air temperature showed slightly linear decreasing trend during most of the period of the year. Minimum air temperature showed decreasing trend during winter and summer seasons, but it showed increasing trend during monsoon. Monthly wind speed and bright sunshine hours showed linear decreasing trend, whereas maximum and minimum relative humidity showed linear increasing trend. Linear decreasing trend was obtained in open pan evaporation at Akola. Similarly, monthly reference evapotranspiration showed slightly decreasing trend for all the months of the year.

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