Climate Change in Bihar, India:A Case Study

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Abstract-**The present study focuses on the trend analysis of some parameters of climate change. These include annual mean temperature, rainfall, potential evapotranspiration and reference crop evapotranspiration for the 37 districts of Bihar, which is an eastern state in India. The study focuses on the period 1901-2002. The moving average method was for smoothening the time series curve. In order to detect the trend, MATLAB software was. For this study, in order to test the significance, the widely used Mann-Kendall test was run at a 5% significance level on a time series data. For annual mean temperature, all districts indicate a statistically significant increasing trend, whereas in the case of annual rainfall and a potential evapotranspiration trend, all districts indicate a statistically significant decreasing trend. However, this decreasing trend excludes the Araria and Kisanganj districts where a potential evapotranspiration trend indicates an increasing trend. For annual reference crop evapotranspiration, all districts show a statistically insignificant increasing trend. For the Bihar state as a whole, the annual mean temperature and reference crop evapotranspiration show an increasing trend of 0.0047°C/year and 0.07248 mm/year, respectively. Further rainfall and potential evapotranspiration for the state indicate a decreasing trend of 1.974 mm/year and 0.02672 mm/year, respectively.**

Keywords- Climate Change; Statistically Significant Value; Rainfall Deficit; Moving Average; Trend Analysis

I. INTRODUCTION

Bihar is an eastern Indian state with great cultural heritage. It is one of the oldest inhabited places in the world. Climate is one of the major factors that made Bihar a major agricultural hub. Due to its geographical location, its climate is greatly affected by the Himalayas and the Ganga plateau. Bihar's climatic conditions are divided into four segments: summer, winter, monsoon and post monsoon. The winter season is marked with low temperatures, which may be as low as 5°C to 10°C. Summer is marked with high temperatures and a characteristic hot wind referred to as 'Loo'. Bihar gets a reasonably good amount of rainfall that contributes greatly to the agriculture and fisheries sectors. Studies on identifying the trend in the climatic parameters were carried out by different researchers in India. Parthasarathy (1984) [1] summarized long-term changes in the Indian monsoon rainfall on local and regional scales, which have important social and economic consequences. Adamowski and Bougadis (2003)[2] have detected the trend in annual extreme precipitation using the Mann-Kendall S-trend test. Kumar et.al, (1994) [3] studied trend analysis for maximum and minimum temperature. He reported a countrywide increase in annual mean maximum temperature by 0.6°C.He also reported a decrease in the annual mean minimum temperature by 0.1°C. Pant and Kumar (1997) [4] suggest that India has a significant warming trend of 0.57°C per hundred years. Arora et.al (2005) [5] studied the trends in temperature rise over India for pre-monsoon, monsoon, winter and post-monsoon seasons. They indicated a rising trend in most cases, except for the mean monsoon temperature, the mean pre-monsoon temperature, the monsoon mean minimum temperature and the pre-monsoon mean minimum temperature. Bandopadhyay et al. (2009) [6] determined the temporal trend in the estimates of reference crop evapotranspiration over all India using the Mann-Kendall's significant test.

In this paper, climate change in Bihar, an eastern state of India, has been described in detail. The trend analysis on annual mean temperature, rainfall, potential evapotranspiration, reference crop evapotranspiration, relative humidity and wind speed series was carried out. Based on this several useful conclusions have been drawn.

II. STUDY AREA

Bihar is one of the most prominent states of India, which plays an important role in the Indian economy. It is a state with an area of 94,163 square km. It is a landlocked state of India covered by forest, mines, and huge resources of rivers and varied water bodies, which change their formation every year due to natural calamities. It is located in the eastern part of India. It lies between latitudes ranging from 24° 17' 6" N to 27°30'93"N and longitudes ranging from 83°19' 17" E to 88° 17' 47" E. It has 38 districts and Patna is its capital, which is geographically very near to the centroid of the state. Nepal in the North, West Bengal in the East, Uttar Pradesh in the West and Jharkhand in the South bound the state. The 38 districts are named the following:, Araria, Arwal, Aurangabad, Banka, Begusarai, Bhagalpur, Bhojpur, Buxar, Darbhanga, Gaya, Gopalganj, Jahanabad, Jammui, Kaimur, Katihar, Khagaria, Kisanganj, Lakhisarai, Madhepura, Madhubani, Munger, Muzaffarpur, Nalanda, Navada, Paschimi Champaran, Patna, Purba Champaran, Purnia, Rohtas, Saharsha, Samastipur, Saran, Seohar, Seikhpura, Siwan, Supaul, and Vaishali as indicated in Fig.1. As Arwal is a recently formed new district, its data are not available. Therefore, it is excluded from this study. The state gets a reasonably good amount of rainfall that contributes greatly to the agriculture and fisheries sectors.

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Fig. 1 Map of the Study Area

III. METHODOLOGY ADOPTED

The method-of-moving average is one of the methods, which consists of measurement by smoothing out the fluctuation in the data by moving an average of extent 'm', where m is the average period of oscillatory movements in the time series. In the analyzing trend, it is necessary to smoothen out irregularities in the time series data.

The data for monthly mean temperature, rainfall, potential evapotranspiration and reference crop evapotranspiration, covering a period of 102 years (1901-2002), were downloaded from the Indian Metrological Department (http://indiawaterportal.org/)[7] for the above mentioned 37 districts. In addition, monthly relative humidity and wind speed data covering a period of 30 years (1980-2009) for Bhagalpur, Gaya and Patna districts were obtained from IMD, Pune. The Potential Evapotranspiration (PET) and reference evapotranspiration (ETo) for the study area were determined using Thornthwaite's method (1931)[8] and Penman-Montieth's method, (FAO 56, 1998) [9] respectively.

Mann-Kendall's test (Kendall and Stuart, 1973) [10] is a statistical test widely used for the analysis of trend in climatologic and hydrologic time series. There are two advantages of using this test. First, it is a non-parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to the inhomogeneous time series. Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set. According to this test, the null hypothesis (H_0) assumes that there is no trend (the data is independent and randomly ordered). This is tested against the alternative hypothesis (H_1), which assumes that there is a trend.

IV. RESULTS AND DISCUSSION

The basic statistical characteristics for the average monthly values for temperature, rainfall, PET and ETO for the state were calculated and the results are shown in Tables 1 to 4. Further results for the trends of different parameters for the state are shown in Table 5 and from Fig.2 to 5. As an illustration, the trends of the parameters for the Gaya district are shown in Fig.6 to 11. Based on these results, it is observed that the 5 year moving average graphs for the above six parameters of climate for the 37 districts of Bihar, and Bihar as a whole for the period 1901-2002, show an increasing trend for annual mean temperature and reference crop evapotranspiration. However, it shows a decreasing trend for annual rainfall and potential evapotranspiration, except for the districts of Araria and Kisanganj.

The graphs for the trend analysis for annual relative humidity and wind speed for the three districts of Bihar, namely, Bhagalpur, Gaya and Patna respectively, show an increasing trend for relative humidity, a decreasing trend for wind speed in

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the Bhagalpur and Gaya districts and increasing trend for the Patna district. The relative humidity and wind speed data were limited for only three districts. Therefore, they cannot give clear trends of the Bihar state. Therefore, it has not been done in the present study.

The comparison of the results of the present study with all India trend analyses done by other researchers is given below:

It is shown bythe IMD annual Climate Summary (2009)[11] ,Tyagi and Goswami (2009)[12] and the Attri (2006) [13]analysis of data for the time period of 1901-2009 that the annual mean temperature for the country as a whole has been increasing by 0.56°C during the time period. Meanwhile, warming trends over the globe of the order of 0.74°C was reported by IPCC (2007) [14]. However, in the case of present study, the annual mean temperature of the Bihar state as a whole has increased by 0.479°C during the period of 1901-2002.All of India's annual rainfall for the country as a whole, for the period 1901-2009, did not show any significant trend as per the above referred studies. However, in the case of the Bihar state as a whole, the annual rainfall shows a statistically significant decreasing trend by 201.348 mm over the period of 1901-2002.

TABLE 1 STATISTICAL CHARACTERISTICS OF AVERAGE MONTHLY PET FOR DIFFERENT DISTRICTS OF BIHAR FOR THE PERIOD 1901-2002

Statistical Characteristics	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Average	4.85	5.61	6.96	8.21	8.33	7.27	5.77	5.27	5.31	5.70	5.61	4.86
Standard Deviation	0.04	0.12	0.10	0.27	0.61	0.49	0.14	0.03	0.07	0.20	0.17	0.06
Variance	0.001	0.01	0.01	0.07	0.38	0.24	0.02	0.0009	0.004	0.04	0.03	0.003

TABLE 2 STATISTICAL CHARACTERISTICS OF AVERAGE MONTHLY ETO FOR DIFFERENT DISTRICTS OF BIHAR FOR THE PERIOD 1901-2002

Statistical Characteristics	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Average	2.79	3.65	5.25	6.64	7.04	6.25	4.91	4.41	4.23	3.97	3.36	2.72
Standard Deviation	0.01	0.06	0.14	0.40	0.79	0.66	0.23	0.08	0.20	0.20	0.08	0.00
Variance	0.0001	0.003	0.02	0.16	0.62	0.43	0.05	0.01	0.04	0.04	0.01	0.00

TABLE 3 STATISTICAL CHARACTERISTICS OF AVERAGE RAINFALL FOR DIFFERENT DISTRICTS OF BIHAR FOR THE PERIOD 1901-2002

Statistical Characteristics	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Average	14.87	17.25	12.80	13.49	39.26	159.26	315.55	302.34	210.89	73.40	6.91	2.54
Standard Deviation	0.28	7.78	1.91	13.51	43.74	64.13	40.42	0.00	31.97	4.76	1.09	0.36
Variance	0.08	60.46	3.66	182.53	1912.93	4112.13	1633.88	0.00	1022.11	22.63	1.20	0.13

TABLE 4 STATISTICAL CHARACTERISTICS OF MEAN MONTHLY TEMPERATURE FOR DIFFERENT DISTRICTS OF BIHAR FOR THE PERIOD 1901-2002

Statistical Characteristics	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Average	16.38	18.96	24.41	29.44	31.84	31.44	29.17	28.67	28.47	26.31	21.38	17.16
Standard Deviation	0.28	0.52	0.96	1.71	2.60	2.29	1.00	0.52	0.66	0.28	0.02	0.21
Variance	0.08	0.27	0.91	2.92	6.76	5.25	0.99	0.27	0.43	0.08	0.0004	0.05

TABLE 5 RESULTS OF TREND ANALYSIS FOR 5 YEAR MOVING AVERAGE OF ANNUAL MEAN TEMPERATURE (°C), RAINFALL (MM), PET (MM), ETO (MM) FOR DISTRICTS OF BIHAR FOR THE PERIOD 1901-2002

SN.	District	Increase in temp per year (^{0}C)	Decrease in rainfall per year (mm)	Increase/decrease in PE per year (mm)	Increase in ET per year (mm)
1	Araria	0.0053	-1.507	0.00799	0.1140
2	Aurangabad	0.0045	-1.710	-0.02187	0.0504
3	Banka	0.0056	-2.149	-0.01371	0.0513
4	Begusarai	0.0047	-2.067	-0.04878	0.0451
5	Bhagalpur	0.0056	-2.003	-0.01097	0.0733
6	Bhojpur	0.0042	-1.905	-0.03279	0.0540
7	Buxar	0.0044	-1.885	-0.01899	0.0705
8	Darbhanga	0.0045	-2.138	-0.03207	0.0676
9	Gaya	0.0047	-1.736	-0.02491	0.0411
10	Gopalganj	0.0041	-2.238	-0.03563	0.0734
11	Jahanabad	0.0043	-1.878	-0.0402	0.0479
12	Jammui	0.0053	-2.027	-0.03031	0.0482
13	Kaimur	0.0046	-1.548	-0.02935	0.0747

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14	Katihar	0.0057	-1.623	-0.01204	0.1043
15	Khagaria	0.0051	-2.025	-0.02915	0.0634
16	Kisanganj	0.0058	-1.322	0.04709	0.1438
17	Lakhisarai	0.0048	-2.064	-0.05044	0.0366
18	Madhepura	0.0051	-1.788	-0.02679	0.0772
19	Madhubani	0.0047	-2.027	-0.02599	0.0879
20	Munger	0.0052	-2.130	-0.02973	0.0538
21	Muzaffarpur	0.0040	-2.248	-0.03856	0.0554
22	Nalanda	0.0044	-1.950	-0.04818	0.0419
23	Navada	0.0049	-1.920	-0.02115	0.0439
24	Paschimi Champaran	0.0045	-2.771	-0.02362	0.1063
25	Patna	0.0043	-1.967	-0.03387	0.0383
26	Purba Champaran	0.0042	-2.460	-0.04281	0.0726
27	Purnia	0.0055	-1.605	-0.01782	0.1039
28	Rohtas	0.0045	-1.644	-0.01415	0.0666
29	Samastipur	0.0044	-2.063	-0.05013	0.0442
30	Saran	0.0040	-2.055	-0.05181	0.0501
31	Seikhpura	0.0046	-1.990	-0.04937	0.0324
32	Saharsha	0.0050	-1.894	-0.03511	0.0646
33	Sheohar	0.0041	-2.371	-0.03734	0.0692
34	Sitamarhi	0.0044	-2.414	-0.03314	0.0788
35	Siwan	0.0040	-2.141	-0.03495	0.0682
36	Supaul	0.0049	-1.675	-0.02884	0.0679
37	Vaishali	0.0041	-2.094	-0.05521	0.0685

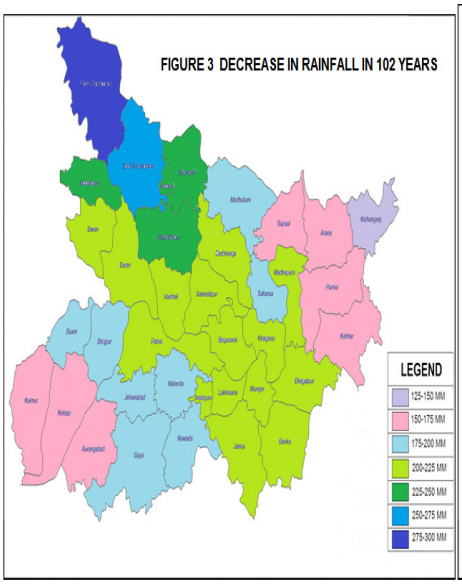

Fig. 2 Increase in Mean Temp

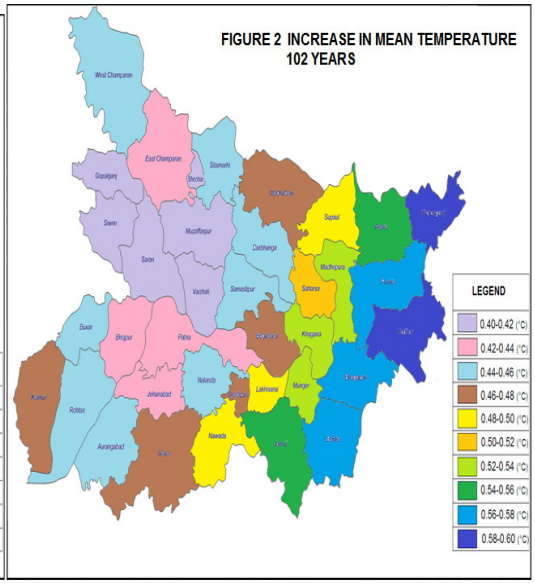

Fig.3 Increase in Rainfall

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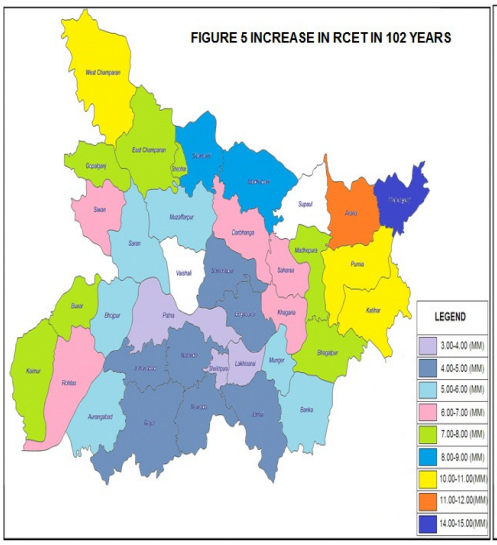

Fig.4 Increase in ET

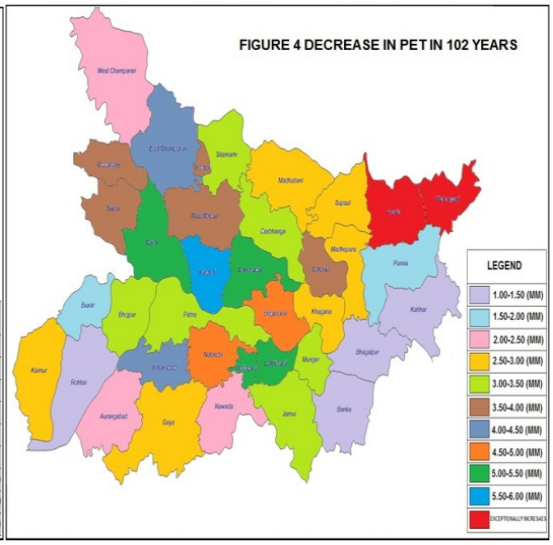

Fig.5 Increase in PET

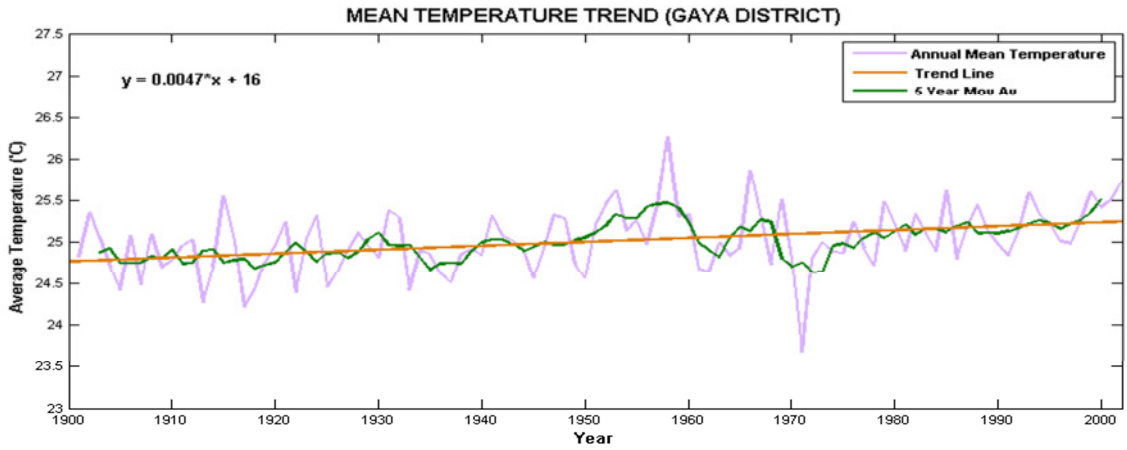

Fig. 6 Mean Temperature Trend for Gaya District

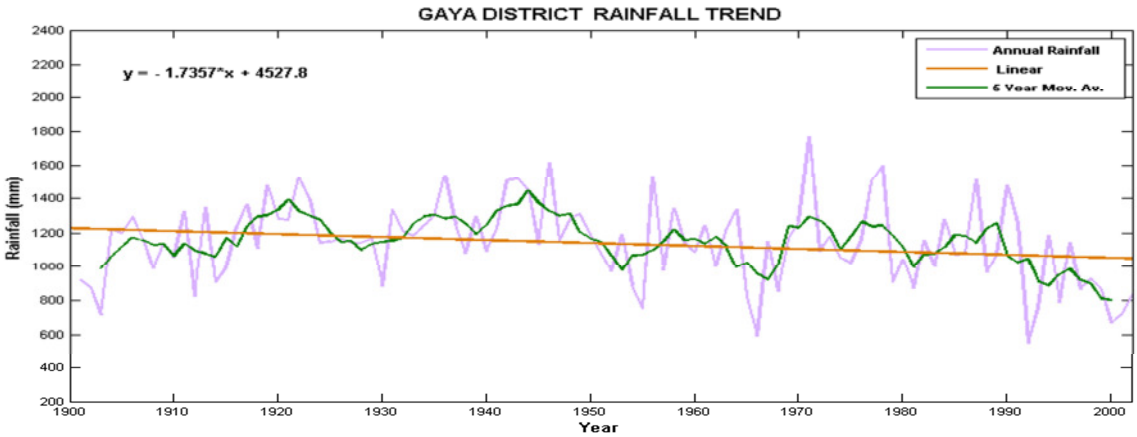

Fig. 7 Rainfall Trend for Gaya District

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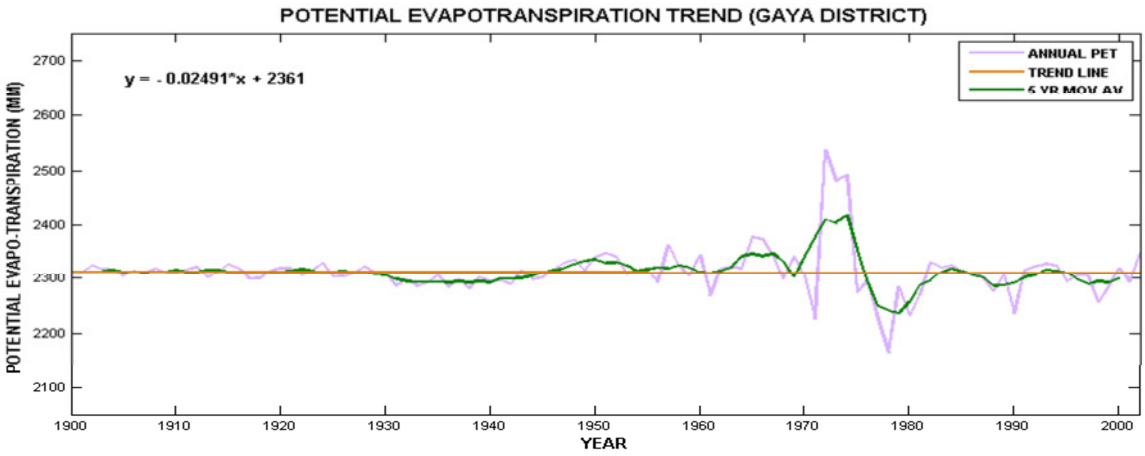

Fig. 8 Potential Evapotranspiration Trend for Gaya District

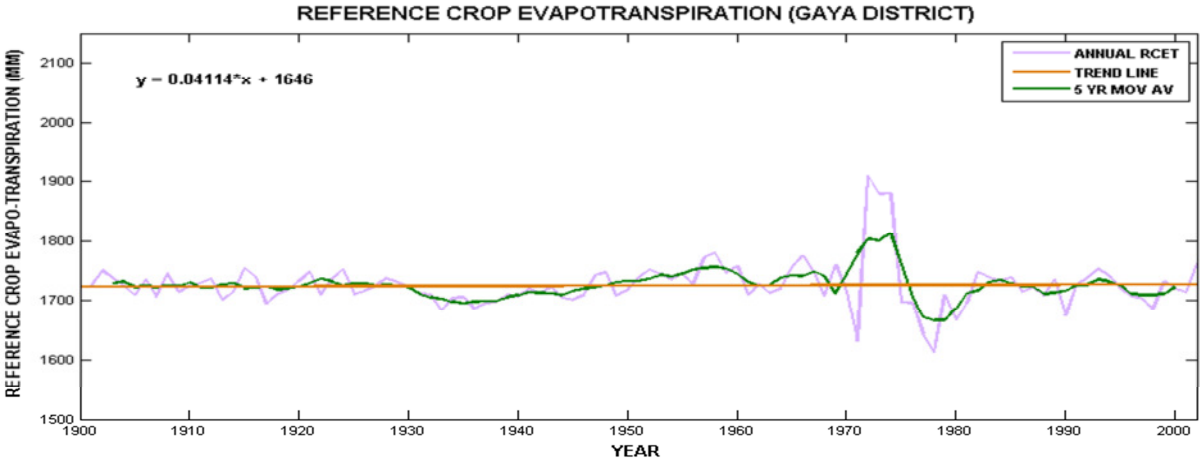

Fig.9 Reference Evapotranspiration Trend for Gaya District

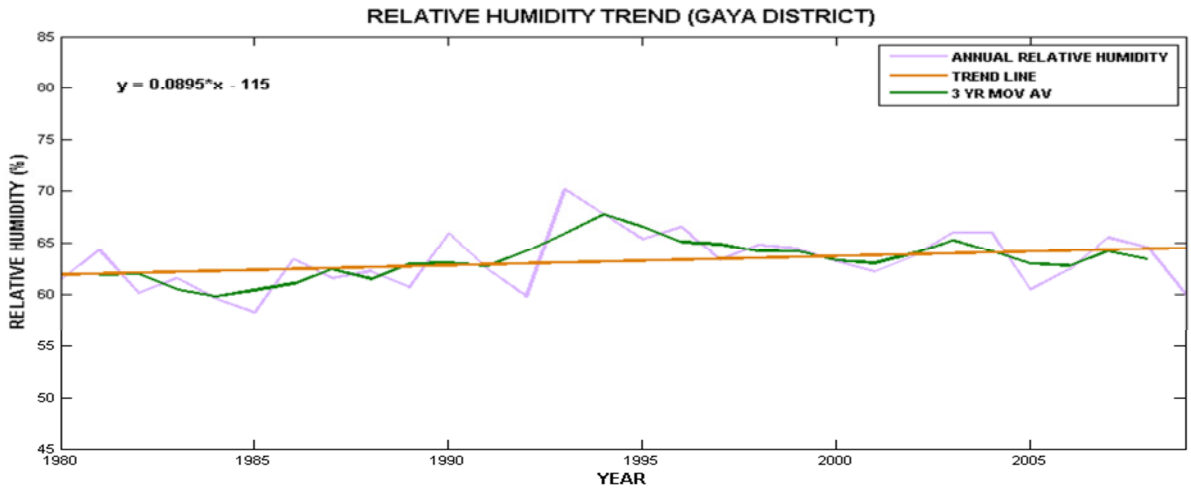

Fig. 10 Relative Humidity Trend for Gaya District

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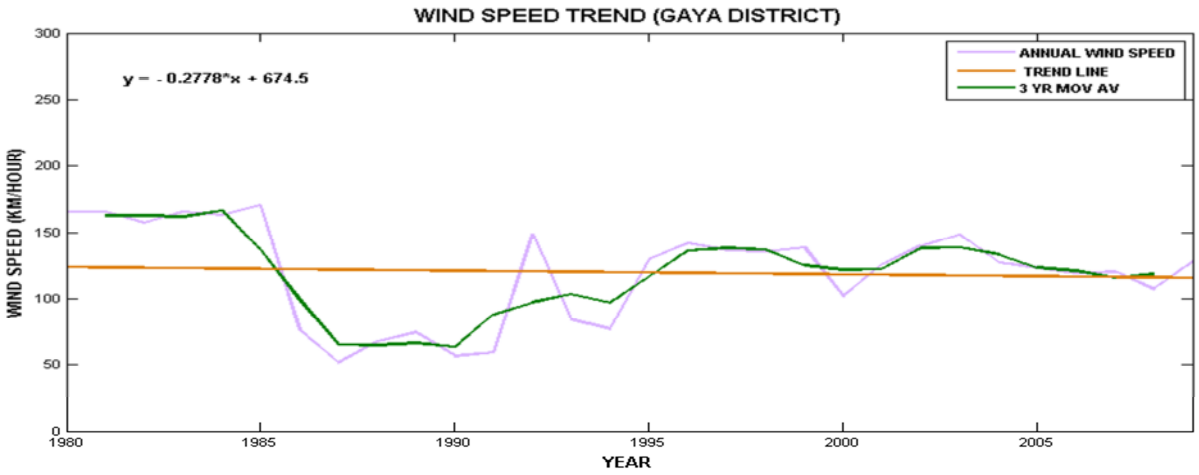

Fig. 11 Wind speed Trend for Gaya District

V. CONCLUSIONS

From the above result and discussion, the following conclusions are drawn:

1. There is a significant increasing trend for the annual mean temperature for all the districts during the 102 years (1901-2002).
2. There is a statistically significant decreasing trend of the annual rainfall during the above period for all the districts of Bihar.
3. There is a significant decreasing trend for the annual potential evapotranspiration during the period of study, except for Araria and Kisanganj, which show a statistically significant increasing trend.
4. There is a significant increasing trend for the annual reference crop evapotranspiration for all the districts of Bihar during the period.
5. There is a significant increasing trend for Relative humidity during 1980-2009 for the Bhagalpur district and an insignificant increasing trend for the Gaya and Patna districts.
6. There is a significant increasing trend for the Wind speed for the Patna district, a significant decreasing trend for the Bhagalpur district and an insignificant decreasing trend for the Gaya district during 1980-2009.

REFERENCES

[1] Parthasarathy B,"Inter-annual and long term variability of Indian summer monsoon rainfall," Proc. Indian Acad. Sci. (Earth Planet. Sci.), 93, 371-385, 1984.

[2] Adamowski K., and Bougadis J., Detection of trends in annual extreme rainfall, Hydrological Processes, 17, 18, 3547-3560, 2003.

[3] Rupa Kumar K., Krishankumar, and Pant, G. B., Diurnal asymmetry of surface temperature trends over India, Geophysics. Res. Lett., 21, 677-680, 1994.

[4] Pant, G.B., and Rupa Kumar, K., Climates of South Asia, John Wiley & Sons, 1997.

[5] Arora M., Goel, N.K., and Singh, P., "Evaluation of temperature trends over India," Hydrological Sciences Journal, 50, 81-93, 2005.

[6] Bandyopadhyay A., Bhadra A., Raghuwanshi N.S, and Singh R., Temporal trends in estimates of reference evapotranspiration over India, Journal of Hydrologic Engineering, 14(5), 508-515, 2009.

[7] http://www.indiawaterportal.org/met_data.

[8] C.W. Thornthwaite, "The Climates of North America: According to a New Classification," Geographical Review, vol.21, no. 4,pp. 633-655, Oct.1931.

[9] FAO, 1998, Irrigation and Drainage paper No. 56, Crop Evapotranspiration, Guidelines for computing crop water requirements, pp. 65-78.

[10] Kendall M.G. and Stuart, A., The advanced theory of Statistics (II), Griffin and co. London, 1973.

[11] IMD, 2009, "Annual Climate Summary 2009". National Climate Centre, Pune.

[12] Tyagi, A. and Goswami, B. N., 2009. "Assessment of Climate change and adaptation in India". Climate Sense, 68-70.

[13] Attri, S.D. and Tyagi, A., "Climate Profile of India," Met. Monograph Environmental Meteorology No 1, pp. 1-122, 2010.

[14] IPCC 2007, Climate Change 2007. The Physical Science Basis, Cambridge United Kingdom and New York, NY, USA. pp. 665-732.

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