Journal of Agrometeorology 17 (2) : 199-203 (December 2015)

Trends and variability in evapotranspiration at Jabalpur, Madhya Pradesh

REENA CHAKRAVARTY, MANISH BHAN, A.V.R. KESAVA RAO[1] and M.K. AWASTHI

College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, M. P.

[1]International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Telangana

E-mail: reena15chakravarty@gmail.com

ABSTRACT

Evapotranspiration demands and trends were analysed for Jabalpur region in eastern Madhya Pradesh by assessing reference evapotranspiration (ET_o), energy balance and aerodynamic components for 31 years (1983-2013). Analysis indicated multiple trends in annual ET_o and annual aerodynamic component of ET_o. In the first half of the study period, a clear decreasing trend was seen with 1994 and 1999 years having low ET_o values. Later, the ETo started increasing and a high ETo of 1425 mm was observed in the years 2009 and 2010. Energy balance component has shown a negative trendwith the reduction in temperature and sunshine hours.Trends in five-year average ETo values indicated a reduction in *kharif* season whilethe ET_oincreased in *rabi* season. Present study highlights the necessity to understand ET_o of the region before planning and management.

Key words: Climate change, Penman-Monteith, evapotranspiration, Madhya Pradesh

Earth's temperature has increased by 0.74°C during the last century (1906 to 2005) due to increase ingreenhouse gasesthrough anthropogenic emissions with temperature may rise from 1.8–4.0°C by the turn of 21st century resulting in an anticipated instability in food, feed and fibre production (Aggarwal, 2008). Agricultural sector is one of the vulnerable sectors influenced by the rise in temperature, rainfall variabilityand climate change. Climate change is likely to alter crop durations, impact pest populations, hasten mineralization in soils, increase evapotranspiration (ET) and bring in more uncertainties in crop yields. Demand for irrigation water is more sensitive to agricultural production as climatic variability increased dryness therebycreating more demand of water to fulfil crop growing period (IPCC, 2001). In addition, change in normal pattern of temperature, precipitation and amount of rainfall also influence soil water content (Mall *et al.,* 2006). ET is a major component of hydrological cycle and maximum portion of total rainfall falling on land surface is returned to the atmosphere throughET. Increase in the rate of ET along with temperature causes depletion in soil moisture retention capacity and increase salinity in semi-arid situations (Sankaranarayanan *et al.,* 2010).

Chattopadhyay and Hulme (1997) analysed evaporation time series data for different stations in India, and for the country as a whole, for different seasons on both a short-term (15 years) and long-term (32 years) basis for pan evaporation and on a short-term basis alone for potential evapotranspiration. Their analysis shows that both pan evaporation and potential evapotranspiration have decreased during recent years in India. They concluded that future warming seems likely to lead in general to increased potential evapotranspiration over India, although this increase will be unequal between regions and seasons. Evaporation demand or potential evaporation almost increases everywhere in the world in the future climate scenarios (IPCC, 2008).Reference crop evapotranspiration (ET_o) was determined at ICRISAT, Patancheru using FAO Penman Monteith equation using data for the period 1975-2009 and analysis showed that annual reference crop evapotranspiration (ET_o) has decreased during the period. Rate of reduction in ET_o was about 10% for *kharif* and 14% for *rabi* seasons. Contribution of energy balance to the total ET_o has shown negative trend while positive trend was seen for aerodynamic component (Rao and Wani, 2011). In the arid region of China, a study with a dataset of 1955-2008 from 23 meteorological stations indicated that ET_ohas shown a decreasing trend with wind speed as a most sensitive meteorological variable followed by relative humidity, temperature and solar radiation (Huo *et al.,* 2013).

The present study is undertaken to estimate $ET_o$and its components and to assess the trends in ET_o and climate variability of Jabalpur region.

Table 1: Normal monthly climatic parameters at Jabalpur

Month	MaxT (°C)	MinT (°C)	RH-I (%)	RH-II (%)	Wind speed (km h^{-1})	Rainfall (mm)	Bright sunshine (h day^{-1})	Rainy days
Jan	24.3	8.6	90	41	2.1	20	7.6	2
Feb	27.4	10.9	84	35	2.5	25	8.5	2
Mar	32.9	15.1	71	24	3.1	15	8.5	1
Apr	38.3	20.5	50	16	4.1	4	8.7	1
May	41.4	25.9	42	18	5.8	11	8.6	1
Jun	37.5	26.3	66	42	7.1	181	5.8	8
Jul	31.1	24.5	88	72	6.3	430	3.2	17
Aug	29.7	23.9	92	78	5.4	457	3.2	17
Sep	30.8	23.2	91	68	3.8	278	5.2	10
Oct	31.2	18.4	89	46	2.2	36	7.9	2
Nov	28.9	12.6	89	36	1.8	13	7.9	1
Dec	25.7	8.8	91	37	1.7	11	7.5	1

MATERIALS AND METHODS

Jabalpur is situated at79°562 E longitude and 23°102 N latitude at an altitude of about 411 m above the mean sea level. This region enjoysa humid subtropical climate and is predominant with Vertisols. Major cropping system is rice-wheat system in Kymore plateau and Satpura hills agro-climatic zone in Madhya Pradesh.

Climate data were collected from the Department of Physics and Agrometeorology, College of Agricultural Engineering, JNKVV, Jabalpur. Daily data on maximum temperature, minimum temperature, relative humidity, rainfall, wind speed, and sunshine hours were collected for a period of 31 years (1983-2013). Normal monthly climatic parameters at Jabalpur are presented in Table 1. Average annual rainfall is about 1481 mm with 63 rainy days. About 91% of the annual rainfall is received during southwest monsoon season (Jun-Sep). Average relative humidity in the morning and evening were observed to be highest in August as it is the rainiest month with a rainfall of 457 mm. Maximum number of rainy days are 17 in the months of July and August. Bright sunshine varies from 3 to 9 hours per day over the year with February-May experience above 8 hours of bright sunshine. July and August experience lowest, about 3 hours of sunshine due to cloud cover in monsoon season.

Daily reference crop ET was computed for 31 years using the FAO Penman-Monteith method (Allen *et al.,* 1998) as followed in CROPWAT model (2009) version 8.0 in which outputs are generated for component wise viz. energy balance and aerodynamic term along with daily ET_o.Daily values of ET_o and its components were converted into monthly, seasonal, and annual formats.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

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 [k Pa]

e_a = actual vapour pressure [k Pa]

$e_s - e_a$ = saturation vapour pressure deficit [k Pa]

Δ = slope vapour pressure curve [k Pa $°C^{-1}$]

γ = psychometric constant [k Pa $°C^{-1}$]

RESULTS AND DISCUSSION

ET_o showed a decreasing trend in the first half of the study period as maximum temperature and sunshine hours also decreased during this period with lowest ET_o observed in the 1994 and 1999 years (Fig. 1). ET_o increased in the second period as wind velocity and rainfall also increased during 1995 to2012 with highest values of 1425 mm

Fig. 1: Trend in reference crop evapotranspiration (ET_o) at Jabalpur

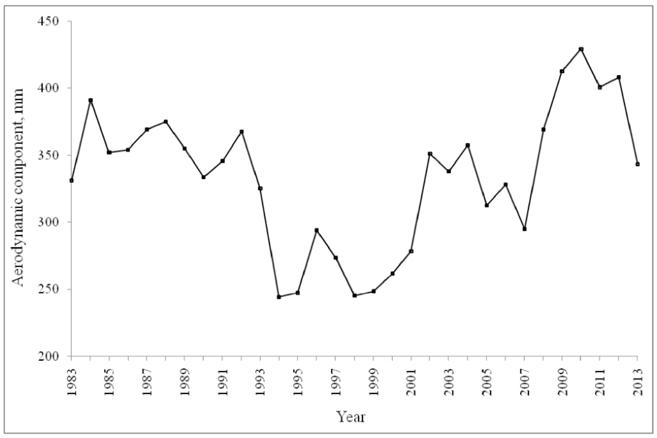

Fig. 3: Trend in aerodynamic component of ET_o at Jabalpur

observed in the 2009 and 2010 years.Thomas (2000) worked on spatial and temporal characteristics of PET trend over China and reported that the wind speed, relative humidity and maximum temperature are the primary factors to be associated with evapotranspiration changesin northwest, central and north-east China. A 10% increase in temperature and actual vapour pressure coupled with 10% decrease in net solar radiation could result in a marginal decrease of total ET by 0.30 (Goyal, 2004).

The energy balance component has shown negative trend with values ranging from 1067 to 941 mm (Fig. 2). During the years 1983 to 1994, the ET_o did not show any trend; after the highest value of 1067 mm in 1995, it decreased to reach to 941 mm in 2012 as sunshine hours also decreased continuously duringthis period. Similar to the total ET_o, aerodynamic component shown curvilinear trend with a decreasing trend up to 1995 and then by an increasing trend up to 2012 (Fig. 3). After 1995, wind velocity and rainfall observed increasing trend up to 2012. Low values of 244 mm were observed in the 1994 and 1998 years while high

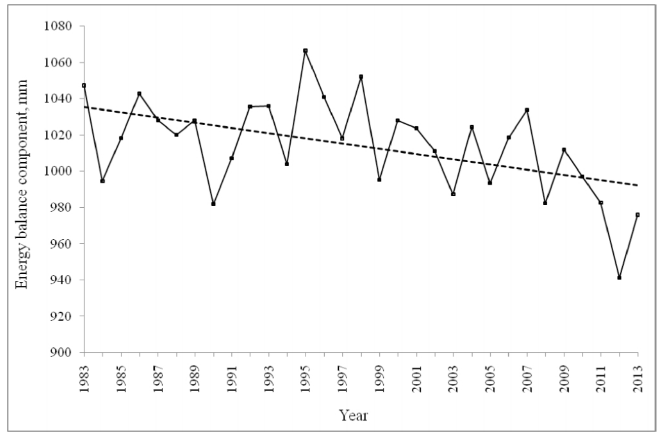

Fig. 2: Trend in energy balance component of ET_o at Jabalpur

Table 2: Normal ET_o and its components on monthly, seasonal and annual basis

Month/ Season	ET_o (mm)	Energy balance component (mm)	Aerodynamic component (mm)
Jan	66.8	53.9	12.9
Feb	83.6	66.6	17.1
Mar	124.6	93.0	31.5
Apr	158.9	106.4	52.5
May	197.2	119.3	77.9
Jun	162.1	104.6	57.5
Jul	110.8	90.0	20.7
Aug	99.7	87.0	12.7
Sep	104.7	92.6	12.1
Oct	102.8	89.4	13.5
Nov	74.8	61.7	13.1
Dec	61.5	49.8	11.7
Kharif	473.7	370.4	103.2
Rabi	393.5	325.7	67.9
Zaid	480.7	318.8	161.9
Annual	1348	1014	333

ET_o of 429 mm was observed in 2010. At Jabalpur, energy balance contributes about 75% while aerodynamic component by 25% to the total ET_o. Energy and aerodynamic components were observed to be contributing 70% and 30% respectively to ET_o at ICRISAT, Patancheru (Rao and Wani, 2011).This reported that the energy balance component was the dominating factor than aerodynamic component to ET_o.

To evaluate temporal changes in evapotranspiration demands, a five-year average ET_o of *kharif* (Jun to Sep), *rabi* (Oct to Feb) and *zaid* (March to May) seasons are computed.

ET_o observed negative trend during *kharif* season, while positive trend during*rabi* season. In *kharif* season, reduction of ET_o during the study period was 4% while it increased by 2.5% in *rabi* season. In *zaid* season, the ET_o did not show any trend. Rao and Wani (2011) analysed ET_o at a semi-arid location of southern India and observed a decreasing trend in both *kharif* and *rabi* seasons, with 10% reduction in *kharif* and 14% in *rabi* seasons. Normal values of ET_o and its components for *kharif*, *rabi* and *zaid* season along with monthly and annual mean values over the last 31 years are computed and presented in Table 2. Variation of ET_o is an extremely important variable to be considered for agriculture purpose. Mean annual ET_oobserved 1348mm while 1014mm and 333mm for energy balance component and aerodynamic component respectively. When comparing *kharif*, *rabi* and *zaid* season, ET_o and aerodynamic components observed minimum in *rabi* season with 393 mm and 68 mm respectively while maximum in *zaid* season with 481 mm and 162 mm respectively. Summer season ET_o values observed highest while lowest in winter season among all the seasons (Rao *et.al*, 2013). In energy balance component, maximum $ET_o$of 370 mm observed in *kharif* season while lowest ET_o in *zaid* season with 319 mm. Mean monthly ET_o, energy balance component and aerodynamic component found maximum in the month of May having highest maximum temperature of 41.4°C with ET_o of 197mm, 119mm and 78mm respectively. Lowest mean monthly ET_o, energy balance component and aerodynamic component observed in the month of December with ET_o of 62mm, 50mm and 12mm respectively.

CONCLUSION

Analyses of 31 years of daily meteorological data of Jabalpur indicated that energy balance component of ET_o has shown a negative trend, while a curvilinear trend is seen in the aerodynamic component as well as in the ET_o. Seasonal analysis has shown that ET_o has an increasing trend during *rabi* season. Mean annual ET_o is 1348 mm with 1014 mm for energy balance component and 333 mm for aerodynamic component.Mean monthly ET_o, energy balance component and aerodynamic components observed maximum in the month of May while lowest in the month of December. Crop water requirement are more during April to June as ET_o is observed to be highest during this period. Trend analysis provides indication on patterns in historical data of evapotranspiration. Monthly ET_o variation is very useful for analysis of various water requirement of crops, irrigation plans etc. Present study highlights the necessity of ET_o trend analysis as it depend on different weather parameters.

ACKNOWLEDGEMENT

One of the authors (AVR Kesava Rao) acknowledges the support from the CGIAR Research Programs on Climate Change, Agriculture and Food Security (CCAFS) and Water, Land and Ecosystems (WLE).

REFERENCES

Allen, R.G., Pereria, L.S., Raes, D. and Smith, M. (1998). Crop Evapotranspiration – Guideline for computing crop water requirement, FAO Irrigation and drainage paper No 56, FAO, Rome, Italy, 300p.

Aggarwal, P.K. (2008). Global climate change and Indian agriculture: impacts, adaptation and mitigation. *Indian J. Agric. Sci.,* 78(10): 911-19.

Bapuji Rao, B., sandeep, V.M., Chowdary, P.S., Pramod, V.P. and Rao, V.U.M. (2013). Reference crop evapotranspiration over India: A comparison of estimates from open pan with Penman-Monteith method. *J.Agrometeorol.,*15 (2):108-114.

Chattopadhyay, N. and Hulme, M. (1997).Evaporation and potential evapotranspiration in India under conditions of recent and future climate change.*Agric. Forest Meteorol.,* 87(1):55-73.

CROPWAT(2009). Food and Agricultural Organization of the United Nations available at www.fao.ay/nr/water/ infores.databases.cropwat.html

Goyal, R.K. (2004). Sensitivity of evapotranspiration to global warming: a case study of arid zone of Rajasthan, India. *Agric. Water Manag.*, 69:1–11.

Huo, Z., Dai, Z., Feng, S., Kang, S. and Huang, G. (2013).Effect of climate change on reference evapotranspiration and aridity index in arid region of China.*J. Hydrol.,* 492: 24–34.

IPCC (2001).Climate Change. *In:* The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the IntergovernmentalPanel on Climate Change [Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell and C. A. Johnson (eds.)], Cambridge University Press, Cambridge, UK, 881 pp.

IPCC (2008).Special report on managing the risks of extreme events and disasters to advance climate change adaptation. http://www.ipcc-wg2. gov/SREX/images / uploads/ SREXAll_FINAL.pdf.

Kesava Rao A.V.R, Nageswara Rao G, Ramakrishna Y.S and Rao G.G.S.N.(2002).Crop weather scenario *Kharif* 2002. In: Drought Management in Indian Arid Zone (Eds. PratapNarain, Joshi D.C, Kathju S and Kar A). CAZRI, Jodhpur.

Mall, R., Singh, Ranjeet, Gupta, Akhilesh, Srinivasan, G. and Rathore, L.S. (2006). Impact of climate change on Indian agriculture: *A review on climatic change,* 78: 445-478.

Rao A.V.R.K, and Wani, S.P. (2011). Evapotranspiration paradox at a semi-arid location in India. *J. Agrometeorol.,* 13 (1):3-8.

Sankaranarayanan, K., Praharaj, C.S., Nalayini, P., Bandyopadhyay, K.K. and Gopalakrishnan, N. (2010).Change and its Impact on cotton (Gossypium sp.).*Indian J. Agric. Sci.,* 80 (7): 561–75.

Sivakumar M.V.K, Maidoukia A and Stern R.D. (1993). Agroclimatology of West Africa: Niger. Information Bulletin No. 5. Patancheru, Andhra Pradesh 502 324, India.International Crops Research Institute for the Semi-Arid Tropics.10 pp.

Thomas, A. (2000). Spatial and temporal characteristics of potential evapotranspiration trends over china.*Int.J.Climatol.,*20: 381–396.

Received : December 2014 ; Accepted : July 2015