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Research Article

TRENDS AND VARIABILITY IN EVAPOTRANSPIRATION AT JUNAGADH, GUJARAT

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ABSTRACT

Objectives: Evapotranspiration (ET) demands and trends were analyzed for Junagadh region in western Gujarat by assessing reference ET_o, energy balance, and aerodynamic components for 32 years (1984-2015).

Methods: The daily data on maximum temperature, minimum temperature, morning and afternoon relative humidity, rainfall, wind speed, and sunshine hours were collected for the period of 32 years (1984-2015). The use of Penman-Monteith methods for trends in ET.

Results: The analysis indicated multiple trends in annual ET_o and an annual aerodynamic component of ET_o. In the first half of the study period, a clear decreasing trend was observed with 2002 and 2004 years having low ET_o values. Later, the ET_o started increasing and the highest ET_o of 1522 mm was observed in the years 1987, which was drought year. Energy balance component has shown increasing trend with the increasing in temperature and sunshine hours. The trends in 32 years average ET_o values indicated to increase in *kharif* season while the ET_o reduction in *rabi* season.

Conclusion: This study highlights the necessary to understand ET_o of the region before planning and management.

Keywords: Weather parameters, Climate change, Penman-Monteith, Evapotranspiration, Gujarat.

INTRODUCTION

In agriculture, a crop water use is determined by crop evapotranspiration (ET). Reference, potential, and actual ET are distinguished. The potential ET of a given crop is defined as soil evaporation and plant transpiration under unlimited soil water supply and actual meteorological conditions. The actual ET is the amount of water transpired from plants and evaporated from soil surface under actual meteorological conditions and under non-optimal soil, biological, management, and environmental conditions. The ET from a reference surface is called the reference ET.

Recently, considerable interest has been shown to climate variability and its effect on the hydrological cycle and water supply [16]. ET is an essential component of both climate and hydrological cycles and has 37 significant agricultural, ecological, and hydrological implications. ET uses approximately three-fifths of the available annual solar radiation globally received at the Earth's surface [20]. In addition to the energy balance, ET is also a major component of the water cycle, as it accounts for approximately two-thirds of the precipitation falling on land [4]. ET is important in several atmospheric processes, as it determines the supply of water to the atmosphere from the oceans and terrestrial areas. It affects the magnitude and spatial distribution of global temperature and pressure fields [18].

Earth temperature has increased by 0.74°C during the last century (1906-2005) due to increase in greenhouse gases through anthropogenic emissions with temperature may rise from 1.8 to 4.0°C by the turn of 21^{st} century resulting in an anticipated instability in food, feed and fiber production [2]. Agricultural sector is one of the vulnerable sectors influenced by the rise in temperature, rainfall variability, and climate change. Climate change is likely to alter crop durations, impact pest populations, hasten mineralization in soils, increase ET, and bring in more uncertainties in crop yields. Demand for irrigation water is a more sensitive to agricultural production as climatic variability increased dryness thereby creating more demand of water to fulfill crop growing period [9,11].

In addition, change in the normal pattern of temperature, precipitation and amount of rainfall also influence soil water content [12]. ET is a major component of hydrological cycle and maximum portion of total rainfall falling on a land surface is returned to the atmosphere through ET. Increase in the rate of ET along with temperature causes depletion in soil moisture retention capacity and increase salinity in semi-arid situations [15].

Chattopadhyay and Hulme (1997) [5] analyzed 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 ET. Their analysis shows that both pan evaporation and potential ET have decreased during recent years in India. They concluded that future warming seems likely to lead in general to increase potential ET 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 [10] (Reference crop 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 ET_o has decreased during the period. The rate of reduction in ET_o was about 10% for *kharif* and 14% for *rabi* seasons. Contribution of energy balance to the total ET has shown negative trend while the positive trend was seen for aerodynamic component [13]. In the arid region of China, a study with a dataset of 1955-2008 from 23 meteorological stations indicated that ET has shown a decreasing trend with wind speed as the most sensitive meteorological variable followed by relative humidity, temperature and solar radiation [8].

METHODS

Junagadh is situated at 21°30 N' and 70°31'E and altitude of about 82 m above the mean sea level. This region tropical and subtropical climate and is predominant with black soil. The climatic data were collected from the Agro-Meteorological Cell, Department of Agronomy, and College of Agriculture, Junagadh Agricultural University, Junagadh. The daily data on maximum temperature, minimum temperature, morning and afternoon relative humidity, rainfall, wind speed, and sunshine hours were collected for the period of 32 years (1984-2015). Normal monthly climatic parameters at Junagadh are presented in Table 1. Average annual rainfall is about 903 mm with 45 rainy days. About 91% of the annual rainfall is received during southwest monsoon season (June-September) (Table 2). Average relative humidity in the morning and afternoon were observed to be highest in August and rainiest month is July as it with a rainfall of 330 mm. The maximum number of rainy days is 13 and 11 in the months of July and August. The bright sunshine varies from 1.8 to 9.8 h per day over the year with February-May experience above 9 h of bright sunshine. July and August experience lowest, about 1-2 h of sunshine due to cloud cover in monsoon season. The FAO PM method was developed by defining the reference crop as a hypothetical crop with an assumed height of 0.12 m, a surface resistance of 70 s/m and an albedo of 0.23. This closely approximates the evaporation expected from an extensive surface of actively growing and adequately watered green grass of uniform height [1], and is defined by the equation:

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

where,
ET: Reference evapotranspiration (mm/day)
R_n: Net radiation at the crop surface [MJ/m/day]
G: Soil heat flux density [MJ/m/day]
T: Mean daily air temperature at 2 in height (°C)
u_2: Wind speed at 2 in height (m/s)
e_s: Saturation vapor pressure (kPa)
e_a: Actual vapor pressure (kPa)
e_s–e_a: Saturation vapor pressure deficit (kPa)
Δ: Slope vapor pressure curve (kPa/°C)
γ: Psychometric constant (kPa/°C)

RESULTS AND DISCUSSION

Temporal variability of reference ET

ET showed a decreasing trend in the first half of the study period as maximum temperature and sunshine hours also decreased during this period with the highest ET observed in the 1987 and 1994 years (Fig. 1). ET_o decreased in the second period as wind velocity and rainfall also increased during 2002-2012 with lowest values of 1221 and 1333 mm observed in the 2004 and 2012 years. Thomas (2000) [19] 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 ET changes in northwest, central and north-east China. A 10% increase in temperature and actual vapor pressure coupled with 10% decrease in net solar radiation could result in a marginal decrease of total ET by 0.30 [7,11].

The energy balance component has shown a positive trend with values ranging from 1303 to 1046 mm (Fig. 2). During the years 1993-2001, the ET did not show any trend; after the highest value of 1303 mm in 2012, it increased to reach to 1216 mm in 2015 as sunshine hours also increased continuously during this period. Similar to the total ET, aerodynamic component shown curvilinear trend with a decreasing trend up to 1988 and then by an increasing trend up to 2003 (Fig. 3). After 1988, wind velocity and rainfall observed increasing trend up to 2003 and then decreasing up to 2015. At Junagadh, energy balance contributes about 74% while aerodynamic component by 26% to the total ET. Energy and aerodynamic components were observed to be contributing 70% and 30%, respectively, to ET_o at ICRISAT, Patancheru [13]. This reported that the energy balance component was the dominating factor than aerodynamic component to ET_o.

ET observed negative trend during *kharif* season, while positive trend during *rabi* season. In *kharif* season, reduction of ET during the study

Table 1: Normal monthly climatic parameters at Junagadh

Month	Tmax (°C)	Tmin (°C)	RH-I (%)	RH-II (%)	Wind speed (km/hrs)	Rainfall (mm)	Bright sunshine (hrs)	Rainy days
January	29.6	11.7	66.5	29.2	5.4	1.0	8.9	0
February	32.1	14.5	66.4	26.1	5.7	1.9	9.4	1
March	36.4	18.9	65.4	22.3	6.2	1.7	9.5	0
April	39.2	22.6	72.5	24.0	7.2	1.2	9.8	0
May	38.9	25.7	82.6	39.0	9.7	3.9	9.3	2
June	36.0	26.6	85.5	58.8	10.7	165.5	4.9	6
July	31.7	25.4	93.8	78.4	9.2	330.5	1.8	13
August	30.6	24.6	94.8	78.3	6.8	197.2	2.1	11
September	32.6	23.9	91.6	65.1	4.7	159.8	6.0	6
October	35.8	21.3	78.3	37.7	3.8	33.3	8.6	4
November	34.2	17.0	70.6	31.4	3.7	6.8	8.8	2
December	31.1	12.8	71.0	33.1	4.6	0.0	8.4	0

ET: Evapotranspiration

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)
January	51.9	41.9	10.0
February	67.3	53.6	13.8
March	117.1	87.4	29.6
April	196.5	131.5	64.9
May	270.8	163.8	107.0
June	170.9	110.3	60.6
July	96.2	78.2	18.0
August	62.9	54.9	8.0
September	80.0	70.8	9.2
October	98.4	85.6	12.9
November	68.6	56.6	12.0
December	53.9	43.6	10.3

ET: Evapotranspiration

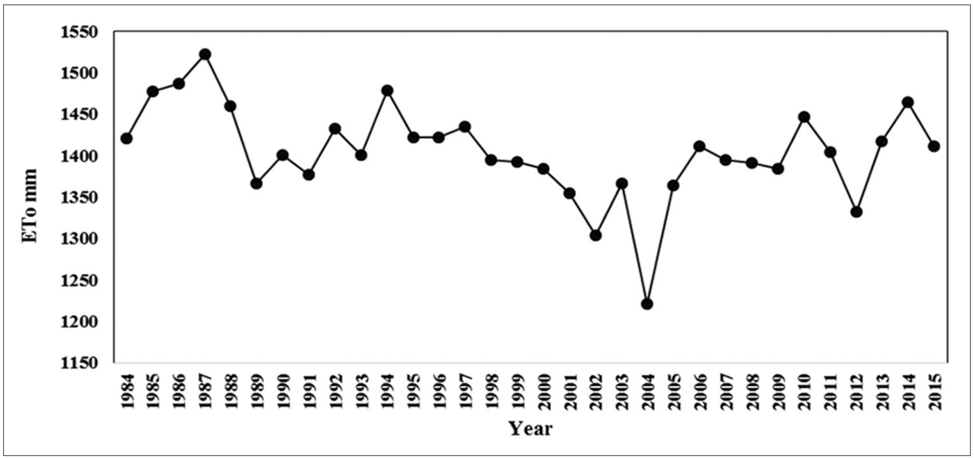

Fig. 1: Trend in reference crop evapotranspiration at Junagadh

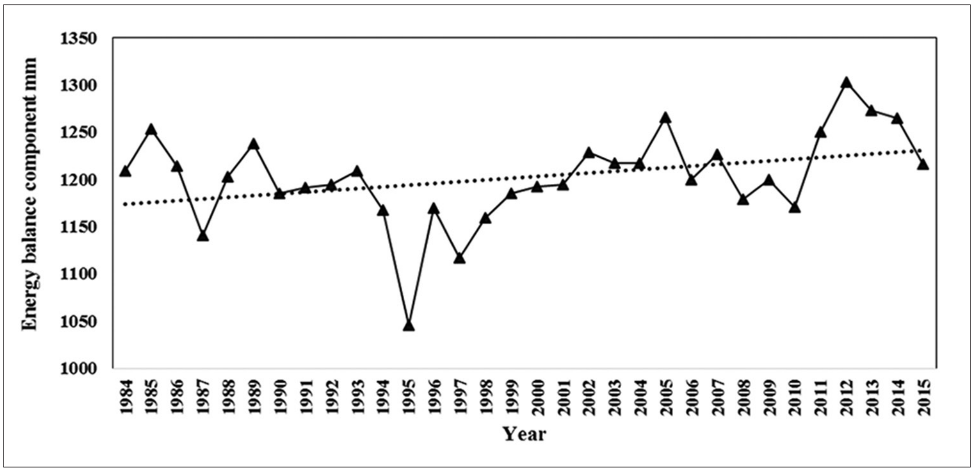

Fig. 2: Trend in energy balance component of evapotranspiration at Junagadh

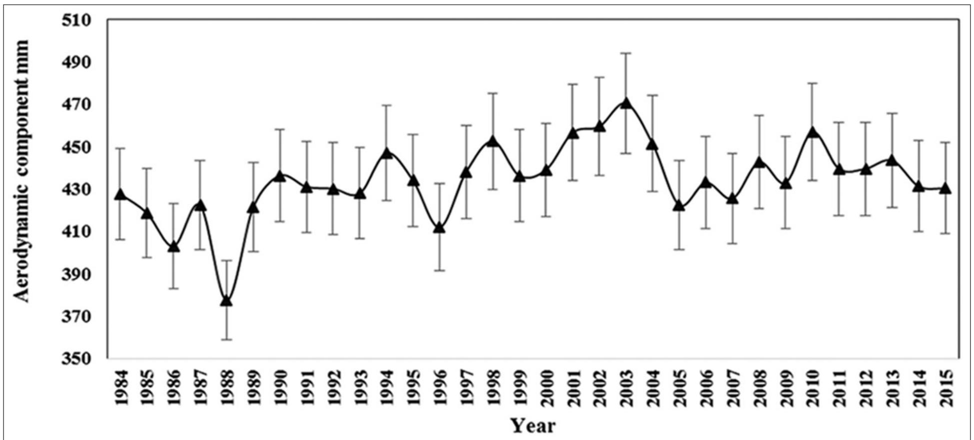

Fig. 3: Trend in aerodynamic component of evapotranspiration at Junagadh

period was 4.0% while it increased by 2.5% in *rabi* season. In *zaid* season, the ET_o did not show any trend [14]. Rao and Wani (2011) [13] analyzed ET_o at a semi-arid location of western India and observed a decreasing trend in both *kharif* and *rabi* seasons, with 10% reduction in *kharif* and 14% in *rabi* seasons.

Mean monthly ET_o, energy balance component and aerodynamic component found maximum in the month of May having maximum temperature of 38.9°C with ET of 271, 164 and 107 mm, respectively. The lowest mean monthly ET_o, energy balance component, and aerodynamic component observed in the month of January with ET of 52 mm, 42 mm and 10 mm, respectively. The normal values of ET_o and its components for summer (March-May), monsoon (June-September), post monsoon (October-November) and winter (December-Febuary) seasons over the last 32 years are computed and presented in Table 3.

The mean annual ET observed 109.6 mm while 80.9 mm and 28.8 mm for energy balance component and aerodynamic component, respectively. When comparing different seasons, the normal ET and aerodynamic components observed minimum in winter season with

Table 3: Normal seasonal climatic parameters, ET_o and its components

Season	Climatic parameters								ET_o and its components		
	Tmax (°C)	Tmin (°C)	RH-I (%)	RH-II (%)	Wind speed (km/hrs)	Rainfall (mm)	Bright sunshine (hrs)	Rainy days	ET_o	Energy balance	Aerodynamic component
Summer	38.2	22.4	74	28	7.7	2.3	9.5	0.7	194.8	127.6	67.2
Monsoon	32.7	25.1	91	70	7.9	213.3	3.7	9.0	102.5	78.6	24.0
Post monsoon	35.0	19.2	75	35	3.8	20.1	8.7	3.0	83.5	71.1	12.5
Winter	30.9	13.0	68	30	5.2	1.0	8.9	0.3	57.7	46.4	11.4
Annual	34.2	19.9	77	41	6.2	59.2	7.7	3.0	109.6	80.9	28.8

57.7 mm and 11.4 mm, respectively, while maximum in summer season with 194.8 mm and 67.2 mm, respectively. Summer season ET_o values observed highest while lowest in winter season among all the seasons [3]. In normal energy balance component, maximum ET of 127.6 mm observed in summer season while lowest ET in winter season with 46.4 mm.

CONCLUSION

Analyses of 32 years of daily meteorological data of Junagadh indicated that energy balance component of ET_o has shown a positive trend, while a curvilinear trend is seen in the aerodynamic component as well as in the ET_o. Seasonal analysis has shown that ET has an increasing trend during *kharif* season. Mean annual ET_o 1334 mm with 978 mm for energy balance component and 356 mm for the 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 January. Crop water requirement is more during April to June as ET is observed to be highest during this period. Trend analysis provides indication on patterns in historical data of ET. Monthly ET variation is very useful for analysis of various water requirements of crops, irrigation plans, etc. This study highlights the necessity of ET_o trend analysis as it depends on different weather parameters.

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