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Rainfall, temperature and reference evapotranspiration trend in the context of climate change over undivided Koraput district, Odisha, India

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ABSTRACT

In the present study, an attempt has been made to know the long−term changes in rainfall, temperature, and reference evapotranspiration (ET_o) over undivided Koraput district (Koraput, Malkangiri, Nabarangapur and Rayagada). Rainfall (1901−2017), temperature and ET_o (1901−2002) data were analyzed in this study. Statistical trend analysis technique such as Mann−Kendall (M−K) test was used to examine and analyze the data trend. The detailed analysis of the data for 117 years indicates that mean annual rainfall of Koraput, Malkangiri, Nabarangapur and Rayagada is 1316.1 mm, 1180.1 mm, 1451.0 mm and 1270.8 mm, respectively. Statistically significant trends were detected for rainfall, and also the result was statistically significant at 95% confidence interval. Annual rainfall showed an increasing trend at the rate of 2.49, 3.86 mm yr^{-1} at Koraput, and Malkangiri, respectively, however there was no trend for Nabarangapur and Rayagada districts. Similarly, rainfall during monsoon showed an increasing trend for Koraput (2.73 mm yr^{-1}) and Malkangiri (4.05 mm yr^{-1}). With respect to maximum and minimum temperatures, and ET_o, all the four districts of the study area showed an increasing trend. The highest ET_o trend of 0.112 mm $season^{-1}$ was observed during pre−monsoon season at Malkangiri, whereas the lowest significant trend of seasonal ET_o (0.06 mm $season^{-1}$) was noticed during the monsoon season at Rayagada. The study area is mostly undulating in nature, thus increase in rainfall and temperature may aggravate the present soil erosion rate. Various soil and water conservation measures are suggested to manage natural resources and to increase crop productivity under climate change condition. This study will be helpful in planning, management and conservation of natural resources for sustainable development of the region.

1. INTRODUCTION

Rainfall, temperature and evapotranspiration are the important climatic factors that affect crop production. In Indian condition, these are very important because nearly 60% of its area is rainfed, distress−prone and vulnerable to climate. Not only crop productions, other livelihood activities based on agriculture are also affected by these parameters (Panigrahi and Panda, 2001; Kumar and Gautam, 2014). As climatic parameters, particularly rainfall, temperature and subsequently evapotranspiration are the major factors influencing agricultural productivity and sustainability, their trend analysis over time is thus utmost important. Understanding the changes or variation in patterns and / or presence of trends in rainfall, temperature, evapotranspiration series over different spatial and temporal horizons have been the vital aspects in climatological, hydrological and meteorological studies worldwide (Chatterjee *et al*., 2016; Yang *et al*., 2017).

Sethi *et al*. (2015) performed a trend analysis for precipitation and inflows time series for Salia river basin of Odisha, India which drains into Chilika lake using the Mann−Kendall (M−K) test. In order to assess the impact of climate change, ARNO model was used to simulate the inflows into Salia reservoir calibrating the observed inflow. In another recent study, Asfaw *et al*. (2017) detected trends in the gridded rainfall and temperature (1901−2014) datasets of Woleka sub–basin, north–central Ethiopia using M–K test. The results revealed a significant decline in the annual rainfall at a rate of 15 mm decade^{-1} whereas the mean and minimum temperatures were found increasing at the rate of 0.046°C and 0.067°C decade^{-1}, respectively. Further, Ul Shafiq *et al*. (2018) analyzed rainfall and temperature trends in 1980–2014 time series for the six stations of the Kashmir valley, India using M–K test. It was found that the mean maximum temperature in plain regions is increasing at a higher rate than that in the mountainous areas. In contrast, the mean minimum temperature was found increasing at higher rate in the mountainous regions. Similarly, Panda and Sahu (2019) studied the trend of seasonal rainfall and temperature pattern in KBK districts of Odisha, India (1980–2017), using M–K test, and they reported a quite good increasing trend of rainfall and temperature. Prabhakar *et al*. (2019) assessed long term gridded rainfall variability over the Odisha state of India, and they observed both positive and negative trends for different districts of Odisha.

Reference evapotranspiration (ET_o) is a key parameter used to estimate actual crop water use by multiplying ET_o with specific crop coefficients. Under the changing climate, the trend analysis of ET_o is important for sustainability in food production, water deficit or flooding conditions, relative to the total rainfall. Knowledge of the dynamics in ET_o is therefore critical for water resources management under rainfed conditions and planning of strategies to reduce vulnerability of food production to the climatic changes in any region.

Odisha is an agrarian state of India, and its economy is significantly dependent upon gross production of agricultural commodities, and agriculture is the mainstay of millions of population with crops pre–dominantly dependent upon natural rainfall. The economy of undivided Koraput district of Odisha consisting of Koraput, Malkangiri, Nabarangapur and Rayagada mainly depends on agriculture, where more than 90% of people depend on agriculture (Madhu *et al*., 2016) and this in turn largely depends on available water resources, and favourable climatic condition. Therefore, it is important to analyze and investigate the variability of rainfall, temperature and ET_o of undivided Koraput district (Koraput district was divided into four districts namely Koraput, Malkangiri, Nabarangapur, Rayagada in the year 1992), which is one of the most backward regions in the state of Odisha, India. Understanding the uncertainties associated with rainfall, temperature and ET_o patterns will provide a knowledge base for better management of agriculture, irrigation and other water related activities in the district.

2. MATERIAL AND METHODS

Study Area

The undivided Koraput district (Koraput, Malkangiri, Nabarangapur and Rayagada districts) is one of the economically backward districts of Odisha. The study area lies between 81°24′52.042″ and 84°03′39.487″ East longitudes and 17°47′58.7″ and 20°05′13.027″ North latitudes (Fig. 1). The population of the study area is 37.87 lakhs having a population density of 152 sq km^{-1}. The climate of the study area is tropical humid. In this study, according to cropping season, the whole year is divided into three seasons. The pre–monsoon season (also known as summer season) is hot which starts from March and ends at May. The monsoon season (also known as *kharif* season) prevails from June to October. November to February constitute the post–monsoon season (known as *rabi* season). The average annual rainfall of the study area is 1,350 mm. The south–west monsoon is the principal source of rainfall in the districts. This region mostly comprises of hills and mountains. Both soil depth and texture vary with the topography, and become less favourable for cultivation with increasing slope steepness (Dash *et al*., 2017). Agricultural practices extend from valley bottom to hilltop, with variety of cropping systems and management practices. The agriculture production system in this region is mostly rainfed (nearly 65%: Koraput – 57%, Malkangiri –

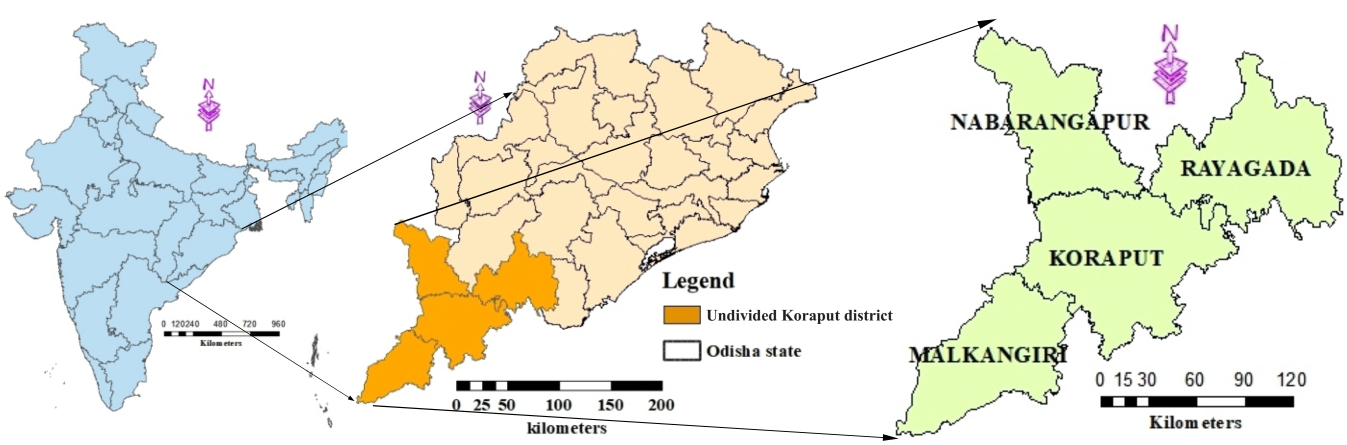

Fig. 1. Study area of undivided Koraput district of Odisha state consisting of Malkangiri, Koraput, Nabarangapur and Rayagada districts

54%, Nabarangaour−75%, and Rayagada−73%) and mono cropped. As rainfed farming is subjected to high risk due to heavy and intense rainfall, drought and other climatic variability, there is always a threat to livelihood security of rural mass, which further leads to weakening of the socio−economic condition of the farmers.

Data Used

Monthly rainfall, maximum, minimum, mean temperatures and ET_o data for the study area were collected from India Water Portal (www.indiawaterportal.org/met_data/) and India Meteorological Department, Pune, and analyzed over a period of more than 100 years. Trend is defined as the general movement of a series over an extended period of time or it is the long−term change in the dependent variable over a long period of time (Webber and Hawkins, 1980). Trend was determined by the relationship between these variables (temperature, rainfall and ET_o) and their temporal resolution. Statistical method such as regression analysis was used to know the significance of trend of these three variables. The trend were derived and tested by M−K trend test. The mean, standard deviation (SD) and coefficient of variation (CV) of these three variables were calculated to analyze the relationship.

Mann−Kendall (M−K) Test

The M−K test is a non-parametric test most widely used for trend analysis in hydrological and climatological time series data analysis. Mann (1945) first suggested this test, and now it has been extensively used with environmental time series. The main advantages of M−K test includes a) it is a non-parametric test and does not require the data to be normally distributed, and b) the test has low sensitivity to abrupt breaks due to inhomogeneous time series. 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 (Panigrahi and Panigrahi, 2016). The M−K statistic, S is defined as follows:

$$S = \sum_{j=1}^{m-1} \sum_{k=j+1}^{m} sign\left(x_k - x_j\right) \qquad ...(1)$$

Where, x_j and x_k are the j^{th} and k^{th} term in the sequential data of sample size m and for $x_k - x_j = 0$.

$$Sign(\theta) = \begin{cases} 1 & if \;\; \theta > 1 \\ 0 & if \;\; \theta = 0 \\ -1 & if \;\; \theta < 1 \end{cases} \qquad ...(2)$$

Assuming independent data to be identically scattered, the variance and mean of the S statistic in eq. 2 may be calculated as given by (Kendall, 1975; Dinpashoh *et al*., 2011):

$$E(S) = 0, \qquad Var(S) = \frac{m(m-1)(2m+5)}{18} \qquad ...(3)$$

The standard normal deviate (Z statistics) is computed as follows:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & if \;\; S > 0 \\ 0 & if \;\; S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & if \;\; S < 0 \end{cases} \qquad ...(4)$$

A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a decreasing trend. The presence of a statistically significant trend is evaluated using Z value. At 5% significance level, the null hypothesis of no trend is rejected if the absolute value of Z is higher than 1.96.

3. RESULTS AND DISCUSSION

Rainfall Characteristics

The rainfall characteristics such as mean, SD, CV, kurtosis and skewness over undivided Koraput district for the period 1901−2017 are presented in Table 1. Mean annual rainfall is 1304.5 mm with a SD of 292.7 mm. Rainfall during monsoon season contributes 87.4% of the annual rainfall in the study area; whereas the contribution of post−monsoon season rainfall is only 4.1%. It has been observed that CV values for average monthly rainfall ranged from 38.9% (during August) to 227.8% (during December). Patra *et al*. (2012) analyzed rainfall trend for entire Odisha (1871−2006) and observed lowest CV for the month of July (26.5%) and highest for month of December (195.7%). Similar results also reported by Panda and Sahu (2019) for KBK (Koraput, Bolangir and Kalahandi) districts of Odisha. In this study, it was observed that during the monsoon season, the CV was low (24.9%) in comparison to other seasons which showed a dependable monsoon rainfall. Monthly rainfall of July, August and September may also be considered as dependable. This result was in accordance with those reported by Panigrahi and Panda (2001) and Patra *et al*. (2012) for entire Odisha. Both the coefficients of kurtosis and skewness were observed to be highest for the month of December, indicating high variation and presence of outliers.

The monthly variation of rainfall over the study area is presented in Fig. 2. The rainfall mostly concentrates during monsoon season occurring between June and October. The rainfall during monsoon season contributes approximately 86.1%, 87.0%, 89.0%, and 86.8% of total annual rainfall for Koraput, Malkangiri, Nabarangapur and Rayagada districts, respectively.

Annual and Seasonal Rainfall Trend

The mean annual rainfall trend over the study area is presented in Fig. 3 and Table 2. It showed a long−term significant increasing trend for Koraput and Malkangiri

Table: 1
Rainfall characteristics in undivided Koraput district (1901-2017)

Time Scale	Maximum (mm)	Minimum (mm)	Mean (mm)	SD (mm)	CV (%)	Skewness	Kurtosis	Contribution to annual (%)
January	64.2	0.0	5.8	9.8	169.5	2.4	6.3	0.4
February	56.1	0.0	8.6	11.9	138.9	1.6	2.0	0.7
March	110.6	0.0	12.2	16.9	138.9	2.3	6.3	0.9
April	263.2	0.0	45.9	43.7	95.1	2.0	5.0	3.5
May	226.2	0.0	54.3	36.5	67.3	1.5	3.4	4.2
June	847.3	37.9	186.6	96.4	51.7	1.8	7.2	14.3
July	783.8	78.0	303.7	123.9	40.8	1.0	1.3	23.3
August	972.8	66.5	307.9	119.8	38.9	1.3	3.1	23.6
September	680.7	32.0	225.9	94.5	41.9	1.1	2.1	17.3
October	397.7	0.0	114.6	74.6	65.1	0.7	0.0	8.8
November	180.6	0.0	34.6	40.1	115.9	1.4	1.5	2.7
December	77.4	0.0	4.5	10.2	227.8	4.0	18.6	0.3
Pre-monsoon	393.0	0.6	111.7	59.0	52.8	1.2	2.4	8.5
Monsoon	2731.6	603.6	1139.8	283.8	24.9	1.3	3.6	87.4
Post-monsoon	204.8	0.0	53.2	44.8	84.3	1.1	0.6	4.1
Annual	3035.6	713.5	1304.5	292.7	22.4	1.3	3.6	100.0

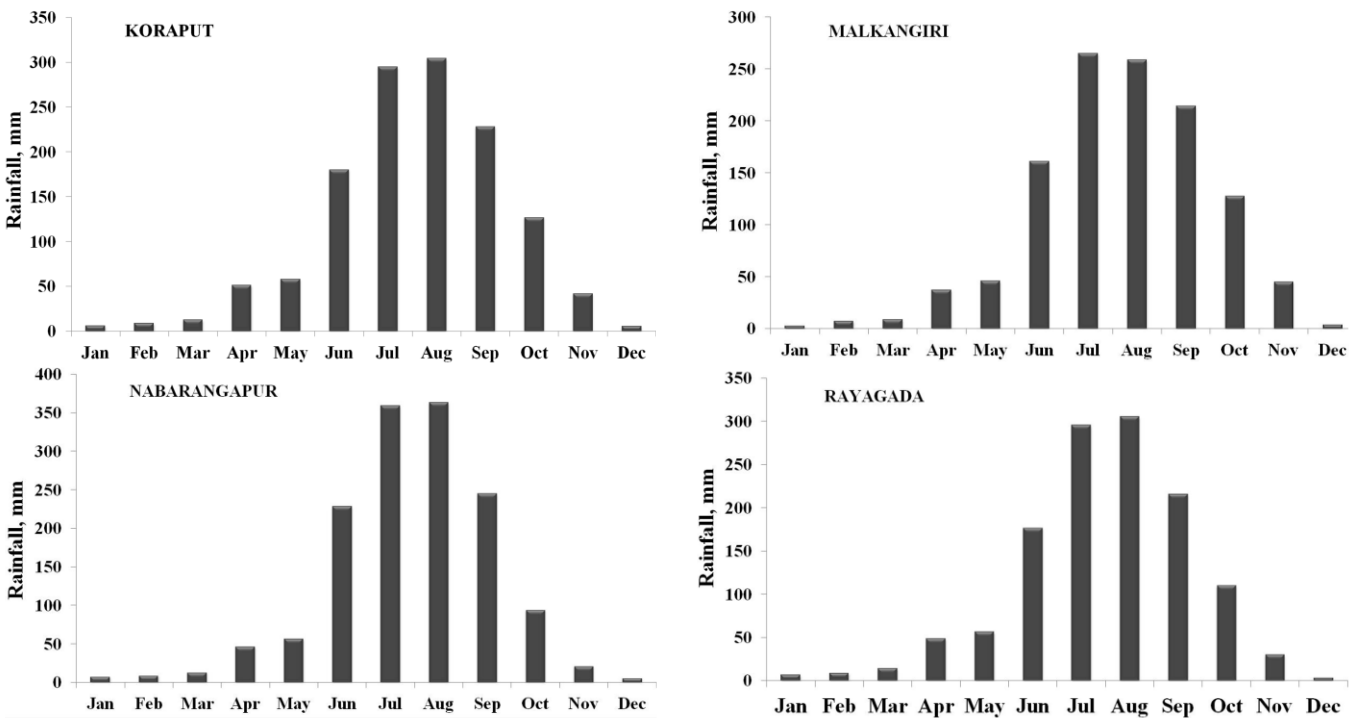

Fig. 2. Monthly rainfall pattern in four different districts of undivided Koraput (average of 117 years)

(Fig. 3), but no significant increasing trend for Nabarangapur and Rayagada. Nath *et al*. (2018) reported no significant annual rainfall trend for Koraput, Nabarangapur and Rayagada districts whereas significant increasing trend for Malkangiri district considering the analysis period from 1901 to 2010. The contradictory result with respect to Koraput may be attributed to variation in length of rainfall period considered under these two studies. Linear regression between annual rainfall and the corresponding year showed an increasing trend in annual rainfall at the rate of 2.49 mm yr^{-1} and 3.86 mm yr^{-1} at Koraput and Malkangiri, respectively (Fig. 3). With respect to seasonal rainfall, rainfall during monsoon showed an increasing trend for Koraput (2.73 mm yr^{-1}) and Malkangiri (4.05 mm yr^{-1}) (Table 2), whereas pre–monsoon and post–monsoon rainfall showed no trend over the years for all the four districts of undivided Koraput. The significant increase in the rainfall during monsoon seasons is mainly due to climate variability resulting into high–intensity and short–duration rainfall events in the area (Dash *et al*., 2013; Dash *et al*., 2019). The significant rise in the rainfall may also be due to cyclones of increased intensity arriving at the coastal land, rising sea– surface temperature (Rao and Vivekanandan, 2008), and / or cosmic influence on the sun–earth environment (Mukherjee, 2008).

A variability analysis of rainfall is of great importance for researchers and policy makers in their decision making

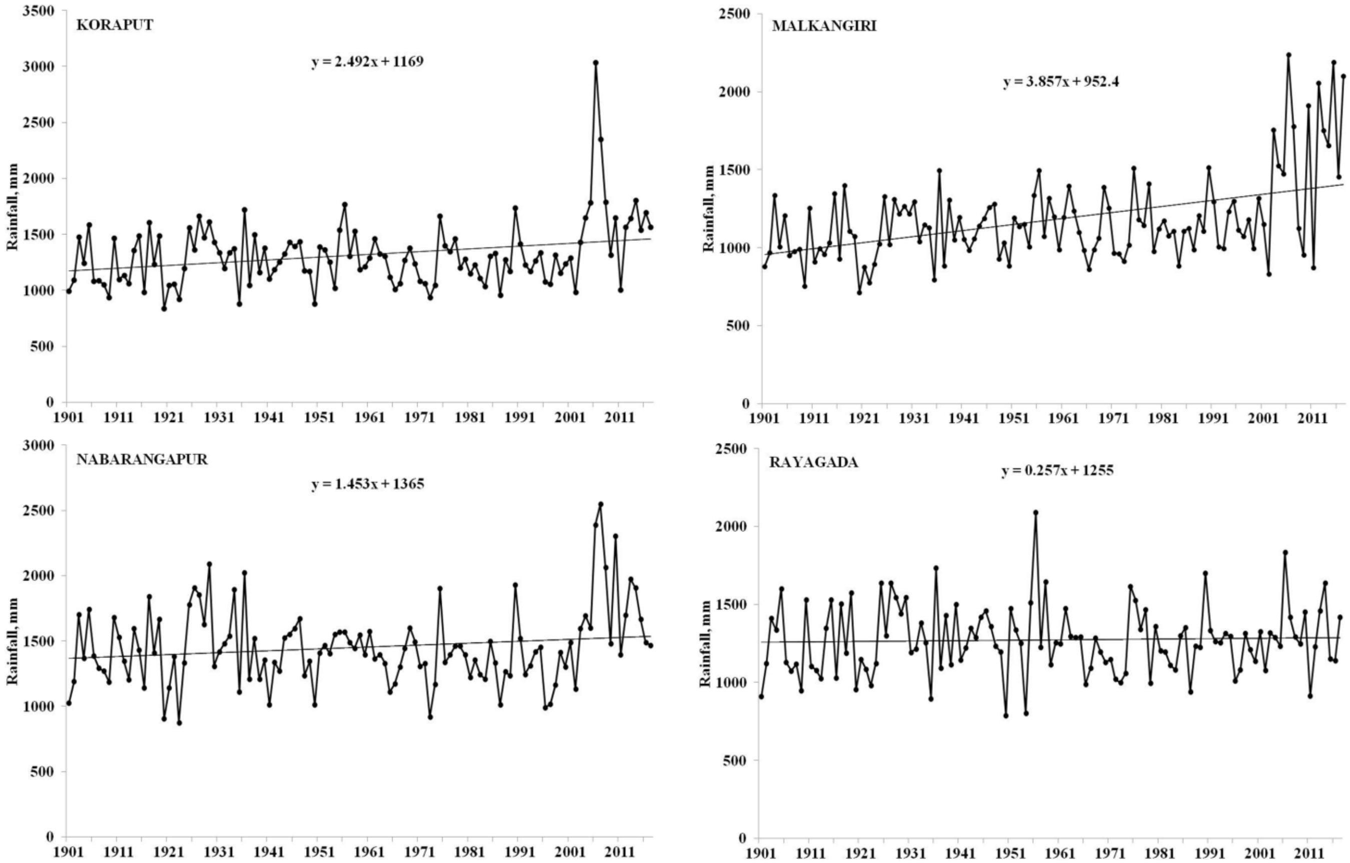

Fig. 3. Variation in annual rainfall over the study area (1901-2017)

Table: 2
Rainfall trend over undivided Koraput district

District	Annual trend	Seasonal trend		
		Pre-monsoon (March-May)	Monsoon (June-Oct)	Post-monsoon (Nov-Feb)
Koraput	Rising	No trend	Rising	No trend
Malakangiri	Rising	No trend	Rising	No trend
Nabarangapur	No trend	No trend	No trend	No trend
Rayagada	No trend	No trend	No trend	No trend

as rainfall plays a dominant role in deciding the optimum use of water availability in the areas, and developing and modifying the crop management practices for sustainable production. As two districts of the study area showed increasing trend, definitely there is a more chance of natural hazards like high flood risk, soil erosion etc. and at the same time, availability of more water will help farming community to increase more area under crop production. It has been reported that potential soil erosion greater than 15 t $ha^{-1}yr^{-1}$ occurs more than 45%, 30%, 30% and 40% of the TGA of Koraput, Malkangiri, Nabarangapur and Rayagada, respectively. It indicates that presently soil erosion rates are higher than the permissible limit and with higher amount of rainfall, there is a need of adoption of suitable soil and water conservation measures in the study area.

Characteristics of Temperature and Trend

The characteristics of temperature over the study area are given in Table 3. The highest maximum temperature was observed to occur during the month of May (41.3°C), whereas lowest maximum temperature happen during the month of December (23.8°C). Similarly, the highest minimum temperature was observed to occur during the month of May (28.2°C), whereas lowest minimum temperature happen during the month of December (9.7°C). The CV for both maximum and minimum temperature was found to be low as compared to rainfall. It has been observed that CV for maximum temperature ranged from 2.8% (during September) to 4.9% (during June) and the same for minimum temperature ranged from 3.3% (during August) to 12.2% (during December). Although the variation is less, but it can be inferred from this study, that minimum temperature shows more variation than the maximum (Table 3).

Regarding trend in temperature, increasing trend was found for maximum, minimum and mean temperatures data for all the four districts of undivided Koraput (Table 4). The daily maximum and minimum temperature trend analysis for Koraput, Malkangiri, Nabarangapur and Rayagada are presented in Fig. 4. Linear regression between maximum temperature and the corresponding year showed an increasing trend in daily temperature at the rate of 0.008°C

Table: 3
Characteristics of maximum and minimum temperature in undivided Koraput district (1901-2002)

Time scale	Maximum temperature					Minimum temperature				
	Maximum (°C)	Minimum (°C)	Mean (°C)	SD (°C)	CV (%)	Maximum (°C)	Minimum (°C)	Mean (°C)	SD (°C)	CV (%)
January	30.2	24.3	27.4	1.2	4.3	18.0	10.5	14.1	1.6	11.0
February	32.3	26.7	29.8	1.2	3.9	19.7	13.6	16.3	1.3	8.2
March	36.5	30.2	33.3	1.3	3.9	22.8	17.2	19.7	1.1	5.5
April	39.4	31.6	35.5	1.5	4.3	26.0	19.7	22.8	1.1	5.0
May	41.3	32.3	36.8	1.7	4.6	28.2	21.3	24.8	1.3	5.2
June	37.8	29.6	33.6	1.6	4.9	28.0	20.9	24.2	1.4	5.7
July	32.4	27.6	29.5	1.0	3.5	25.6	21.1	22.8	0.8	3.7
August	31.6	27.2	29.2	0.9	3.0	24.8	20.8	22.7	0.7	3.3
September	32.4	27.9	29.9	0.8	2.8	24.9	20.9	22.4	0.8	3.5
October	32.1	27.7	29.8	0.9	3.0	23.2	18.5	20.6	0.9	4.6
November	31.1	25.1	28.0	1.2	4.3	20.9	13.3	16.7	1.5	9.2
December	30.1	23.8	26.6	1.2	4.5	18.6	9.7	13.5	1.6	12.2
Pre-monsoon	39.1	31.4	35.2	1.5	4.3	25.7	19.4	22.4	1.2	5.2
Monsoon	33.5	28.1	30.5	1.1	3.5	25.8	20.9	23.0	0.9	4.0
Post monsoon	31.6	26.4	28.9	1.1	3.7	22.1	15.9	18.6	1.2	6.9
Winter	30.8	24.9	27.9	1.2	4.2	18.8	11.3	14.6	1.5	10.5

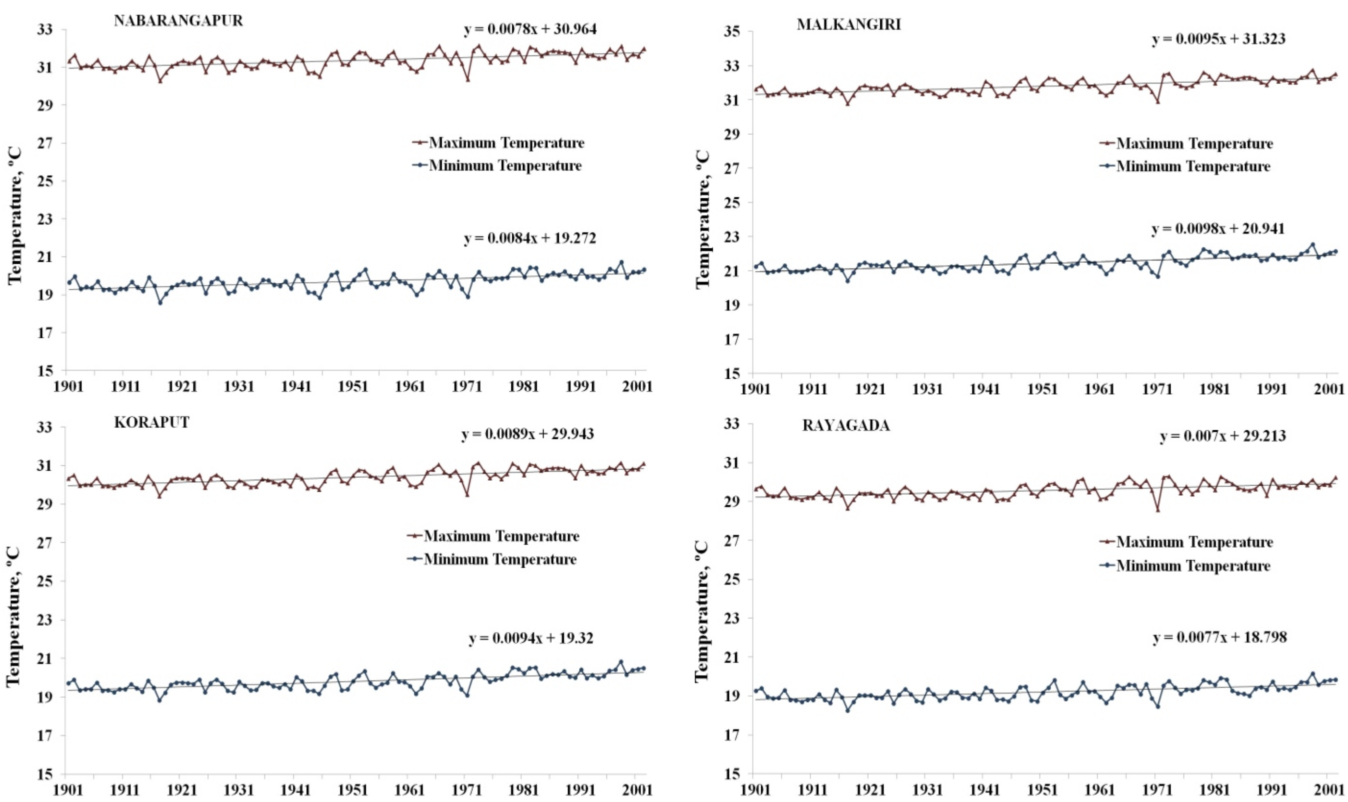

Fig. 4. Variation in daily maximum and minimum temperature over the study area (1901-2002)

Table: 4
Maximum, minimum and mean temperature trend over undivided Koraput district

District	Maximum temperature	Minimum temperature	Mean temperature
Koraput	Rising	Rising	Rising
Malakangiri	Rising	Rising	Rising
Nabarangapur	Rising	Rising	Rising
Rayagada	Rising	Rising	Rising

yr^{-1}, 0.009°C yr^{-1}, 0.007°C yr^{-1} and 0.007°C yr^{-1} at Koraput, Malkangiri, Nabarangapur and Rayagada districts, respectively (Fig. 4). Similarly, there was an increase in daily minimum temperature at the rate of 0.009, 0.009, 0.008 and 0.007°C yr^{-1} at Koraput, Malkangiri, Nabarangapur and Rayagada districts, respectively (Fig. 4). Similar results of increasing trend in maximum temperature was also reported by Panda and Sahu (2019) for KBK districts of Odisha, however they reported a decreasing trend for minimum temperature in the KBK districts of Odisha. The variation in the results may be due to short analysis period (only 37 years: 1980–2017) by Panda and Sahu (2019). Not only in Odisha, Machiwal *et al*. (2019) also reported increasing trend both in maximum and minimum temperature in Kachchh district of Gujarat, India. It is emphasized that the rising maximum temperature may hamper crop growth due to enhanced metabolic–activities and shortened crop–duration. On the other hand increased minimum temperature may result in lesser crop and biomass yields owing to the increased respiration.

Characteristics of Reference Evapotranspiration and Trend

The variation of monthly ET_o over the study area is presented in Fig. 5. It showed monthly ET_o first increased

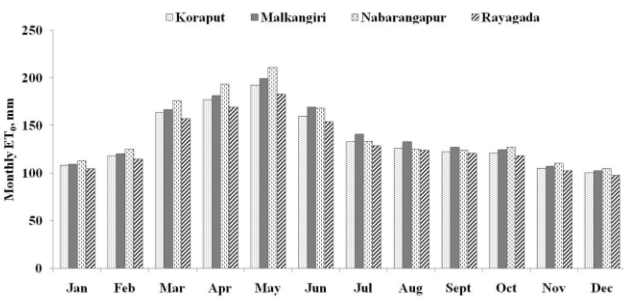

Fig. 5. Monthly ET_o pattern over the study area (average of 102 years)

and then decreased during a year. The ET_o value reaches at peak in the month of May followed by April and June, whereas the bottom values occur during November and December (Fig. 5). The highest ET_o values of 177 mm month^{-1}, 183 mm month^{-1}, 191 mm month^{-1}, and 169 mm month^{-1} observed for Koraput, Malknagiri, Nabarangapur and Rayagada, respectively. Annual ET_o varied with locations across the study area and ranged from 1580 mm to 1670 mm at Koraput, 1636 mm to 1723 mm at Malkangiri, 1662 mm to 1765 mm at Nabarangapur and 1521 mm to 1625 mm at Rayagada for the period 1901–2002. Linear regression between annual ET_o and the corresponding year showed an increasing trend in annual ET_o at the rate of 0.31 mm yr^{-1}, 0.27 mm yr^{-1}, 0.34 mm yr^{-1} and 0.22 mm yr^{-1} at Koraput, Malkangiri, Nabarangapur and Rayagada, respectively. Similarly, increasing trend was also observed for all the three seasons in the study area (Fig. 6, Table 5). The highest ET_o trend of 0.112 mm season^{-1} was observed during pre–

Table: 5
Reference evapotranspiration trend over undivided Koraput district

District	Annual trend	Seasonal trend		
		Pre-monsoon	Monsoon	Post-monsoon
Koraput	Rising	Rising	Rising	Rising
Malakangiri	Rising	Rising	Rising	Rising
Nabarangapur	Rising	Rising	Rising	Rising
Rayagada	Rising	Rising	Rising	Rising

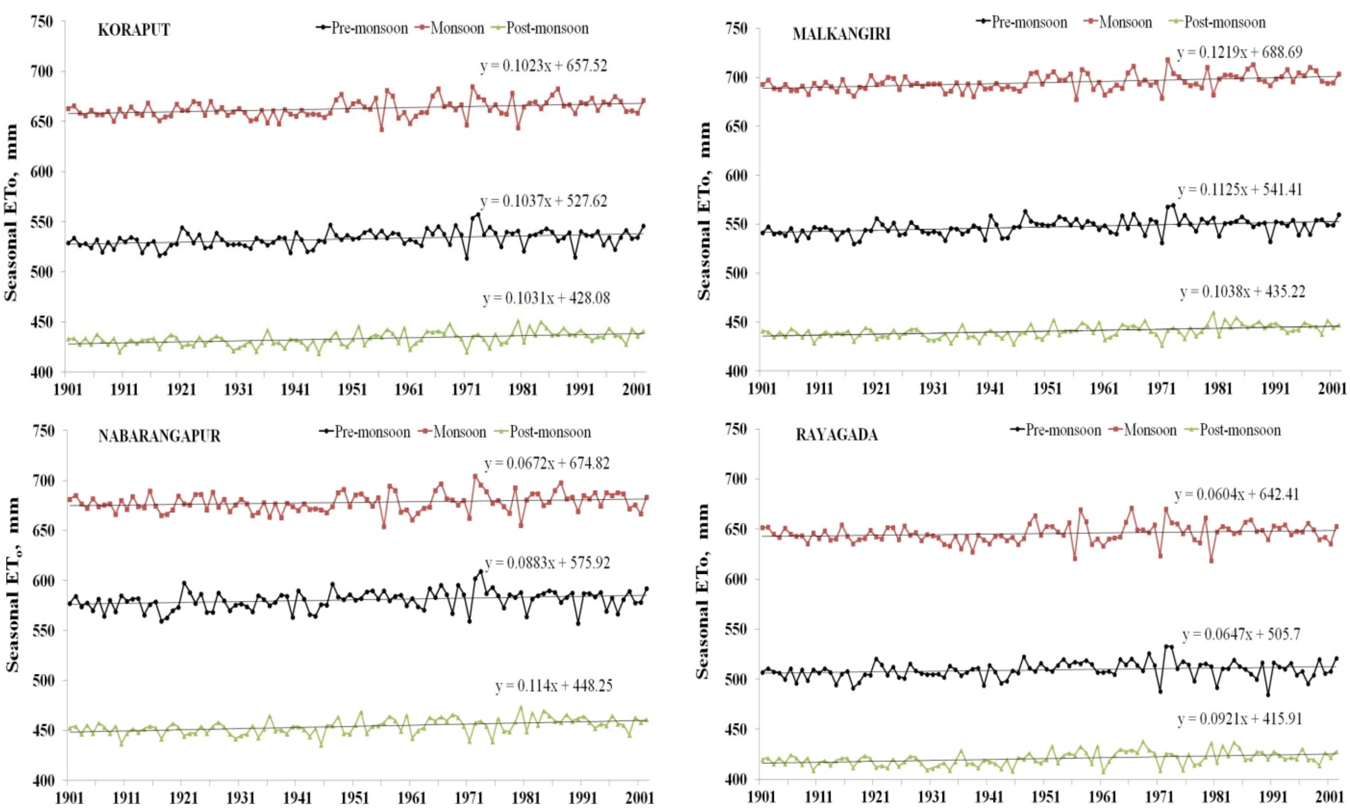

Fig. 6 . Seasonal variation of ET_o in the study area

monsoon season at Malkangiri. The lowest significant trend of seasonal ET_o (0.006 mm season^{-1}) was noticed during the monsoon season at Rayagada. Increasing trend of ET_o was reported by many researchers. Increasing trend in RET was observed at Kao–Hsiung, South Taiwan (Yu *et al*., 2002), in Iran (Tabari *et al*., 2012) and Southern Russia (Golubev *et al*., 2001). Hess (1998) reported an increasing trend in ET_o in the northeast arid zone of Nigeria, due to the increases in wind speed. Myneni *et al.* (1997) and Milly and Dunne (2001) reported that the accelerated ET_o over North America is assumed to be due to a rise in temperature over the past century. Djaman and Ganyo (2015) also found a significant increase in RET across the southern Togo.

The increasing air temperature trend helped towards the increase in ET_o in the study area. Therefore, crop water requirement will be high which in turn requires more irrigation facilities during post monsoon. Fig. 7 shows the seasonal variation of rainfall and ET_o. The combination of rainfall and ET_o trend will be helpful to devise effective cropping pattern, and soil and water management strategy.

Possible Impact of Increased Rainfall, Temperature and ET_o on Crop

Rainfall showed an increasing trend in the study, both for annual rainfall and monsoon seasonal rainfall, which has impact on runoff and soil erosion. In the study area, as millets (finger millet, small millet) are the predominant crops cultivated on the uplands, which are drought hardy. Thus, this increase in rainfall may not have significant impact on growth and productivity. However, the intensity of rainfall may play a role in crop damage. Rising temperature and ET_o value may have slight impact on evapotranspiration rate of crops, which is very much supported by the slight increase in monsoon rainfall. However, it may have impact on post monsoon and summer crops where vegetables are grown from the available water resources. The raise in temperature and ET_o values may affect water resources and increased evapotranspiration values will demand more irrigation water. Thus, to overcome this effect, use of mulching and micro irrigation systems are advocated for efficient use of limited available water resources under this climate changed scenarios. Farmers are also advocated to cover the small water bodies with the locally available thatching materials and shade nets to prevent evaporation loss due to open sunlight. Skip or alternate row irrigation may be followed with changed crop/planting geometry into paired row system.

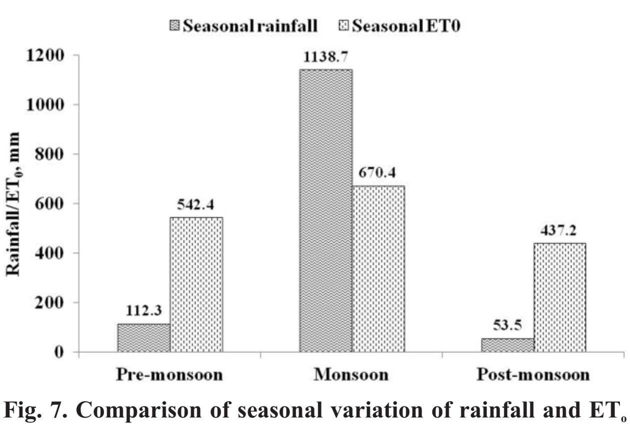

Fig. 7. Comparison of seasonal variation of rainfall and ET_o over the study area

Soil and Water Management Strategy for Better Crop Production

The increasing trend of rainfall indicated by the study alongwith temperature and ET_o will exert much stress on natural resources, especially soil and water resources, thereby likely reducing crop productivity. As the majority of the study area lies in Eastern Ghats, the topography is undulating with high slope. Uncontrolled runoff and soil loss may lead to land degradation and consequently reduce the farmer's income through low crop productivity. Therefore, soil and water conservation measures along with crop management activities are necessary to cope up with climate change scenario. Many time–tested technologies for soil and water conservation *viz.* staggered contour trenching in non–arable land, diversion drain at the foot hills, field and contour bunding, stone bunding within the field, brushwood check dam in first order streams, loose boulder check dams in second order streams, gabions check dams in third and fourth order streams, RCC check dams in fourth and higher order streams need to be adopted for proper management of soil and water resources (Madhu *et al*., 2016; Dash *et al.,* 2017; Madhu *et al*., 2018). In the lands where slope varies between 4% and 8%, bio–engineering measures like construction of earthen bund with broom grass along the contour line will be helpful to conserve soil and water resources. Construction of stone bund with broom grass along the contour line can not only conserve soil and water in this area, it can also increase the yield of finger millet significantly over normal sloppy lands (Sahoo *et al.,* 2018). In the areas with low land slope (2% slope), strip cropping of finger millet with groundnut can be advocated. It can increase the yield by 17% over no strip cropping system (Jakhar *et al.,* 2015). Within the study area where land slope is up to 10 %, intercropping of finger millet with hedge rows of *Gliricidia* and *Leucaena* can conserve water and soil by 30–50%, plant available nutrients by 53–62% and carbon by 44–47% over no hedge row inter cropping system (Adhikary *et al.,* 2017). As this technology can increase the upland paddy yield by 16–21%, this can be helpful to cope with climate change condition. Adoption of multi–tier agroforestry system with drumstick, pigeon pea and ginger also has the potential to conserve soil and water and to increase farmer's income (Jakhar *et al.,* 2017). In the non–arable lands where agricultural crops cannot be cultivated, growing of aromatic grasses like lemon grass and citronella grass will be the best alternatives. Lemon and citronella grass can reduce soil loss by 54% and 60%, respectively over finger millet. Grass cultivation is also capable of giving more economic return than cultivation of finger millet alone (Adhikary *et al.,* 2018). For plantation crops, different *in–situ* soil and moisture conservation measures like micro–catchment with circular basin, half–moon trenching, contour trench with straw mulching and construction of silpauline lined micro ponds will be beneficial to cope up with the adverse effects of climate change.

5. CONCLUSIONS

Agrarian state like Odisha is very much susceptible to climate variability and change. The undivided Koraput district also experiences the same. Variations in climatic parameters such as rainfall, temperature and subsequently ET_o are recurring phenomena in the studied area. As the people are mainly dependant on agriculture and allied activities, there is a tremendous effect on socio–economical conditions of people due to changing climatic parameters. The present study analyzed the rainfall, temperature and ET_o data for the undivided Koraput district of Odisha. The analysis of the time series was carried out using non-parametric M–K test. The detailed analysis of the data for 117 years indicates that mean annual rainfall of Koraput, Malkangiri, Nabarangapur and Rayagada are 1316.1 mm, 1180.1 mm, 1451.0 mm and 1270.8 mm, respectively. Annual rainfall is showing a quite good increasing trend for Koraput and Malkangiri districts, however there is no trend for Nabarangapur and Rayagada districts. Both maximum and minimum temperatures and ET_o have shown an increasing trend for all the four districts. Similarly, both annual and seasonal ET_o have shown an increasing trend. Therefore, it can be suggested that the concerned stakeholders should take into consideration the rainfall variability, temperature and ET_o variability of the area into their climate change adaptation strategy.

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