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Chapter - 100

Investigating Regional Trends for the KBK Region of Odisha, India

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Abstract : The study investigates trend for rainfall, temperature and potential evapotranspiration for the Kalahandi-Bolangir-Koraput (KBK) region in the state of Odisha using Mann-Kendall (MK) test and Sen's Slope estimator. The rainfall trend analysis indicates Malkangiri with significant increasing and Nuapada with significant decreasing trend at 95% significant level. The study also investigates monthly, annual and seasonal trend of meantemperature of KBK districts for the period 1901 to 2002 (102 years). Seasonal analysis has also been carried out for the annual mean temperature. MK test indicate a significant increasing temperature trend in the mean annual series. The districts like Kalahandi, Koraput, Malkangiri, Nabarangpur, and Nuapada, the increasing temperature trend is significant at alpha = 0.001 level of significance. The seasonal mean temperature is also showing an increasing trend in the region. The Southern and Western part of the KBK region (Nabarangpur, Malkangiri), in particular, are experiencing significant increasing temperature trend at alpha = 0.001 level of significance in comparison to the Northern and Eastern part (Bolangir and Sonepur). On investigation of the potential evapotranspiration of the eight districts and whole KBK region, it has been found that the trend is upward in nature i.e. increasing. This will increase the water demand in the region with higher crop water requirement in future.

Keywords:Trend,Mann-Kendall test, Sen's slope, KBK region.

1. INTRODUCTION

In the recent few decades, importance of climate change has immensely increased due to global warming and its projected effects on hydrologic cycle. Rainfall pattern is extremely varied both spatially and temporally. Temperature is also changing fast triggering a higher evapotranspiration. These changes in the rainfall, temperature and evapotranspiration have considerable impact on the water resources. According to IPCC's Fifth Assessment Report (AR5), precipitation trends, including extremes, are characterized by strong variability, with both increasing and decreasing trends observed in different parts and seasons of Asia. Over India, the increase in the number of monsoon break days and the decline in the number of monsoon depressions are consistent with the overall decrease in seasonal mean rainfall. But an increase in extreme rainfall events occurred at the expense of weaker rainfall events over the central Indian region and in many other areas. Almost all models and all scenarios project an increase in both the mean and extreme precipitation in the Indian summer monsoon. In a study of the Mahanadi River Basin in India, a water availability projection (A2, CGCM2) indicated increasing possibility of floods in September but increasing water scarcity in April (Asokan and Dutta, 2008). Constant occurrences of events like flood, drought, high intensity rainfall, hailstorm etc. are being reported throughout the world (Mirza, 2003; Kundzewicz et. al, 2005; Kyselý, 2008). These increasing extreme incidents have led to the rising concern of climate change. Changes in the spatial and temporal distribution of precipitation and temperature are a major component in many studies.In India, many studies have been undertaken to understand climate change. Basistha et al., 2009 reported 1964 as the most probable year when a shift is detected in the annual and monsoon rainfall over Himalaya. Ghosh et al., 2009 analyzed the Indian summer monsoon rainfall at different scales. Kumar and Jain (2010) analyzedrainfalltrend in Kashmir valley. The study indicated decreasing trend in monsoon rainfall, while increasing trend is found in annual, pre-monsoon, post-monsoon and winter rainfall. Kumar et al., 2010 carried out the regional trend analysis of long-term rainfall. The study showed no significant trend in the annual, seasonal and monthly rainfall in most of the months. For the whole of India no significant trend was detected for annual, seasonal, or monthly rainfall. Patra et al., 2012 analyzed rainfall trend over Orissa state for the period 1871-2006. The analysis revealed non-significant decreasing trend of annual and monsoon rainfall, whereas increasing trend in post-monsoon season over the state. However, rainfall during winter and summer seasons showed an increasing trend. Jain and Kumar (2012) reviewed trends of rainfall, rainy days, and temperature at basin level for India. The study indicated decreasing annual rainfall trends in sixteen basins, one basin with significant decreasing trend with 95% confidence level. The study also showed a rising trend in the mean maximum temperature series at most of the stations. The mean minimum temperature showed a rising as well as a falling trend. At most of the stations in the south, central and western parts of India a rising trend was found. Some stations located in the north and northeastern India showed a falling trend in annual mean temperature. Thus, wide variability in the precipitation and temperature trend has triggered the growing concern of climate change and its future impact on the environment. The present study involves trend analysis of rainfall, temperature and evapotranspirationfor the KBK region situated in the Western- Southern part of Odisha. The trend analysis has been done with Mann-Kendall (MK) test in 8 administrative districts*viz. Bolangir, Kalahandi, Koraput, Malkangiri, Nabarangpur, Nuapada, Rayagada and Sonepur*. Seasonal trend analysis has also been carried for the region.

2. MATERIAL AND METHODS

2.1Study Area

The Kalahandi-Koraput-Bolangir (KBK) is comprises of eight districts viz. Malkangiri, Nabarangpur, Rayagada, Nuapada, Sonepur, Kalahandi, Koraput and Bolangir covering 12,293 villages. This region is inhabited by 19.72% of State population (43 million) occupy over 30.59% of State geographical area (155820 Km^2). The climate in the area is sub-humid, dry with extreme summer and winter. The population in the region is a mixed group dominated by tribal. The area is endowed with mineral dominated natural resources and Non-Timber Forest Produce (NTFP) in the large encompasses of forest. The location of the KBK districts in the state of Odisha has been shown in Figure 1.

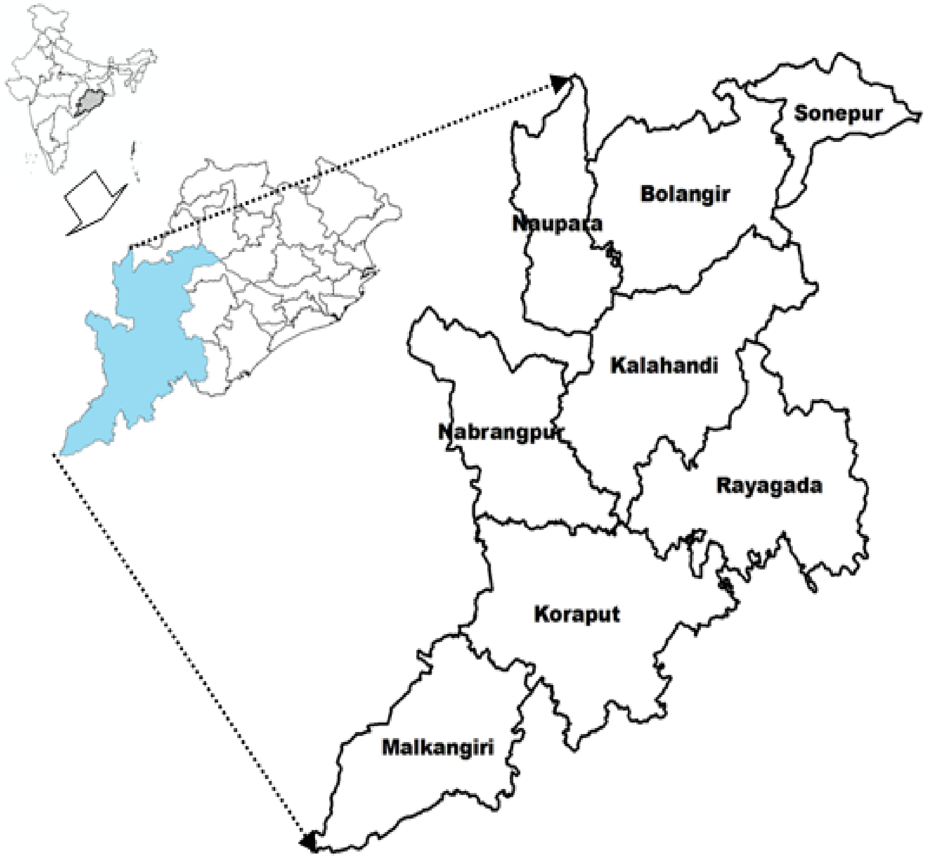

Figure 1. KBK districts in the state of Odisha

2.2 Data used

Monthly rainfall for 110 years (1901-2010), monthly temperature for 102 years (1901-2002) for mean, maximum and minimum, and monthly potential evapotranspiration for 102 years (1901-2002) have been considered for trend analysis in the study across eight KBK districts (source: www.indiawaterportal.org).The trend has been investigated on monthly (Jan-Dec), seasonal (pre-monsoon, monsoon, post-monsoon, winter) and annual basis.

2.3 Mann-Kendall Test and Theil-Sen's Estimator

To determine the presence of trend in the rainfall, temperature and potential evapotranspiration series, the non-parametric Mann-Kendall (MK) test has been employed (Mann, 1945; Kendall, 1975; Bayazit andOnoz, 2007)as shown in the Figure 2.

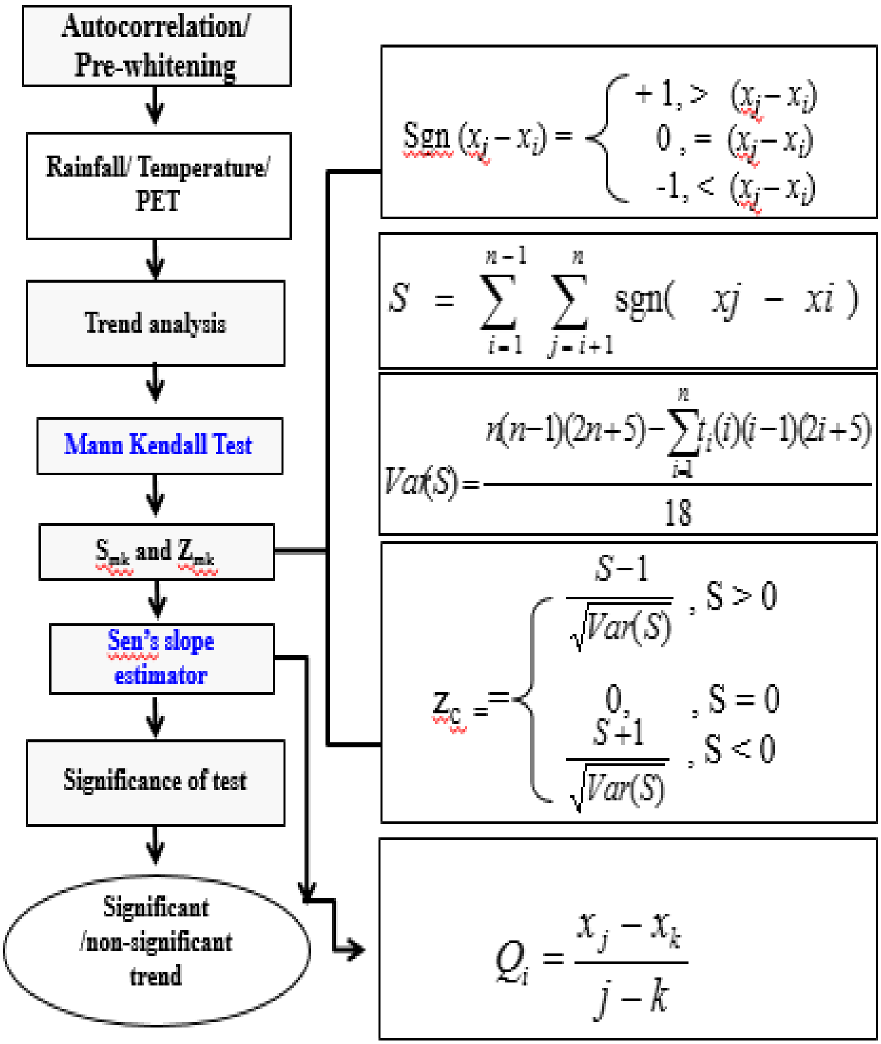

Figure 2. Steps for trend analysis usingMK test and Sen's Slope Estimator

Where,

Sign ( ) = sign or signum function; S = Variance; Z_c = MK statistic; Q_i = Sen's slope; t_i= number of tied pairs. Here x_j and x_i show the data values which are in sequence with n data, sgn (θ) is equivalent to 1, 0 and -1 in case θ is more than, equal to or less than 0 respectively. If Z_c found to be more than $Z_{\alpha/2}$ then the trend is believed to be significant where α is the level of significance(Yue and Hashino, 2003). The trend magnitude was calculated by Theil-Sen's estimator(Theil, 1950; Sen, 1968).

3. RESULTS AND ANALYSIS
3.1 Rainfall trend

Table 1 indicates the basic rainfall statistics with an annual average rainfall of 1196.57 mm with a standard deviation of 205.49mm for the period 1901 to 2010. The skewness in the annual average rainfall varied from 0.51 to 2.40, with an average positive skewness of 1.07 indicating a skewed asymmetric curve.The test results indicate two districts with significant trend (Malkangiri with increasing and Nuapada with decreasing) in the annual rainfall (Table 2 & 3). The magnitude of the decreasing trends in the annual rainfall varies from 0.204 mm/ year (Kalahandi) to 1.419 mm/ year (Nuapada). The analysis also indicates a non-significant increasing trends in the annual rainfall in the districts of Koraput (+0.935 mm/ year) and Rayagada (+0.382 mm/ year). The annual rainfall series for the districts of Bolangir, Nabarangpur and Sonepur indicates non-significant decreasing trend. Seasonal analysis of trend showed non-significant increasing as well as decreasing trend in pre-monsoon, monsoon and post monsoon rainfall in the study area. Koraput, Nabarangpur and Rayagada districts showed non-significant increasing trends and Bolangir, Kalahandi, Malkangiri, Nuapada and Sonepur districts showed non-significant decreasing trends in the summer rainfall (pre-monsoon). However, in case of seasonal monsoon rainfall, five districts (Bolangir, Kalahandi, Nuapada, Rayagada and Sonepur) showed non-significant decreasing trend and the remaining (Koraput, Malkangiri and Nabarangpur) showed increasing trends. Winter rainfall in the entire region showed decreasing rainfall trend which will considerably affect the rabi crops grown.

Table 1. Basic statistics of seasonal and annual mean rainfall series for KBK region

Rainfall series (mm)	Mean	Max	Min	Standard deviation	Coefficient of variation	Skewness	Kurtosis
Annual	1296.57	2123.48	928.28	205.49	0.16	0.88	1.80
Pre-monsoon	97.47	310.68	19.81	47.91	0.49	1.37	3.50
Monsoon	1063.36	1872.91	643.94	187.67	0.18	0.99	2.79
Post-monsoon	114.00	283.76	7.08	57.62	0.51	0.47	0.16
Winter	21.73	76.68	0.00	17.18	0.79	0.80	-0.04

Table 2. Mann-Kendall test statistics (Z value)

Districts	Rainfall				
	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
Bolangir	-1.643	-0.305	-1.069	0.041	-0.625
Kalahandi	-0.279	-0.579	-0.015	-0.036	-1.348
Koraput	0.935	0.243	0.625	1.183	**-2.203**
Malkangiri	**2.041**	-0.641	1.715	1.860	-1.379
Nabarangpur	-0.398	0.858	0.031	0.439	-1.173
Nuapada	**-2.221**	-0.682	-1.555	-0.036	-0.863

Rayagada	0.382	1.137	-0.062	0.403	-1.193
Sonepur	-1.028	-0.517	-1.038	-0.212	-1.111
KBK region	0.062	-0.155	-0.098	0.465	-1.250

Table 3. Sen's slope (β-value)

Districts	Rainfall				
	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
Bolangir	-0.852	-0.034	-0.661	0.003	-0.039
Kalahandi	-0.204	-0.099	-0.013	-0.007	-0.062
Koraput	0.673	0.038	0.428	0.278	-0.098
Malkangiri	1.312	-0.081	0.851	0.526	-0.046
Nabarangpur	-0.310	0.142	0.055	0.084	-0.048
Nuapada	-1.419	-0.077	-0.960	-0.006	-0.034
Rayagada	0.259	0.225	-0.027	0.098	-0.051
Sonepur	-0.599	-0.080	-0.538	-0.020	-0.069
KBK region	0.055	-0.026	-0.053	0.098	-0.057

3.2Temperature trend

The mean annual temperature in the regions stands at 25.43°C. Winter temperature reaches less than 20°C (Table 4). MK test indicates a significant increasing temperature trend in the mean annual series. The districts like Kalahandi, Koraput, Malkangiri, Nabarangpur, and Nuapada, the increasing temperature trend is significant at alpha = 0.001 level of significance. The seasonal mean temperature is also showing an increasing trend in the region (Table 5 & 6). The northern part of the KBK region covering districts of Sonepur and Bolangir, showing increasing trend at alpha = 0.01 level of significance.

Table 4. Basic statistics of annual mean temperature series for KBK region

Annual mean temperature series (°C)	Mean	Max	Min	Standard deviation	Coefficient of variation	Skewness	Kurtosis
Annual	25.43	26.25	24.41	0.37	0.01	-0.12	-0.31
Pre-monsoon	29.13	30.65	27.48	0.65	0.02	-0.20	-0.10
Monsoon	26.93	27.96	26.05	0.43	0.02	0.19	-0.66
Post-monsoon	23.67	25.25	22.13	0.70	0.03	0.19	-0.44
Winter	20.92	22.27	19.66	0.57	0.03	0.09	-0.58

Table 5. Mann-Kendall test statistics (Z value)

Districts	Mean temperature				
	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
Bolangir	3.267 **	1.741 +	1.660 +	2.967 **	3.932 ***
Kalahandi	3.568 ***	3.013 **	2.660 **	3.117 **	3.632 ***
Koraput	3.689 ***	4.325 ***	4.083 ***	3.290 **	3.285 **
Malkangiri	3.660 ***	4.291 ***	3.834 ***	3.233 **	3.111 **
Nabarangpur	3.921 ***	3.793 ***	3.261 **	3.071 **	3.423 ***
Nuapada	3.643 ***	2.527 *	1.978 *	3.071 **	4.054 ***
Rayagada	3.718 ***	3.655 ***	3.632 ***	3.111 **	3.533 ***
Sonepur	2.741 **	0.544	1.047	2.729 **	3.718 ***
KBK region	3.689 ***	3.406 ***	2.995 **	3.209 **	3.643 ***

Level of significance
*** if trend at α = 0.001 level of significance; ** if trend at α = 0.01 level of significance; * if trend at α = 0.05 level of significance; + if trend at α = 0.1 level of significance.

Table 6. Sen's slope (β-value)

Districts	Mean temperature				
	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
Bolangir	0.004	0.004	0.003	0.008	0.008
Kalahandi	0.004	0.007	0.005	0.008	0.008
Koraput	0.004	0.010	0.007	0.008	0.007
Malkangiri	0.004	0.010	0.006	0.007	0.006
Nabarangpur	0.005	0.009	0.006	0.008	0.008
Nuapada	0.004	0.006	0.004	0.008	0.008
Rayagada	0.004	0.008	0.005	0.007	0.007
Sonepur	0.003	0.001	0.002	0.008	0.007
KBK region	0.004	0.008	0.005	0.008	0.007

3.3Potential evapotranspiration trend

Recurring drought and water stress is a common scenario in the KBK region. Potential evapotranspiration is affected by many factors including the temperature of a region. A higher temperature coupled with dry atmosphere results in higher evaporation and transpiration loss by the plants. To sustain plant/ crop growth it is essential to meet the plant/ crop water requirement timely. With this in mind, the study investigated the trend in the potential evapotranspiration in the KBK districts as well as entire KBK region using 102 years data from 1901 to 2002. The basic statistics of the annual maximum temperature series is presented in Table 7. Z statistics (MK test) and Sen's slope is presented in Table 8 and Table 9 respectively. The trend test indicates an increasing trend in the potential evapotranspiration series. This will result in higher crop water requirement in the region.

Table 7. Basic statistics of potential evapotranspiration series for KBK region

Potential ET series (mm)	Mean	Max	Min	Standard deviation	Coefficient of variation	Skewness	Kurtosis
Annual	6.15	6.31	6.00	0.05	0.01	0.13	1.01
Pre-monsoon	7.65	7.83	7.41	0.07	0.01	-0.20	1.73
Monsoon	5.54	5.82	5.24	0.09	0.02	-0.19	2.11
Post-monsoon	5.67	5.95	5.45	0.09	0.02	0.13	0.86
Winter	5.78	5.97	5.55	0.07	0.01	-0.01	1.47

Table 8. Mann-Kendall test statistics (Z value)

Districts	**Potential evapotranspiration**				
	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
Bolangir	1.157	1.295	0.353	0.257	1.460
Kalahandi	1.775 +	2.385 *	1.122	0.445	2.148 *
Koraput	3.088 **	3.238 **	2.406 *	1.700 +	1.775 +
Malkangiri	3.944 ***	3.420 ***	2.995 **	1.865 +	2.088 *
Nabarangpur	2.764 **	2.912 **	1.576	1.671 +	1.770 +
Nuapada	1.596	1.532	0.541	0.558	1.868 +
Rayagada	1.891 +	2.556 *	1.434	0.801	1.492

Sonepur	0.758	0.824	0.197	-0.136	1.018
KBK region	1.937 +	2.325 *	1.209	0.648	1.399

Level of significance
*** if trend at α = 0.001 level of significance; ** if trend at α = 0.01 level of significance; * if trend at α = 0.05 level of significance; + if trend at α = 0.1 level of significance

Table 9. Sen's slope (β-value)

Districts	**Potential evapotranspiration**				
	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
Bolangir	0.0002	0.0003	0.0001	0.0001	0.0003
Kalahandi	0.0004	0.0005	0.0003	0.0001	0.0005
Koraput	0.0005	0.0006	0.0005	0.0004	0.0003
Malkangiri	0.0005	0.0006	0.0005	0.0003	0.0003
Nabarangpur	0.0004	0.0006	0.0004	0.0005	0.0004
Nuapada	0.0003	0.0004	0.0001	0.0002	0.0004
Rayagada	0.0004	0.0006	0.0004	0.0002	0.0004
Sonepur	0.0002	0.0002	0.0001	0.0000	0.0003
KBK region	0.0003	0.0005	0.0003	0.0001	0.0003

Figure 3 presents the interpolated Z value distributed across the KBK region by Kriging method. On close investigation of the rainfall trend with respect to different districts, it has been found that districts with significant forest coverage (Koraput, Malkangiri) are receiving more rainfall in comparison to other districts such as Kalahandi, Nuapada, Sonepur with less forest coverage. Although several other factors govern the rainfall phenomenon in a region, this aspects requires further investigation. The annual mean temperature is significantly increasing in the western part of the region (Nabarangpur), whereas the potential evapotranspiration is witnessing an increasing trend in the southern parts (Malkangiri, Koraput) followed by non-significant increase in the trend in the northern parts (Sonepur, Bolangir).

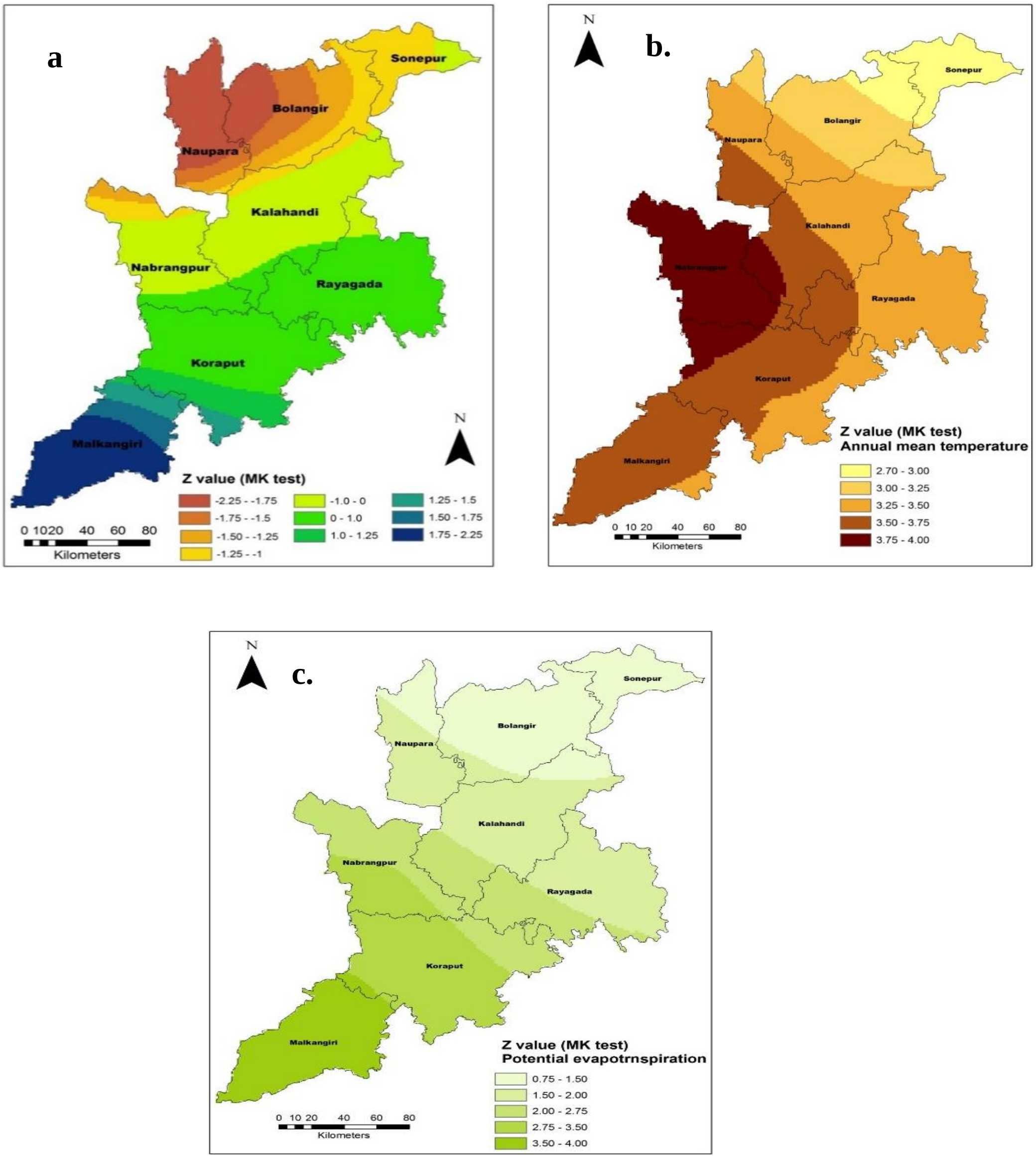

Figure 3. Spatial trend of annual (a) rainfall, (b) mean temperature and (c) potential evapotranspiration for the KBK region

4. CONCLUSIONS

Overall, the study concludes based on the trend analysis that the region is witnessing significant decreasing trends in annual rainfall in the northern parts covering the districts of Kalahandi, Nuapada and Sonepur which are already facing water scarcity. Southern districts like Koraput and Malkangiri with considerable forest coverage in comparison to other districts in the KBK region are showing increasing rainfall trend. The study also concludes a significant increasing trend in the mean temperature, and potential evapotranspiration in future. This will result in higher crop water requirement by the crops to meet the high evaporation and transpiration losses. How far these trends sustain in long-run requires further investigations using data simulated from different global climate models before finalizing water resources availability, distribution and utilization to meet current and future need.

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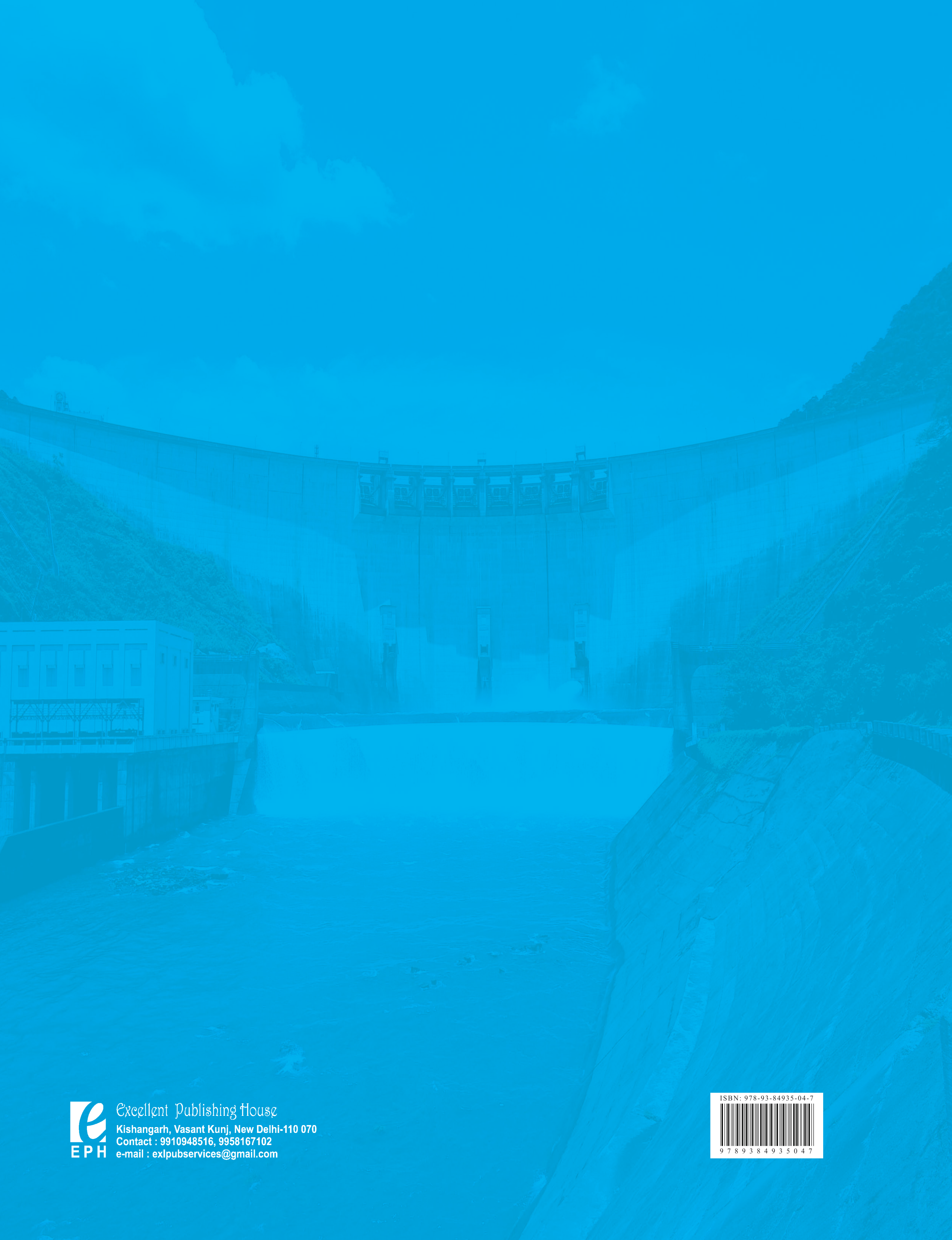

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