Climate Change Pattern in Kendujhar District of Odisha – A Trend Analysis

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Abstract. The frequencies of natural calamities such as drought, flood, and cyclones are projected for the next years. These are expected to have adverse effects on the livelihood of the most vulnerable group of the population in the Kendujhar district of Odisha (marginal and small farmers, and forest dwellers). To delineate the trend of the most important weather factors (Rainfall, Temperature, Relative humidity), the study used non-parametric tests like the Mann-Kendall test and Sen's Slop estimator, which was used to accomplish the objectives of this study. The Agricultural Statistics Department and the Special Relief Commissioner of Odisha are reliable sources of climatic data. The method of data analysis is outlined with the description of the quantitative outcomes using the MAKESENS version 1.0 developed by the Finnish Meteorological Institute in Finland. The study reveals that the average rainfall maximum temperature and relative humidity have changed last three decades significantly. The rainfall declined inconsistently in June (Z=-1.86, Sen's slope= -2.96), while the maximum temperature had a significant increase of 0.05 ° C. The study concludes that there is a need for more research on the link between the agricultural farmer's behaviour of cropping time and pattern with the trend of three indicators which has been studied.

Keywords: Agriculture, Climate change, Relative humidity, Rainfall, Temperature.

1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) refers to climate change as "the state of the climate along with the change in the mean and/or the variability of its properties, which can be identified using statistical tests, for an extended period, typically decades or longer" (IPCC, 2018). Climate change is currently one of the most pressing issues to address; it is observed as a cause of extreme weather events or natural disasters, with more than 200 million people expected to be displaced globally by

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Frequent emergence of heat waves across land areas	Reduced agricultural yields, heightened wildfire danger, increased water demand, elevated risk of heat-related mortality, and a decline in quality of life for individuals residing in warm areas without suitable housing, particularly impacting poor and disadvantaged people.
Regular heavy rainfall	Crop damage, soil erosion, waterlogged soils hindering cultivation, surface and groundwater quality degradation, increased mortality risks, and strains on urban and rural infrastructure with property loss
The escalating frequency of drought effects	Land degradation and an increased risk of wildfires. It can also result in more widespread water stress, posing challenges to water availability. Furthermore, drought increases the risk of food and water shortages, impacting both agricultural production and human consumption. Additionally, drought can reduce hydropower generation potentials and potentially trigger population migration.
Tropical storms	Devastating crop damage, widespread power outages, disruptions to public water supply systems, an escalated risk of fatalities, the potential for population migrations, and the tragic loss of property.

Source: IPCC 2007

The fluctuating climate patterns exert a crucial influence on altering crop production outcomes by disrupting essential biochemical and metabolic processes. In specific regions, the detrimental impact of exceptionally high temperatures on crop growth and yield is particularly striking. As a consequence, the reduction in the duration of the growing season becomes a significant contributing factor to substantial declines in agricultural productivity (D. Singh et al., 2014). Moreover, when extreme temperatures, both cold and hot, coincide with vulnerable stages of crop development, such as the reproductive phase, the resulting yield losses are further exacerbated (Ahmad et al., 2021).

Even though technology had progressed to the point where it could predict the weather ahead of time, the farmer still relied heavily on private observation and the opinions of neighbours and relatives to forecast the weather. Often, when conditions are unfavourable, human or animal disease, as well as crops, are considered one of the alerts to take preventive steps, reduce the use of groundwater, change the past of agriculture, and diversify the income sources of marginal and small farmers which are among the most effective preventive steps against climate change (C. K. Panda & Singh, 2016).

India is positioned on the Asian continent, entirely within the Northern and Eastern hemispheres, bounded by latitudes 84′ N and 37°6'N, and longitudes 68°7′ E and 97°25′ E. It spans latitudes ranging from 84′ N to 37°6'N and longitudes extending from 68°7′ E to 97°25′ E. A significant geographical demarcation is constituted by the elusive Tropic of Cancer at 23°30′ N, which partitions the nation into near-equal halves. Indian farmers bear a substantial burden of exposure to climate-related risks. Startlingly, as per the ‘Germanwatch Climate Risk Index-2018’, 2016 witnessed India endure the highest toll on human lives, with a staggering count of 2,119 souls lost, alongside property damages exceeding twenty-one billion dollars (Eckstein et al., 2017).

By using rainfall, temperature, and Indian crop production data, it was discovered that high-temperature shocks reduce yield by 4-4.7 per cent in Kharif and Rabi seasons, respectively, whereas high rainfall shocks reduce yield by 6.7-12.8 per cent in Kharif and Rabi seasons. The impact on farm income is evident, as evidenced by the findings that higher temperatures would result in a significant 4.3 per cent decrease in Kharif farm income and a 4.1 per cent decrease in Rabi farm income. Similarly, the occurrences of high rainfall shocks would lead to a substantial reduction in farm income, with estimates indicating a decrease of 13.7 per cent during the Kharif season and 5.5 per cent during the Rabi season (Dev, 2018).

Anticipated climate change and extreme weather events are poised to result in a decline in rainfed paddy production over the next decade unless appropriate measures and technological advancements are implemented to mitigate these challenges. Marginal and small farmers, comprising more than 80 per cent of the total farming population, often struggle to sustain their livelihoods solely from their farms. Instead, they contribute surplus labour to larger farmers and the tertiary and secondary sectors. States with a higher proportion of marginal and small farmers, as well as a larger share of rainfed areas, demonstrate positive correlations with higher levels of rural poverty and State Hunger Index scores (S. Singh et al., 2012).

In recent decades, India's farm size shrunk and the share of marginal farms has risen significantly. Between the 1960s and 2002, the proportion of marginal holdings increased from about 30% to 70%, while medium and large holdings decreased and smallholdings increased from 12% to 20%. At the national level in India. In many states, such as Odisha, the process of marginalization of holdings was underway and increased by 75% (A. K. Singh, 2013).

As per the geographical area Kendujhar district is a major district of Odisha, In Kendujhar district there are mainly two cropping seasons Kharif and Rabi. The total cultivated area of the district is 297873, (High land-158653, Medium Land- 99382, Low land- 39388. Major crops in the districts are Paddy, Black Gram, Green Gram, Horse Gram, Ragi, Maize, and oilseeds like niger, sunflower, groundnut, and mustard. In the Keonjhar district total crop area is 370598 ha, of which rainfed covers 249795 and irrigated covers 120803 ha (Parida et al., 2024).

This research paper presents a comprehensive analysis of climate change parameters in Kendujhar district, focusing on rainfall, temperature, and relative humidity. The study employs appropriate statistical tests, including the widely utilized Mann-Kendall trend test, to examine the monthly, seasonal, and annual data. One notable advantage of the Mann-Kendall test is its resilience to abrupt breaks in time series data, making it suitable for assessing trends in potentially inhomogeneous datasets. Additionally, this test does not impose any specific distribution requirements on the input data, enhancing its applicability. Moreover, the research incorporates the implementation of Sen's slope estimator formula, a linear modelling approach that provides trend estimations for all the climate change parameters under investigation (Drápela et al., 2011). This technique further enhances the understanding of long-term trends and patterns. In terms of adaptation strategies, the study emphasizes the significance of advanced crop management interventions. These interventions are crucial in enhancing adaptation to climate change, specifically in the domains of water resource management and plantation requirements. By integrating advanced crop management practices, such as improved irrigation techniques and crop selection, effective planning and management can be achieved in the face of changing climatic conditions (A. Panda & Murudaiah, 2017).

2 Material and Methods

2.1 Study area and data source

The Kendujhar district is situated in the state of Odisha, India, with geographic coordinates ranging from approximately 21°01'N to 22°10'N latitude and 85°11'E to 86°22'E longitude. It shares borders with various neighbouring districts. To the north, it is bounded by Singhbhum District of Jharkhand. To the south, it is bordered by Jajpur District. In the east, it is surrounded by Mayurbhanj and Bhadrak districts, while to the west, it shares borders with Dhenkanal and Sundergarh districts (Parida et al., 2024).

The data about Kendujhar district, covering a period of 32 years from 1989 to 2020, was gathered from diverse sources. Due to the unavailability of a single comprehensive source, the records were collected from multiple distinct sources, as shown below, to ensure the completeness and accuracy of the data (Table 2).

Table 2. Type of climatic indicator, source, and period

Climatic indicator	Data source	Period
Rainfall	Special Relief Commissioner	1989-2020
Maximum temperature	Agricultural Statistics	1989-2020
Relative humidity	Agricultural Statistics	1995-2017

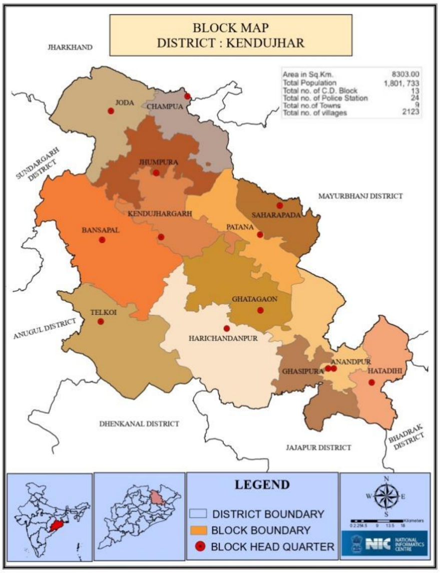

Figure 1. Map of the study area

2.2 Statistical tools

The trend analysis of climatic changes in Kendujhar district employed a diverse range of statistical tests and the widely utilized Mann-Kendall Statistical test. Among these tests, the Mann-Kendall test emerged as a frequently employed non-parametric test for detecting trends in hydrological and climatic time series data, particularly for predicting abrupt changes (Safari, 2012). To assess the magnitude of the identified trends, the analysis incorporated the utilization of the 'Sen's-slope estimator'. This estimator complements the Mann-Kendall test by providing an estimation of the trend's magnitude, contributing to a comprehensive understanding of the observed climatic changes (Zhou et al., 2023). Throughout the analysis, significant trends in various climatic indicators were identified as follows:

Equations

In the Mann-Kendall analysis, the initial step involves organizing the data in a sequential order, typically based on the temporal aspect. Subsequently, the significance (Sgn) of the difference between consecutive data points is computed to determine the trend direction. The Sgn values can assume three possibilities: 1, 0, or -1, depending on the statistical significance of the difference between Xj and Xi, where j > i. The Sgn formula is as follows:

If Xj-Xi>0 .... Sgn(Xj-Xi)= 1
If Xj –Xi=0........ Sgn(Xj-Xi)= 0
If Xj-Xi<0.......... Sgn(Xj-Xi)= 1

Here, Xj represents the value of the climatic parameter (e.g., rainfall, maximum temperature, relative humidity) at time J, while Xi denotes the value at time i. A positive Sgn value indicates an increasing (upward) trend, while a negative value signifies a decreasing (downward) trend. Consequently, X1, X2, X3, X4, ….., Xn denote the monthly data points, with Xj corresponding to the data point at time J.

The Mann-Kendall statistic (S) is calculated as the total number of positive contrasts minus the total number of negative contrasts, quantifying the net direction of the trend. The formula for S is expressed as follows:

$$S = \sum_{(n-1)}^{(k=1)} \sum_{j=k+n}^{n} s(igns - Xi)$$

The Mann-Kendall statistic, denoted as 'S,' indicates the direction of the trend, whether positive or negative, based on its magnitude. Determining the significance of the trend requires calculating the probability associated with 'S' and the sample size 'n.' In cases where the sample size is greater than 10, normal approximations can be utilized.
To compute the variance of the Mann-Kendall statistic, denoted as 'Var S,' the following formula is used:

$$\text{Var S} = \frac{[n(n-1)(2n+5) - \sum_{g=1}^{m} tg(tg-1)(2tg+5)]}{18}$$

g = 1, 2,…, q

Here, 'Var S' represents the variance of the Mann-Kendall statistic. 'M' refers to the number of tied groups, where multiple data points share the same value. 'n' represents the total number of available data points. 'tg' represents the sum of data points within the "gth" tied group. The summation symbol Σ is used to sum up the values for each tied group from g equals 1 to q.
The standardized test statistic, 'Z,' is then calculated based on the value of 'S' and 'Var S.' The formula for 'Z' is as follows

$$S > 0 \ldots\ldots Z = \frac{n-1}{\sqrt{\mathrm{var}(S)}}$$

$$S = 0 \ldots\ldots Z = 0$$

$$S < 0 \ldots\ldots Z = \frac{n+1}{\sqrt{\mathrm{var}(S)}}$$

Various critical values of 'Z' (1.645, 1.960, 2.576) are commonly employed to determine the significance levels of 10%, 5%, and 1%, respectively. 'Z' follows a standard normal distribution and is utilized to assess the significance level of upward or downward trends in mean temperature, precipitation, and relative humidity values. In the context of trend analysis, it is recommended to employ these thresholds to ascertain the significance of the observed trends. Generally, if the computed 'Z' value exceeds Za/2, where 'a' denotes the significance level, it indicates the presence of a significant trend in either an upward or downward direction. This assessment is based on a two-tailed test.

To quantify the magnitude of the trend in time series data, Sen's slope test is commonly employed. Each pair of data points (xj and xk, where j > k) is used to calculate the slope (Qi) using the formula (Agbo et al., 2023; Sen, 1968):

$$Qi \frac{xj-xk}{j-k} \quad \text{for } i=1,2,3\ldots\ldots N$$

The estimator of the slope, Qi, is obtained by averaging these N slope values. The formula for calculating Qi differs depending on whether the sample size, denoted as N, is odd or even:

$$Qi = \begin{cases} Q_{[(N+1)/2]} & \text{if N is odd} \\ 0 & \\ \dfrac{Q_{[N/2]} + Q_{[(N/2)/2]}}{2} & \text{if N is even} \end{cases}$$

A positive value of Qi indicates an upward trend, while a negative value signifies a downward trend. The calculation of Qi is performed at a confidence interval of 100(1-α) per cent, utilizing a two-sided test.

3 Results and Discussion

3.1 Trend analysis of climatic data

A) Rainfall

According to Special Relief Commissioner 2021, the average annual rainfall in Kendujhar district about 1397.06 mm with a standard deviation is 272.69 mm during the period 1989-2020. The slope of the trend of average rainfall last three decades has increased since it is y = 4.1118x + 1324.5. Figures 2 and 3 of the annual and monsoon season trend show positive behaviour with an inconsistent trend (R^2= 0.0196, R^2 = 0.0031 respectively), while Figure 4 of June shows a negative trend which is also inconsistent (R^2 = 0.0513). This result reflects the effect of the inconsistent rainfall trend on the farmer's decision where it will link directly to the production of the crop, since the cropping time and pattern are related also to the farmer's decision of all agricultural processes. The Mann-Kendall test also reveals that June has a significant decrease with Sens's slope value -2.96 mm during the study period (Table 3).

Table 3. Results of the Mann-Kendall test (Z) and Sen's slope estimator (Q) for rainfall during the study period

Months	Avg. Rainfall			
	Var(S)	Z	Significant	Sen's-slope
Jan	3469.00	0.65	No	0.00
Feb	3710.67	1.23	No	0.20
Mar	3786.00	1.64	No	0.35
Apr	3802.67	0.96	No	0.67
May	3802.67	0.66	No	0.85
Jun	3802.67	-1.86	+	-2.96
Jul	3802.67	0.70	No	1.05
Aug	3801.67	-0.03	No	-0.03
Sep	3802.67	0.47	No	0.67
Oct	3801.67	0.39	No	0.43
Nov	3784.00	-0.89	No	-0.09
Dec	2851.67	1.61	No	0.00
Yearly	3802.67	0.86	No	3.982
Before-Monsoon Period	3802.67	1.05	No	1.337
Monsoon	3802.67	0.18	No	0.744
After-Monsoon Period	3802.67	0.34	No	0.576
Summer	3802.67	1.64	No	1.402

Note: The symbols (+), (*), (**), and (***) represent the significance levels of 0.1, 0.05, 0.01, and 0.001, respectively.
Source: Author calculation

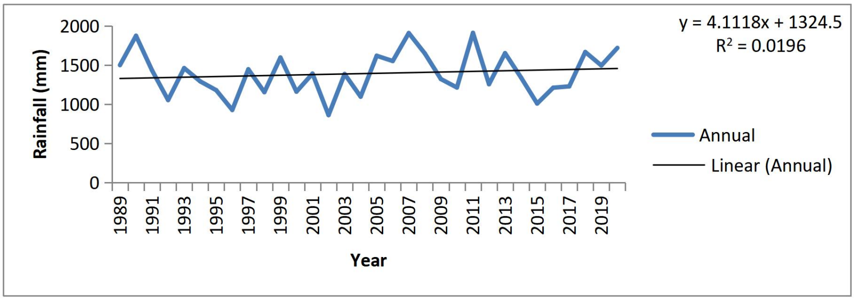

Figure 2. Trend of average annual rainfall in the study area

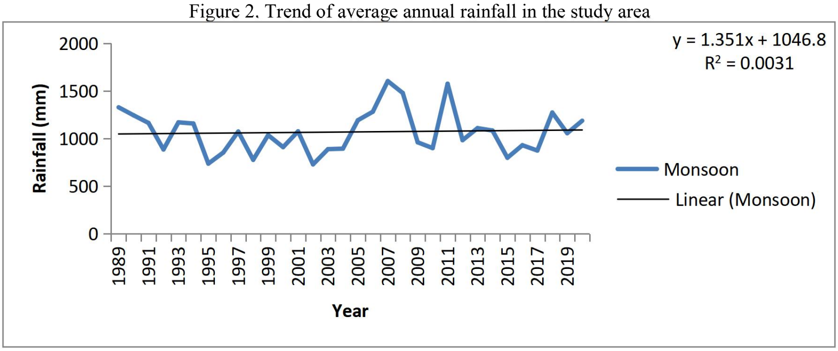

Figure 3. Monsoon season average rainfall trend in the area of study

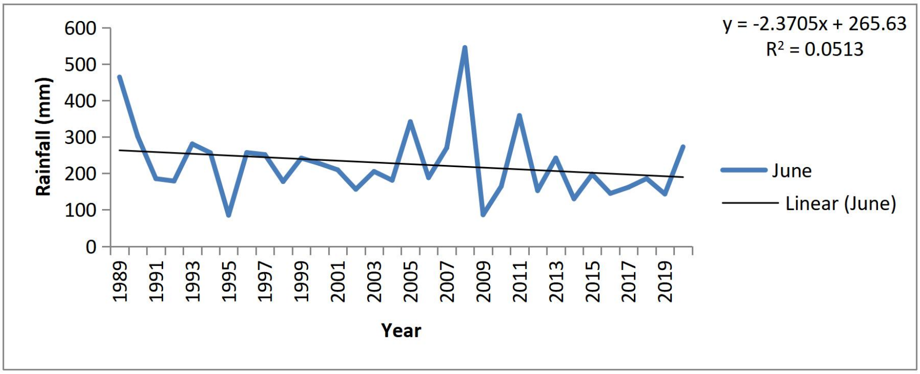

Figure 4. June's average rainfall trend in the study region

B) Maximum temperature

The overall mean annual max-temperature from 1989-2019 is presented in Figure 5, where it is increased with $y = 0.0465x + 30.049$ and $R^2 = 0.3739$. Table 5 shows the significant increase in maximum temperature (January, February, July, and December at 0.1 level of significance while August, October, and November, at 0.05 level of significance. The maximum temperature in September is increased significantly (Z value =3.38, Sen's slope ,(0.05 which is the harvesting time of the paddy crop.

In the monsoon season, farmers usually produce paddy crops because they are dependent on rainfall, where most of the amount of rainfall falls during this period since the maximum temperature significantly increases so most open wells will drought (Z value=3.69) (Table 4). Due to this result, the farmers may face a drought in the next few years, It will impact their livelihood, where the marginal and small farmers get the main income from their paddy fields. The forest dweller's livelihood will be affected due to the decrease in forest products.

Table 4. Results of the Z-test (Mann-Kendall) and Sen's-slope (Q) applied to the mean max-temperature data throughout the study period

Months	Mean Max-Temperature			
	Var(S)	Z	Significant	Sen's-slope
Jan	3752.00	1.98	*	0.06
Feb	3767.67	2.18	*	0.06
Mar	3775.67	1.14	No	0.03
Apr	3675.67	0.46	No	0.00
May	3757.33	1.55	No	0.03
Jun	3766.67	1.52	No	0.04
Jul	3579.33	2.29	*	0.01
Aug	3737.00	2.58	**	0.03
Sep	3580.33	3.38	***	0.05
Oct	3450.00	2.60	**	0.05
Nov	3442.33	3.02	**	0.06
Dec	3749.00	1.99	*	0.04
Yearly	3461.67	3.15	**	0.050
Before-Monsoon Period	3773.33	1.35	No	0.033
Monsoon	3747.67	3.69	***	0.038
After-Monsoon Period	3461.67	2.94	**	0.052
Summer	3796.00	2.32	*	0.063

Note: The symbols (+), (*), (**), and (***) correspond to the significance levels of 0.1, 0.05, 0.01, and 0.001, respectively, indicating the statistical significance associated with the test results.

Source: Author calculation

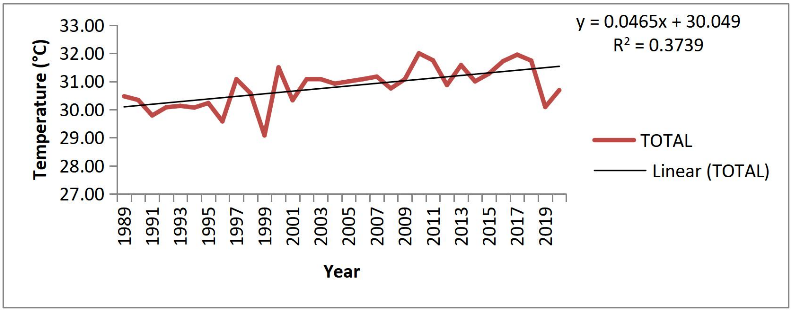

Figure 5. The trend of mean yearly max-temperature from 1989-2019

C) Relative humidity (RH)

The volume of evaporation in the air is captured by Relative Humidity (RH), which represents the percentage of moisture that can be held by the air at a given temperature. (RH) has a direct influence on plant water relations and indirect effects on leaf growth, photosynthesis, pollination, disease occurrence, and overall economic production. Figure 6 shows the increasing average relative humidity from 1995-2017 with slope= 0.16, and Table 5 reveals the relative humidity increase significantly in January, July, and September at 0.1 significance level, while it is increasing in March and May significantly at 0.05 significant level.

Table 5. Results of the Z-test (Mann-Kendall) and Sen's-slope (Q) applied to the mean humidity levels data over the study period

Months	Mean Relative-Humidity			
	Var(S)	Z	Significant	Sen’s-slope
Jan	1418.67	-1.94	+	-0.33
Feb	1416.33	-1.06	No	-0.18
Mar	1428.00	1.98	*	0.62
Apr	1427.00	0.95	No	0.30
May	1427.00	2.01	*	0.50
Jun	1422.33	0.85	No	0.15
Jul	1397.67	1.82	+	0.22
Aug	1394.67	0.83	No	0.07
Sep	1394.67	1.69	+	0.15
Oct	1414.00	-0.51	No	-0.07
Nov	1422.33	-0.48	No	-0.14
Dec	1425.00	0.00	No	0.00
Yearly	1399.00	1.98	*	0.167
Before-Monsoon Period	1422.33	1.38	No	0.333
Monsoon	1403.33	2.16	*	0.167
After-Monsoon Period	1411.00	-0.43	No	0.000
Summer	1423.00	0.27	No	0.048

Note: The symbols (+), (*), (**), and (***) denote the significance levels of 0.1, 0.05, 0.01, and 0.001, respectively, indicating the statistical significance associated with the Mann-Kendall test and Sen's slope estimator for relative.

Source: Author calculation

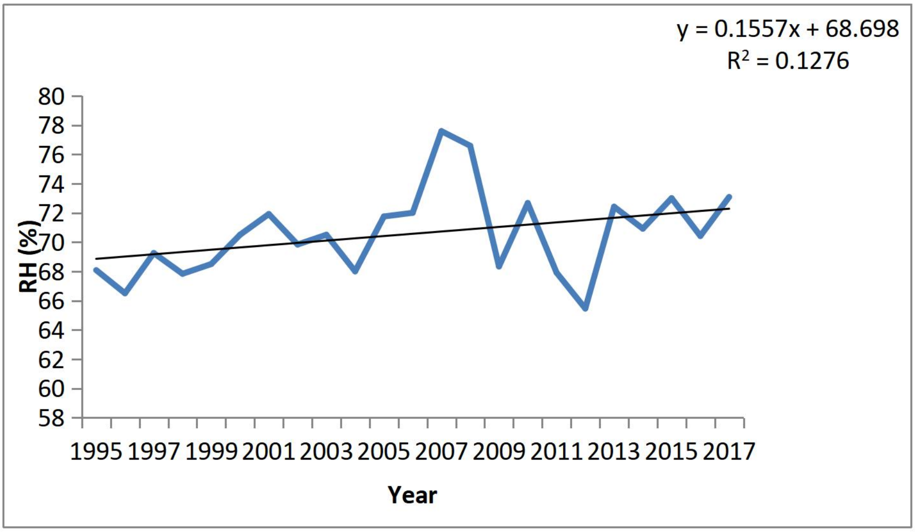

Figure 6. Temporal trend of average relative humidity throughout the study period.

3.2 Natural calamities in Keonjhar district

The negative impacts of climate change, including cyclones, have been felt in Keonjhar district. The district experiences two cyclone seasons: the pre-monsoon season (May-June), locally known as Kalaboisakahi or Thunderstorm, and the post-monsoon season (October-November). The "Super Cyclone" in 1999 had a devastating impact on Keonjhar, particularly affecting the Ghasipura, Anandapur, and Hatadihi blocks. Numerous houses and institutions, totalling 1243 and 27 respectively, suffered severe damage. Agriculture also faced significant losses as a result of the cyclone. Drought is a recurring phenomenon in Keonjhar district, with approximately 77 per cent of the population depending on rainfall for agricultural activities. In 2004, the district experienced a drought that affected more than 30 per cent of all 13 blocks, significantly impacting agricultural productivity due to inadequate rainfall. There were floods in 1995, 1997, 1999, 2001, 2003, 2006, 2007, 2008, 2009, 2011. Keonjhar was devastated by a massive flood in 2011, due to significant rain in Baitarani's catchment area. In 2011, a flash flood in Champua block was caused by a rapid rise in floodwater on the Baitarani River. Table 6 shows the disasters that happened due to natural calamities from 2007- 2017. There were 7 floods, 75000 people were affected and 149 livestock were lost, 6345 houses were damaged. A total of 15,784 Ha of crop area were damaged also. There were 2 droughts, where 1692 people were affected and 3,001,471 ha crop areas were devastated.

Tables 6. Disasters due to natural calamities

Calamity	**Incident Count during the Period of (2007-2017)**	**Mortality Count**	**Population Impacted**	**Livestock Casualties**	**Number of Houses Affected**	**Loss and damage of Cultivated Land (in Hectares)**
Flooding	7	7	75000	149	6345	15784
Drought	2	1	1692	Nil	Nil	3001471
Cyclone	2	Nil	18000	No report	6	-

Climate change occurs the change in agriculture activities, especially for the marginal and small farmers in Keonjhar, they are the most vulnerable group of farmers. So, they change cropping time such as in Kharif season they usually start their farming before 30 years in Rath Yatra, but because of climate change, the rainfall is delayed approximately two weeks. For delayed rainfall, they sow late which also leads to delay of Rabi season. Most of the farmers have changed from growing long-duration paddy to short-duration paddy varieties. Some farmers have changed their cropping pattern, instead of paddy they shifted to other crops like pulses, maize, and vegetables.

4 Conclusion

Climate change is an initial issue for study around the world generally and specifically in the Odisha district of India due to the sequence's adverse effects. The study reveals that average annual rainfall increased inconsistently (R^2=0.0196, Z=0.86) while it significantly decreased in June during the period of the study (Z=-1.86, Sin's=-2.96), the farmers faced challenges in selecting the time of their crop during the critical agriculture period in the year (Monsoon season). The average annual maximum temperature significantly increased (Z=3.15, Sin's slope=0.050) and the annual average of relative humidity also significantly increased (Z=1.98, Sin's slope=0.167). The study reveals that both farmers (marginal and small) are the most vulnerable group of the population, due to the passive effect of climate which may continue in coming years.

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