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ASSESSING THE IMPACT OF CLIMATE CHANGE ON RAINFALL TRENDS IN THE MIDDLE GUJARAT REGION

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ABSTRACT

This research paper delves into the intricate relationship between climate change and rainfall trends in the Middle Gujarat region, situated in the Indian subcontinent. The study employs a multidisciplinary approach, integrating meteorological data, satellite imagery, and climate modelling to comprehensively analyse observed changes and potential implications. Building upon earlier research, the paper explores key parameters such as mean annual rainfall, variance, coefficient of variation, kurtosis, skewness, median, standard deviation, and trend analyses. The findings reveal diverse responses across talukas, emphasizing the dynamic nature of precipitation patterns. While some areas exhibit no overall trend in annual rainfall, significant increasing trends in 3 and 5 years moving averages suggest a shifting pattern over time. The varying coefficients of variation underscore distinct levels of rainfall variability, necessitating localized and nuanced approaches for climate change mitigation and adaptation. The identification of talukas with decreasing trends highlights vulnerable areas, emphasizing the urgency for adaptive strategies in water resource management and agriculture. This research aims to inform policymakers, researchers, and local communities, fostering a better understanding of the complex interplay between climate change and rainfall patterns in the Middle Gujarat region.

KEYWORDS: *Rainfall Analysis, Mann-Kendall, Sen.'s Slope Method*

INTRODUCTION

Climate change, a global phenomenon driven primarily by anthropogenic activities, has emerged as a critical concern with far-reaching consequences on various aspects of the Earth's ecosystems. One of the most significant manifestations of climate change is the alteration of precipitation patterns, which directly influences regional climates and poses substantial challenges to water resource management. In the context of the Indian subcontinent, the Middle Gujarat region stands as a microcosm, experiencing discernible shifts in rainfall patterns that demand in-depth investigation. This research paper seeks to explore the intricate relationship between climate change and rainfall trends in the Middle Gujarat region, aiming to provide a comprehensive analysis of the observed changes and their potential implications. The Middle Gujarat region, known for its agricultural significance and socio-economic diversity, is particularly vulnerable to alterations in precipitation patterns, making it imperative to understand the underlying mechanisms.

The literature on climate change impacts and rainfall trends in South Asia, and specifically in Gujarat, underscores the urgency of research in this domain. Earlier studies by Dash et al. (2007), Krishnan et al. (2012), and Sengupta et al. (2015) have indicated a discernible shift in precipitation patterns, with potential ramifications for water availability and agricultural productivity. Recent research by Patel et al. (2017) builds upon these foundations, indicating a continued trend in changing precipitation patterns in the region. This paper adopts a multidisciplinary approach, integrating meteorological data, satellite imagery, and climate modeling to elucidate the changing rainfall trends in the Middle Gujarat region. By building upon existing research and incorporating recent data, this study aims to contribute valuable insights that can inform policymakers, researchers, and local communities in devising sustainable strategies to mitigate the adverse effects of climate change on water resources and agriculture in the region. In subsequent sections, we delve into the methodology employed, present our findings, and discuss the implications of observed changes. The ultimate goal is to foster a better understanding of the complex interplay between climate change and rainfall patterns in the Middle Gujarat region and to lay the groundwork for informed and adaptive climate-resilient practices.

MATERIAL AND METHODS

Study Area & Data

The study area is different taluka of central Gujarat state. The historical records of rainfall at different station of Gujarat were collected from the Gujarat Water Resources Development Corporation (GWRDC), Gandhinagar and IMD, Ahmedabad.

Mann-Kendall Analysis

The Mann-Kendall test serves as a non-parametric tool for identifying trends within time series data, focusing on the relative magnitudes of sample data rather than the specific data values (Gilbert, 1987). A notable advantage of this test is its flexibility, as it does not require adherence to any specific distribution. Additionally, it accommodates non-detects in the data by assigning them a common value smaller than the smallest measured value in the dataset. The data values are treated as an ordered time series, with each value compared to all subsequent data points. The Mann-Kendall statistic, denoted as S, begins with an initial assumption of 0, indicating no trend. When a data value from a later time period surpasses a value from an earlier period, S is incremented by 1. Conversely, if a later data point is lower than an earlier one, S is decremented by 1. The cumulative effect of these increments and decrements results in the final value of S, reflecting the overall trend in the ordered time series. This approach allows for a robust assessment of trends over time while accommodating variations and uncertainties in the data.

- Mann-Kendall statistic (S) was calculated by
- n-1 n

∑ ∑ Sign (xj – xk) (2)

- k=1 j=k+1
- Sign(xj – xk)=1, 0 and -1, if xj>xk, xj = xk and xj < xk respectively. n is the number of data points in time series.

A very high positive value of S was an indicator of an increasing trend, and a very low negative value indicated a decreasing trend. However, it was necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend. The variance of S, i.e. VAR(S) for each data series was estimated by the following equation (3).

m

VAR(S) = (1/18) [(n (n-1) (2n +5) -∑ (tp (tp-1) (2tp +5)] (3)

- p=1

Where n was the number of data points, m was the number of tied groups (a tied group was a set of sample data having the same value), and tp was the number of data points in the p group. The normalized test statistic Z was computed as follows.

- Z = {[S-1]/ [VAR(S)]½} if S>0
- = 0 if S=0

= {[S+1]/ [VAR(S)]½} if S<0 (4)

If Zcal >0 and Zcal > Ztab, where, Ztab = 3.090, 2.326, 1.645, .282, the trend was considered as increasing and if Zcal < 0 and -Zcal > Ztab the trend was considered as decreasing at 0.1%, 1%, 0.5 and 10 % respectively.

Sen's Slope Method

Interpreting environmental field data poses challenges, particularly in quantifying trends and statistically validating trend estimates. Sen's Nonparametric Estimator of Slope emerges as a valuable method for this purpose. The methodology involves graphing the data initially to observe trends and cycles, aiding in test selection.

Sen's method specifically requires a time series with equally spaced measurements per unit of time. The calculation of slope, as per Equation (6), involves determining the change over time. This nonparametric approach is suitable for cases where a linear trend can be assumed. Overall, Sen's method provides a robust means to estimate and assess the significance of trends in environmental data.

f(t) = m t + c (6)

Where m is the slope and c is a constant. The slope mi within between two values of pair of all data value was estimated using the following equation (7).

mi = (xj -xk) /(j-k), (7)

Where

- k=1, 2, 3 ... (n-1).
- j= k+1=2, 3 ...n.
- i= 1 to N [N= n (n-1)/2]
- The Sen's estimator of slope was estimated using the following expression (8)
- m = m(N+1)/2 , if N is odd

m = ½ [mN/2 + m(N/2)+1] if N is even. (8)

If multiple data measurements are collected at a given time, two options exist if multiple measurements are recorded for a given time step. The first option is to simply combine the measurements for a given time step into a single measurement of central tendency (e.g. mean, median) and proceed as above. The second option is to calculate a slope for each individual measurement. Note that the slope between measurements collected at the same time is not calculated.

RESULT AND DISCUSSIONS

The comprehensive analysis of rainfall trends in various talukas of Middle Gujarat reveals valuable insights into the climatic patterns and potential implications of climate change on precipitation. The study focused on key parameters such as mean annual rainfall, variance, coefficient of variation, kurtosis, skewness, median, standard deviation, and trend analyses using Mann Kendall and Sen's slope statistics. Anand, with a mean annual rainfall of 787.8 mm, exhibited a variance ranging from 285 to 1339 mm, resulting in a coefficient of variation of 37.18%. The Mann Kendall and Sen's slope statistics indicated no significant trend at an 81.54% confidence level. However, the 3 and 5 years moving averages demonstrated a highly significant increasing trend, projecting an expected annual increase of 10.4 mm. This suggests a noteworthy shift in precipitation patterns over the years.

Kapadvanj, characterized by a mean annual rainfall of 1073.2 mm and a coefficient of variation of 25.34%, showed no significant trend in overall rainfall at a 56.30% confidence level. Nevertheless, the 3 and 5 years moving averages revealed a substantial increasing trend, anticipating an annual rise of 85.46 mm. This underscores the importance of considering longer-term trends for a more comprehensive understanding of climate change impacts.

Similarly, Khambhat, Thasar, Nadiad, Petlad, Borsad, Mahemdavad, Matar, Balasinor, Panchmahal District, Godhara, Jambughoda, Jhalod, Dahod, Devgadhbariya, Limkheda, Lunavala, Santrampur, Halol, Shahera, Vadodara district, Karjan city, Jetpurpavi, Dabhoi, Chhotaudepur, Tilakvada, Nasvadi, Padara, Vadodara, Savali, and Sankheda exhibited unique rainfall characteristics. Although each region displayed no overall trend in Mann Kendall and Sen's slope statistics at varying confidence levels, the 3 and 5 years moving averages often demonstrated significant increasing trends.

The coefficient of variation, a measure of relative variability, ranged from 25.34% to 48.78% across the talukas, indicating diverse levels of rainfall variability. Regions with higher coefficients, such as Padara and Jetpurpavi, may experience more pronounced fluctuations in annual precipitation, highlighting the need for robust climate adaptation strategies. Notably, the study identified a few talukas where the 3 years moving average showed a decreasing trend, suggesting potential vulnerabilities to changing climate conditions. For instance, Nadiad and Vadodara displayed decreasing trends at 85.46% and 50% confidence levels, respectively, emphasizing the importance of localized assessments for effective climate change mitigation and adaptation planning. This detailed rainfall trend analysis provides a comprehensive understanding of the climatic variations in Middle Gujarat. While certain talukas show no overall trend in annual rainfall, the significant increasing trends observed in the 3 and 5 years moving averages underscore the dynamic nature of precipitation patterns.

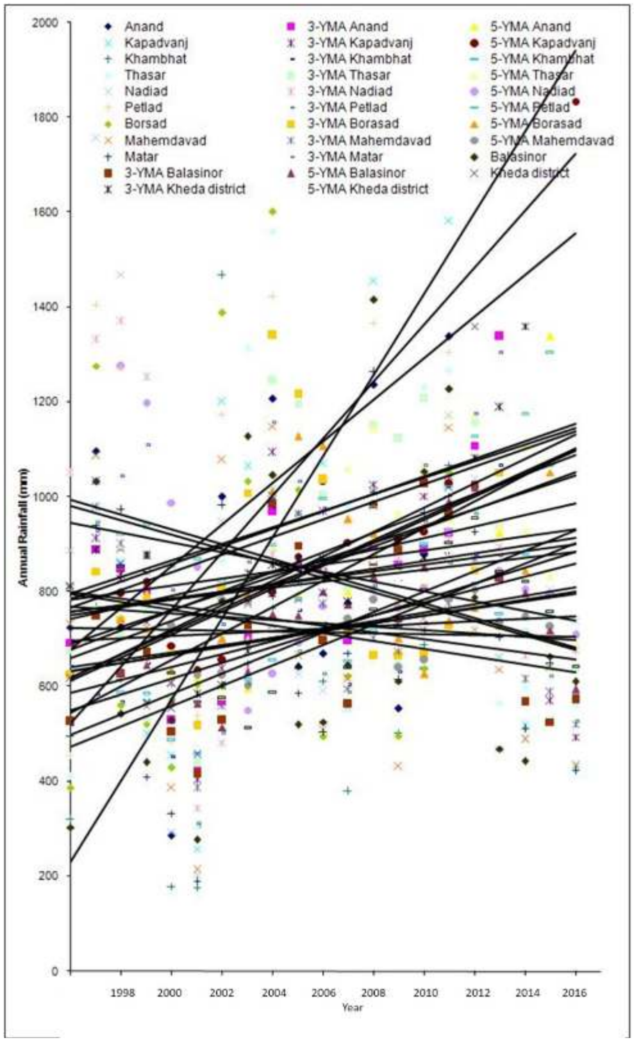

Figure: 1 Annual Rainfall Trend of Different Talukas of Central Gujarat.

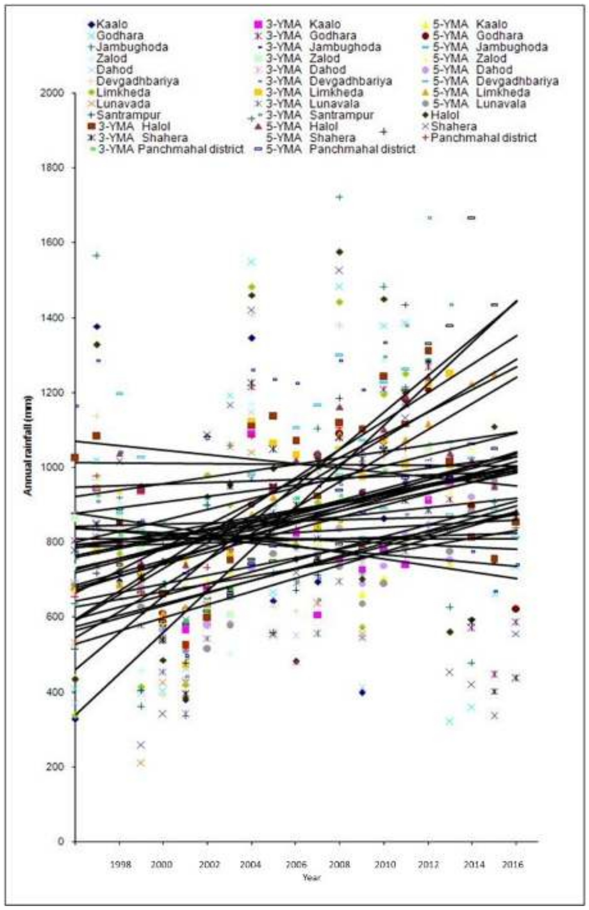

Figure: 2 Annual Rainfall Trend of Different Talukas of Middle Gujarat.

CONCLUSIONS

The comprehensive analysis of rainfall trends in the Middle Gujarat region highlights the intricate dynamics between climate change and precipitation patterns. The study reveals diverse responses across talukas, emphasizing the need for localized and nuanced approaches to climate change mitigation and adaptation. While some areas, like Anand and Kapadvanj, show no significant overall trend in annual rainfall based on Mann Kendall and Sen's slope statistics, the notable increasing trends in their 3 and 5 years moving averages indicate a shifting precipitation pattern over the years. This dynamic nature underscores the importance of considering longer-term trends for a more comprehensive understanding of climate change impacts. Moreover, the varying coefficients of variation across talukas indicate distinct levels of rainfall variability, with regions like Padara and Jetpurpavi experiencing higher relative variability, necessitating robust climate adaptation strategies. The identification of talukas with decreasing trends in the 3 years moving averages, such as Nadiad and Vadodara, underscores the vulnerability of certain areas to changing climate conditions, highlighting the urgency for localized assessments to inform effective climate-resilient planning.

In the face of these observed changes, this research underscores the significance of informed decision-making and adaptive strategies for water resource management and agriculture in the Middle Gujarat region. The potential implications of altered precipitation patterns on water availability and agricultural productivity necessitate a proactive and collaborative approach involving policymakers, researchers, and local communities. By bridging the gap between scientific understanding and practical applications, this study aims to contribute valuable insights that can guide sustainable practices and policies, fostering resilience in the face of climate change. The findings presented here provide a foundation for ongoing dialogue and action, emphasizing the importance of continuous monitoring and adaptive strategies to mitigate the adverse effects of climate change on the vital ecosystems of the Middle Gujarat region.

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