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Groundwater Infiltration Trends in the Major Basin of Ahmedabad District, Gujarat, India

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Abstract: Rapid urbanization and land-use change resulted in a major reduction of groundwater recharge regions. Infiltration through porous terrain is the cause of groundwater recharge. Due to industrialization, urbanization, and population growth, groundwater extraction in the Ahmedabad district's Sabarmati Sub-basin has increased in recent decades. In order to create sustainable groundwater management plans, researchers and local authorities now need to evaluate the water resources in the Ahmedabad district. The spatiotemporal trends of groundwater infiltration upstream of the Vasna Barrage on the Sabarmati River from 1980 to 2020 are investigated in this study. The non-parametric Mann-Kendall test was used to analyze the premonsoon groundwater infiltration trend. Results indicate a statistically significant downward trend in pre-monsoon infiltration.

Keywords: *Groundwater Infiltration, Mann- Kendall, Non-Parametric.*

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I. INTRODUCTION

In many regions of the world, groundwater—a significant component of the global freshwater resource—is the main supply of drinking, industrial, and agricultural water. [1]. In India, more than 90% of the rural and nearly 30% of the urban population depend on groundwater for meeting their drinking and domestic needs [2]. Aquifers in arid and semi-arid areas that rely heavily on groundwater are overused because natural replenishments cannot keep up with groundwater withdrawals. [3].

change in land-cover is expected to reduce recharge and further lower groundwater levels. [4]. Hence, Improved knowledge of the effects of land use and water recharge is necessary and the amount of water recharge is required. The effect of LULC change on groundwater recharge can be evaluated using a variety of methods. As an illustration, statistical methods such as water-table fluctuation analysis [5] and numerical methods like water balance simulation [6] are in use. Nevertheless, the techniques are expensive and time-consuming. Another technique for determining the permeability of surface deposits is effective infiltration. [7].

One of the key elements influencing groundwater recharge is infiltration. Calculating the amount of infiltration in the field has always been challenging. As a result, the majority of the estimations that are currently accessible are derived from theoretical computations that take into account variables like slope, soil properties, rainfall amount and duration, runoff, etc. However, other methods have been used to measure the rate in the field with portable rainfall simulators. [8], double-ring infiltrometer [9]. mini-disc infiltrometer [10], single-ring infiltrometer [11], artificial precipitation simulator [12], run off-on ponding techniques [13], etc. Because it involves additional processes like the movement of water within the soil, the infiltration method is beneficial. [14], soil physical properties [15], surface soil compaction [16], vegetation coverage, and types [17]. Despite its sensitivity, the infiltration approach may be useful to researchers in developing countries because it is easy to understand, inexpensive, and portable. The primary method for examining trends in groundwater is statistical analysis, which have also been used to assess how climate change is affecting groundwater supplies [18]. Consequently, non-parametric tests such as the Mann-Kendall, modified Mann-Kendall, and Sen's slope estimator have been used in hydrologic studies to identify trends in hydrologic variables. [19].

Gujarat is one of the most developed states of India; hence the demand for underground water is high. The overuse of groundwater aquifers, changes in rainfall patterns, and the quickening rate of population and industrial growth are the main causes of groundwater depletion in areas with poor sustainable groundwater management. [20].

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II. MATERIALS AND METHODS

The suggested study is focused on Gujarat state's Ahmedabad district (Figure 1). Ahmedabad city located in the state of Gujarat, India Ahmedabad is located 30 kilometers from Gandhinagar, the state capital, on the banks of the Sabarmati River. The area, which covers 8,087 km^2 in the state of Gujarat, is situated between latitudes 22°55'00" N and 23 °07'30" N and longitudes 72°22'30" E and 72°47'30" E.

It is the most populated and urbanized city in Western India's central Gujarat region. Ahmedabad is physically divided into two sections by the Sabarmati River: the portions in the east and west. Eleven talukas—Barwala, Bavla, Daskroi, Detroj-Rampura, Dhandhuka, Dholka, Mandal, Ranpur, Sanand, and Viramgam—make up the Ahmedabad district, which encircles the city.

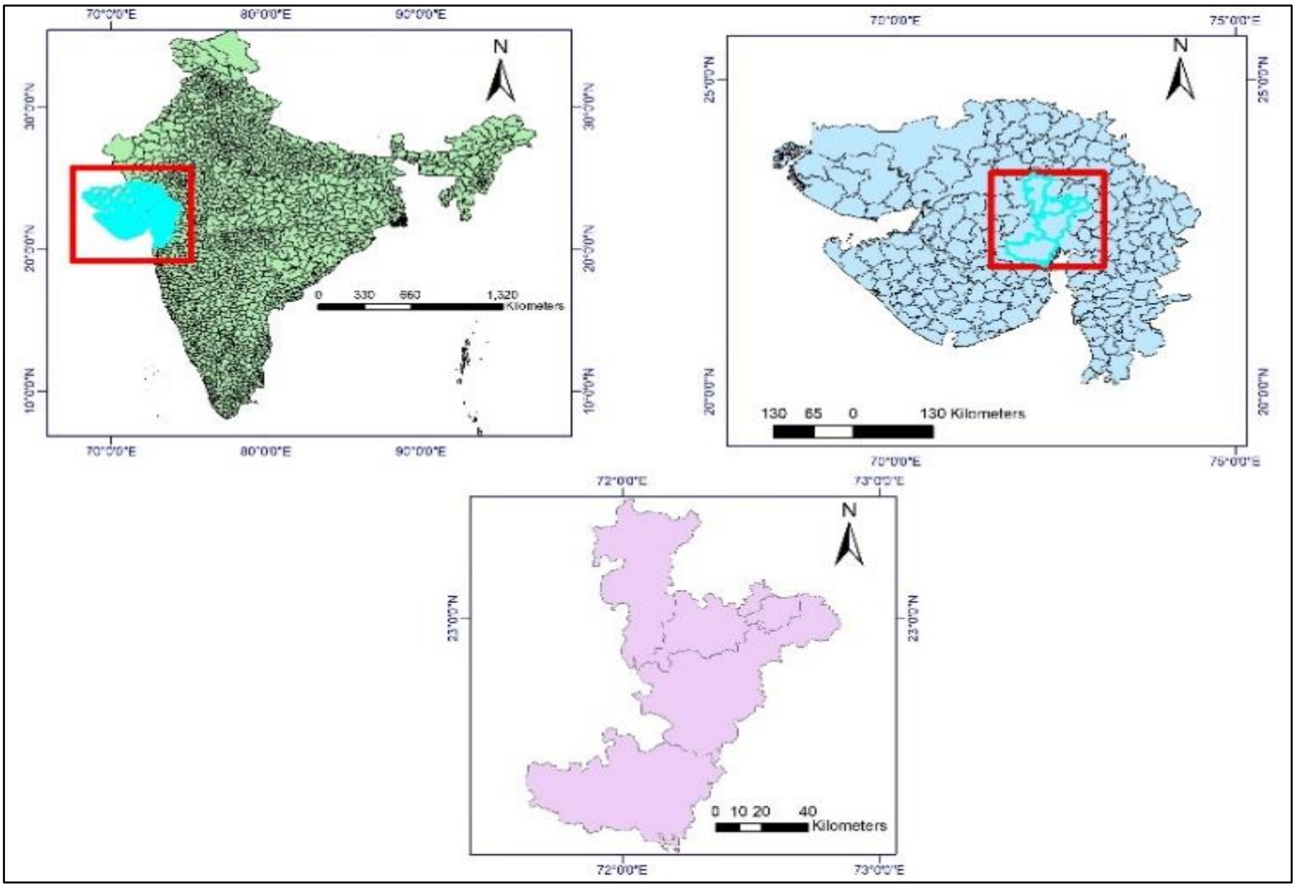

Fig.1. Ahmedabad District Study Area

- *Data Collection*

The mean of the Ahmedabad District's monthly and annual rainfall statistics has been collected from CWC for 40 years period of from 1980 – 2020.

- *Trend Analysis*

According to earlier research, the most popular approach is the non-parametric Mann-Kendall test.

- *Non-Parametric Test*

Nonparametric tests are statistical analysis techniques that satisfy the requirements to be studied without the need for a distribution, particularly in cases where the data is not typically dispersed. For trend analysis and trend line slope detection, the Mann-Kendall [21][22] was employed.

- *Mann-Kendall Test*

The non-parametric Mann-Kendall test is used to analyze time series data trends. The Mann-Kendall test's primary advantage is that it does not require the statistical distributions required for the parametric approach. In contrast to the alternative hypothesis (), which postulates a growing or declining monotonic trend, the null hypothesis () for the Mann-Kennel test states that there is neither a trend nor serial correlation among the population under analysis.

The MK statistic S, which is used to identify trends in time series, is provided as

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\ (xj - xi)$$

Where, 'x' and 'x' are sequential data for i^{th} and j^{th} terms.
'n' is the sample size and
The variance of S is given by

$$var = \frac{1}{18} + [n(n-1)(2n+5) - \sum_{t} ft(ft-1)(2ft+5)]$$

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where t varies over the set of tied ranks and f_t is the number of times (i.e. frequency) that the rank t appears. The MK Test uses the following test statistic:

$$z = \begin{cases} (S - 1)/se, & S > 0 \\ 0, & S = 0 \\ (S + 1)\ se, & S < 0 \end{cases}$$

where se = the square root of var. The MK statistic S, which is used to identify trends in time series, is provided as for a time series with more than 10 components, z ~ N (0, 1), meaning that z has a standard normal distribution, if there is no monotonic trend (the null hypothesis). An increasing trend is shown by a positive z value, and a falling trend is indicated by a negative z value. The z statistic is typically dispersed.

III. RESULT AND ANALYSIS

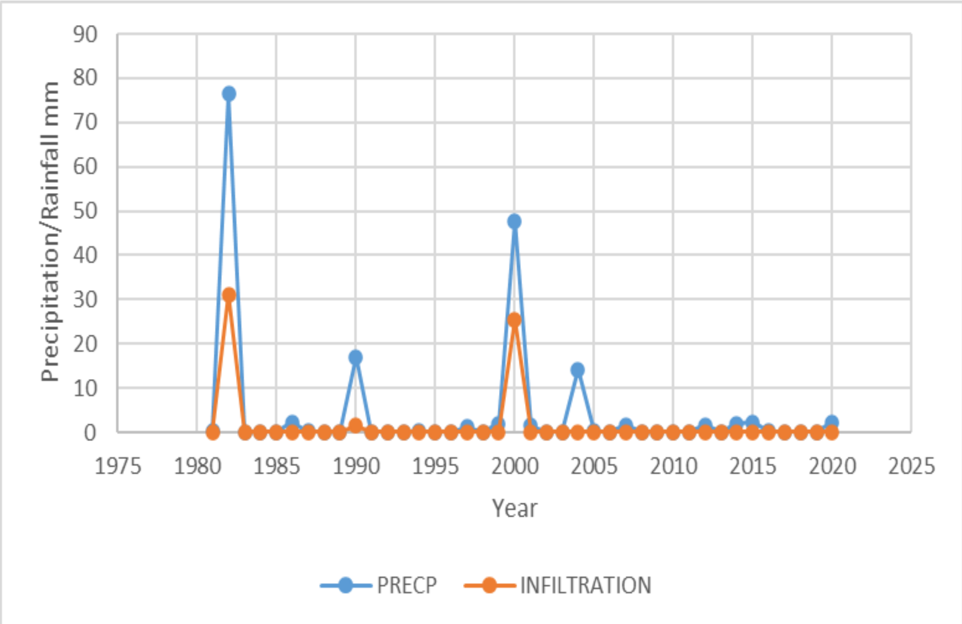

Fig. 2. Precipitation and Groundwater Infiltration Trends (1980-2020)

Above figure represents the conversion of rainfall into infiltration has significantly deteriorated, even in years with sporadic high precipitation: the infiltration line is flat and close to the axis for most years, suggesting little recharge.

Fig 3 summarizes the Mann–Kendall trend analysis results for modelled pre-monsoon groundwater infiltration in sub-basin (the upstream zone of the Vasna Barrage).

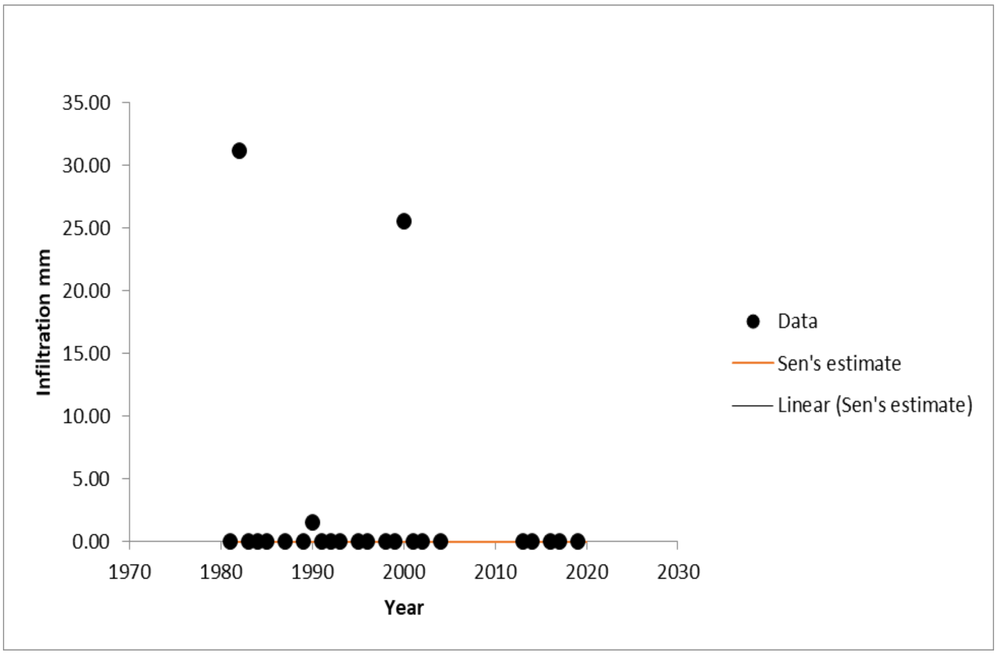

Fig.3. Groundwater Infiltration Trend – Premonsoon – (1980-2020)

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Above figure represents Infiltration levels were comparatively high in the early years 1980s; there are multiple locations above 30 mm and one that is almost 31 mm. The amplitude of infiltration decreases dramatically over time; following the early peaks, the majority of the later values (post-2000) cluster relatively near zero (0-5 mm), suggesting a rapid decline in infiltration. This implies that the conditions favouring infiltration upstream of the Vasna Barrage have deteriorated significantly—possible causes include increased impervious surfaces, reduced recharge zones, changes in rainfall-runoff relationships, or alterations in river–aquifer connectivity due to the barrage or land-use change.

IV. CONCLUSION

In this study, non-parametric Mann-Kendall test, was investigating trends of groundwater infiltration for the period of 40 years (1980-2020). The results showed that there is decreasing in the trend of the infiltration data with significant trends observed at the 95% confidence levels. When the monsoon recharge season begins, the pre-monsoon phase usually establishes the baseline groundwater state; this decline has significant consequences for the sustainability of groundwater as a whole. In order to maintain aquifer resilience, the observed trend highlights how urgent it is to improve recharge methods and control abstraction prior to the monsoon. Evidently, this would assist water resource managers and policymakers in optimizing future planning in line with environmental conservation.

V. FUTURE SCOPE

This study primarily examined pre-monsoon infiltration patterns, applying comparable trend detection techniques (such as Mann-Kendall) to the monsoon and post monsoon period, when the majority of recharge takes place. In order to determine how much of the rainfall input is actually reaching the aquifer and whether that pathway is deteriorating or remaining constant over time, it will be helpful to assess monsoon-season infiltration. A more comprehensive annual-cycle picture of aquifer replenishment upstream of the barrage can be obtained by comprehending the monsoon recharge trend.

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