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Analysis of Ground water level using Mann-Kendall test in Bengaluru urban, Karnataka, India.

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Abstract— *Ground water and Rain water are the important sources of water on earth, Ground water plays a vital role in meeting the demand of human need.However lots of fresh water is wasted due to inadequate monitoring of the water supply system. In 2024 water shortage in Bengaluru had arise due to low rainfall, dried condition of borewells due to improper rainwater harvesting system for recharge of ground water, acquisition of lakes are major issues which causes the scarcity of water.*

Bengaluru town is growing rapidly and water usage becomes more essential, drilling of borewells without proper recharge of ground water, construction of apartments and residential plots by encroaching lakes leads to less storage and conservation of water. The population of Bengaluru is 1.4 crore and daily consumption of water in Bengaluru is 2600 MLD, 1450 MLD is pumped from Cauvery river, 650 MLD is pumped from borewells and every single day there is a shortage of 500 MLD of water in Bengaluru city which leads to water crisis. The Bengaluru Water Supply and Sewerage Board (BWSSB) has brought certain rules and regulations for avoiding wastage of water by installing Aerators to tapes, bypass connections, and controlling of leaking of public tapes. To detect the trends of ground water levels Mann- Kendall test is adopted to reveal the increasing and decreasing trend of water in different seasons.

Keywords—*Analysis, Ground water level, Mann-Kendall.*

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I. INTRODUCTION

Ground water is the important natural source of water available in nature, Rainfall is the principal source for replenishment of moisture in the soil water system and recharge to ground water.The amount of this recharge depends upon the rate and duration of rainfall, the subsequent conditions at the upper boundary, the antecedent soil moisture conditions, the water table depth and the soil type. Groundwater recharge is defined as water that infiltrates through the subsurface to the zone of saturation beneath the water table.The estimation of groundwater recharge from precipitation is a principal part of hydrology and hydrogeology (Xi et al. 2008). The amount of water that may be extracted from an aquifer without causing depletion is primarily dependent upon the ground water recharge.

Groundwater is critical to the environment in terms of maintaining water levels and flowing of water into rivers, lakes and wetlands. Groundwater fluctuations vary upon the recharge of water in different monsoon seasons.Ground water is essential for every individual to survive on earth, it is the most reliable source available with good quality, suspectibility, cheap. Ground water level varies depending on increasing and decreasing trend.

Factors influencing groundwater recharge include characteristics of the recharge beds, such as topography, land use and vegetation cover, existing soil moisture and the ability of the recharge beds and aquifer materials to capture and transmit water. Groundwater recharge may also be defined as ‘The downward flow of water reaching the water table, forming an addition to the groundwater reservoir’. The availability of groundwater-level data and the simplicity of estimating recharge rates from temporal fluctuations or spatialpatterns of groundwater levels. The present study emphasis on estimating groundwater recharge based on knowledge of groundwater levels. The ground water resource management.

In semiarid areas, where groundwater resources are the key to agricultural development, groundwater quantification is very vital issue.

II. MATERIALS AND METHODS

Bengaluru situated in 12.9716° N, 77.5946° E the city population has 1.4 crores in area of 741 sq km, the city is located 920m above mean sea level, Cauvery river is the source of water to the city, annual rainfall to the city is around 820mm. The rainfall has been received maximum during June to September, it is the month of peak rainfalls. The southwest monsoon indicates the increasing trend of ground water level.

The period from January to March receives low rainfall indicating a decreasing trend of ground water level can be seen.

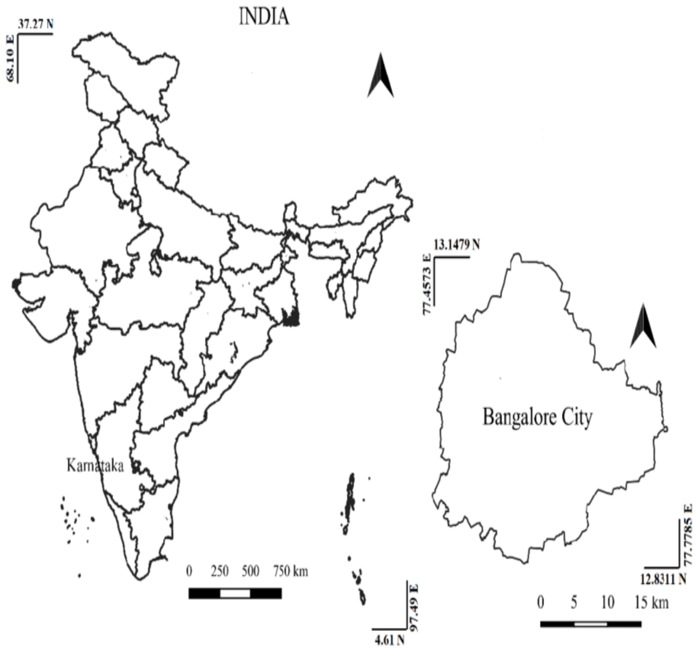

Fig 1 :- Location of study area.

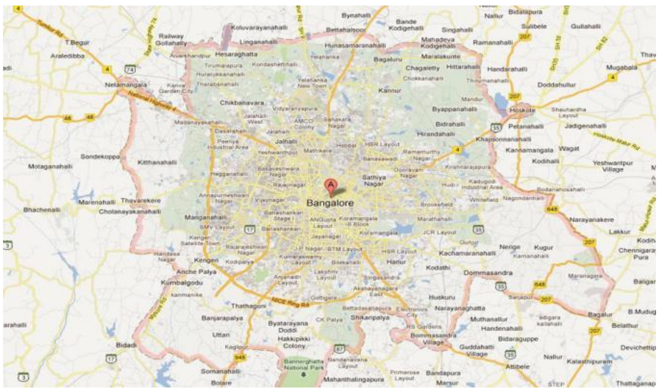

Fig 2:- Bengaluru map covering different localities and areas.

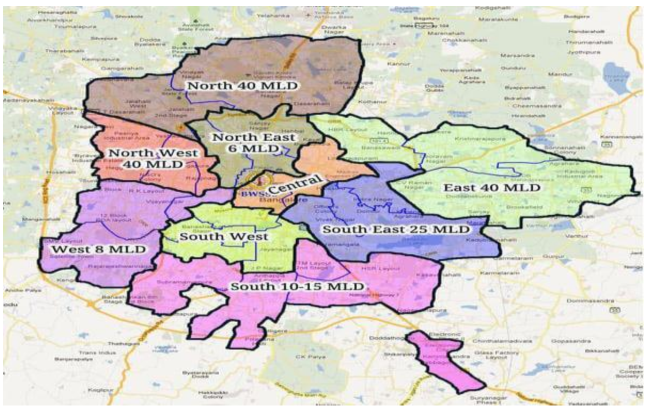

Fig 3 :- Daily consumption of ground water in MLD

GEO-SPATIAL ANALYSIS

It is a crucial component of groundwater resource management. It involves the systematic evaluation historical groundwater level data to identify and understand long-term trends and variations in groundwater levels. This analysis helps in making informed decisions regarding groundwater use, conservation, and sustainability. The steps adopted for the trend analysis of groundwater levels:-

1. Collection groundwater level data from monitoring wells or observation points.
2. Create plots and graphs to visualize the groundwater level data over time.
3. Groundwater levels depends on factors like precipitation, temperature and water usage patterns.

Geo- spatial variations of groundwater level is planned to identify and understand the trend patterns for sustainable management of water resources

Geo-Spatial Trend Analysis of Groundwater Level

Geo-spatial variations in the groundwater level (GWL) has been planned in order to identify and understand trends and patterns for sustainable management of groundwater resources. Here are the key steps involved in geo-spatial trend analysis:

● Data Processing: After data collection, the data must be processed and prepared for analysis. Monthly groundwater level of 37 observation wells were collected and analyzed using the IDW (Inverse Distance Weighting) method.

● Statistical techniques include linear regression, moving averages, and exponential smoothing can help identify whether groundwater levels are rising, falling, or remaining relatively stable over time.

● Spatial Analysis: This is the core of geo-spatial trend analysis, where various analytical methods are applied to the data.

III. Methodology

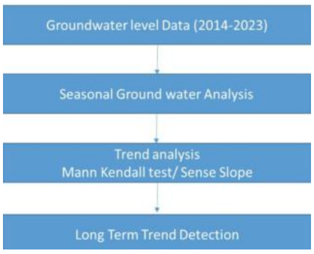

Fig 4:- Steps involved in finding groundwater trend

IV. MANN–KENDALL (M-K) TEST

The Mann-Kendall also termed as M-K rank correlation test is a non-parametric statistical test used for trend analysis. The formula for Mann Kendall Statistic are ;l

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_i - x_j)$$

n= number of data points
xj= data points at time j

$$Z_C = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & \text{if } S < 0 \end{cases}$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(i)(i-1)(2i+5)}{18}$$

Mann - Kendall test is computed for the groundwater level trends.

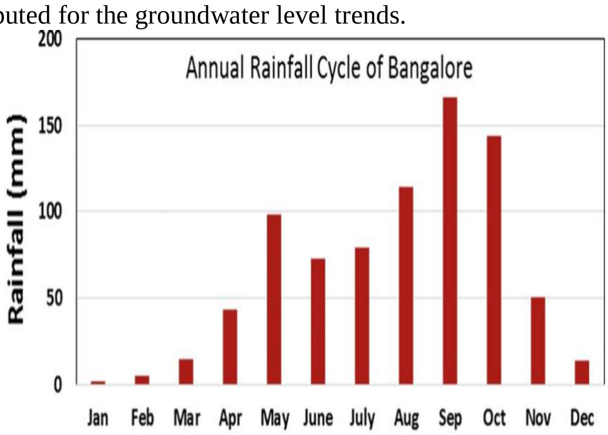

Fig 5:- Annual rainfall of Bengaluru city showing the month September having peak/ heavy rainfall.

Table 1 :Analysis of Groundwater in the study area

Location	LAT	LON	DEPTH	RL
Bengaluru iv	12.94	77.55	13.6	878
Basavanagudi	12.94	77.57	9.1	902
Chennammanakere Achukattu	12.92	77.43	7	882
Dasanapura	13.07	77.43	60	848
Gollahalli	12.86	77.56	9.35	915
Hebbal	13.04	77.57	77	891
Hesaraghatta	13.12	77.47	60	851
Indiranagar	12.97	77.63	80	915
Kodigehalli	13.05	77.56	6.5	899
Lalbagh Garden	12.95	77.58	60	905
Malleshwaram	13.00	77.56	7	918
Gsi Pz	12.91	77.56	200	897
Rajajinagar	12.98	77.55	4.5	883
Vasanthnagar	12.99	77.58	2.12	920

Vasanthapura	12.89	77.55	12.9	862
Thalaghattapura	12.86	77.53	50	889
Adugodi	12.94	77.7	58.4	876
Ban Uni Ars	12.75	77.51	50	727
Chanda Sipalya	12.97	77.41	17	855

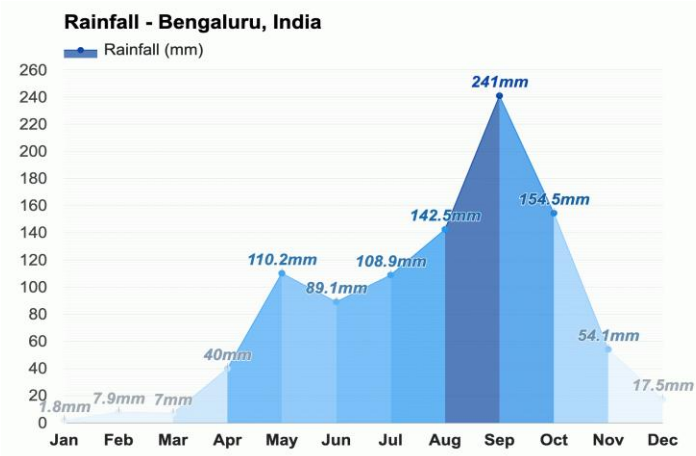

Fig 6:- Annual rainfall of Bengaluru, mm

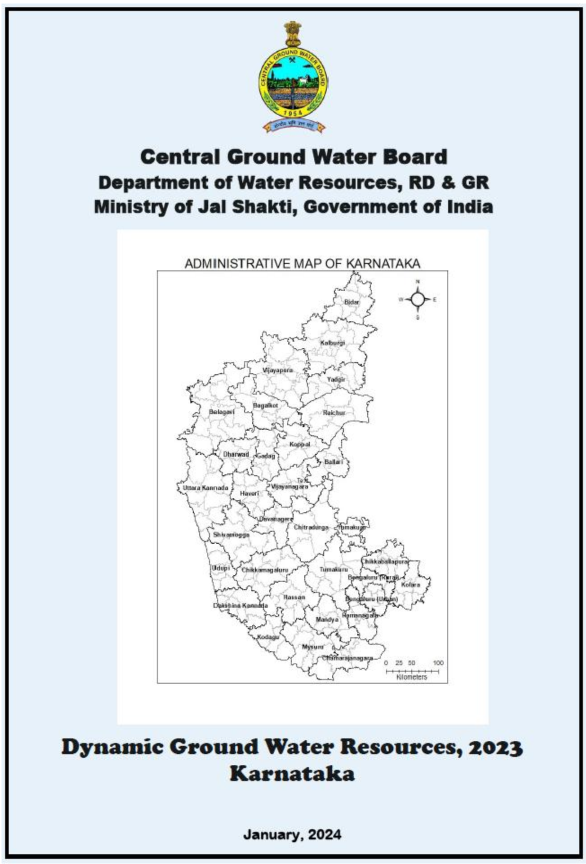

Table 2:- Mann-Kendall Analysis (2014-2023)

In the table '-' sign indicates decreasing trend and '+' sign indicate increasing trend of groundwater level.

Location	North East Monsoon	Pre Monsoon	South East Monsoon	Pre Monsoon	Remarks
Bengaluru iv	-0.0328	-0.034	0.0291	-0.175	-
Basavanagudi	-0.045	-0.035	0.222	-0.109	-
Chennammanakere Achukattu	0.022	0.143	0.167	-0.143	-
Dasanapura	-0.270	-0.143	-0.611	-0.571	-
Gollahalli	0.045	-0.214	0.500	0.143	+
Hebbal	-0.299	-0.242	0.147	-0.178	-
Hesaraghatta	-0.597	-0.500	-0.556	-0.429	-
Indiranagar	-0.690	-0.120	-0.685	-0.215	-
Kodigehalli	-0.424	-0.445	-0.346	-0.411	
Lalbagh Garden	0.353	0.215	0.306	0.126	+
Malleshwaram	0.225	-0.143	0.366	0.071	+
Gsi Pz	0.270	0.571	0.278	0.500	+
Rajajinagar	0.422	0.214	0.572	0.109	+
Vasanthnagar	-0.225	-0.214	0.056	-0.182	-
Vasanthapura	0.022	-0.071	0.278	0.000	+
Thalaghattapura	-0.045	0.113	-0.085	-0.286	-
Adugodi	-0.225	0.000	0.167	-0.357	-
Ban Uni Ars	-0.689	-0.571	-0.444	-0.571	-
Chanda Sipalya	-0.111	-0.500	-0.197	-0.357	-

V. RESULT AND CONCLUSION

The Mann-Kendall test used to check groundwater levels using spatial interpolation methods and statistical techniques The groundwater levels of 20 different locations were collected for the period of 9 years (2014-2023) were employed to understand the increasing and decreasing trends of groundwater level. The study concludes that the groundwater level is declination of groundwater level in major areas of Bengaluru iv, Basavanagudi, Dasanapura, Hesaraghatta , Thalaghattapura that decline in southwestern and northern parts of basin during all the monsoon season.

The result and trend analysis observed 68% of decreasing trend and increasing trend of 32% in the study area.The spatial trend variation analysis of water level indicates that increasing trend is mostly observed in the places, namely Gollahalli, Malleswaram, Rajajinagar, Gsi Pz, Vasanthpura. These variations in groundwater levels with respect to space, time and depth mainly affect the consumers, Therefore it is necessary to enhance the groundwater resources in the affected areas through artificial recharge techniques.

Rainwater harvesting system in every individual houses enhances the storage of water and can reduce the usage groundwater during summer season, from analysis it is found that 80% of houses haven't adopted rainwater harvesting which leads to more usage of groundwater, So preservation of rainwater is essential in conserving the groundwater.

This conclusion is highly important particularly in the context of declining trend of groundwater level in mbgl that might cause increasing scarcity of groundwater in the district in the post-monsoon and winter months.Suitable options would have to be considered for creating resilience against likely hardship in sourcing groundwater that may result from likely redistribution of seasonal rainfall within a water-year and declines in the amount of rainfall in the monsoon and the post-monsoon seasons in particular in future water-years. A feasible alternative would be adoption of suitable policies and implementation of schemes for sustainable development and management of groundwater and conjunctive use of surface water and groundwater.

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