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GROUNDWATER LEVEL FLUCTUATION AND DROUGHT ANALYSIS IN MULBAGAL TALUK USING REMOTE SENSING AND GIS

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Abstract

The groundwater table variation before and after the monsoon seasons, rainfall distribution analysis and drought analysis are discussed in this paper. The groundwater level data and elevation data are used for fluctuation study which were obtained from the field measurements and from CGWB. Mann Kendall's and Sen's slope methods are used to analyze the trend of water level fluctuation in the study area, where ANOVA and SPI were used for rainfall and drought analysis. In this region, as there is no perennial rivers, groundwater is the only and important source for all industrial agricultural and day to day activities. Agricultural activities in this region accounts more consumption of groundwater resources. From the analysis, it is found that, in this region most of the places comes under severe drought category. From Mann Kendall's it has been found that there is a decreasing trend of groundwater levels. A drastic fluctuation in the water table is found where 95 % of the study area is at risk of being overexploited. This indicates that there will soon be a major water supply shortage. Due to decrease of water levels in the aquifers pose a hazard to groundwater quality. It is advised to use an appropriate monitoring system, effective irrigation techniques and efficient groundwater recharge structures. These results provide useful information to ensure sustainable groundwater development.

Keywords: Rainfall, Mann Kendall's, SPI, Sen's slope, Anova

INTRODUCTION

Worldwide, groundwater is a major source of water delivery schemes, particularly in rural areas (Nas & Berkatay, 2010). Groundwater is crucial for human consumption, habitat support and sustaining the standard of base flow to rivers. They frequently have very high quality. They are often clear, colorless and free of microbial contamination because they were naturally filtered throughout their transit through the earth, necessitating little treatment (Insaf S, Babiker, Mohamed A. A. Mohamed and Tetsuya Hiyama, 2007). Globally, groundwater withdrawals have been swiftly and steadily rising and inappropriate use has led to significant decreases in groundwater levels. There are several negative effects of declining groundwater levels on the ecosystem. Most directly, a fall in groundwater levels is a sign of groundwater depletion, which puts at risk the aquifer's ability to sustain growth (Omvir Singh and Amrita Kasana, 2017). Many issues could develop as a result of the static water level dropping quickly. In terms of space and time, the natural supply of groundwater is typically constrained. The demand for this scarce resource has skyrocketed recently. The yield capacity of the groundwater supply is decreasing as a result of this excessive stress and it is now widely understood that they must be conserved. It is obvious that this resource needs to be protected and used wisely for sound

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development. Helsel and Hirsch (1992) and Thakur and Thomas (2011) investigated the changes in the values of a random variable over some period of time using non-parametric test. Tabari (2011) determined the temporal trends in groundwater level using Mann Kendall's test and Sen's slope estimator. Machiwal (2013) identified the long-term trend of annual rainfall time series and pre-monsoon and post-monsoon groundwater levels. Ribeiro (2014) used Mann-Kendall's test to detect monthly trends of piezometric time series and their magnitude. The non-parametric Mann-Kendall statistical test was used in this study for a monotonic and piece wise trend analyses of the time-series data. The Mulbagal Taluk, which is one of the drought affected places of Karnataka, is where this study is being conducted. This study's objective is to comprehend groundwater level fluctuation and its geographical mapping using geographic information systems (GIS). The factors that affect groundwater level changes are carefully examined and their effects on groundwater quality and quantity have been thoroughly studied. The groundwater management in the research region will benefit from this exploratory study.

STUDY AREA

Mulbagal Taluk, Kolar District of Karnataka, covering an area of 824 sq.kms under National Aquifer Mapping Project. Mulbagal Taluk of Kolar District is located between north latitude 160 15' and 160 54' & east longitude 760 17' and 770 17' and is covered in parts of Survey of India Toposheet Nos. 57 K/7, 57K/8, 57K/11 and 57K/12. Mulbagal Taluk has a population of 231302 people, with 116494 men and 114808 women, as per the 2011 Census. Out of the total population of 231302, about 187269 people live in rural areas and 44043 people live in urban areas, or 81% (rural) and 19% (urban) of the total population of the Taluk respectively.

Mulbagal Taluk has a semi-arid climate with hot summers and little rainfall. In terms of agriculture, it is in the eastern dry zone which receives an annual normal rainfall of 760 mm in 50 normal rainy days.

Fig 1: Study area

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Topography

Geomorphologically, the Taluk region is made up of uplands on granite and gneisses, which are excellent for farming. The area's physiography is characterized by undulating scenery with vast valleys and elevations ranging from 700m to 1116m above msl with a considerable degree of slope. Mulbagal Taluk is located in the fertile and undulating Palar Valley. Topographic divides between the Palar, north and south Pennar catchments are what create the region's overall topographic features. There are no rivers that flow continuously. Numerous tanks are fed by a few streams that spring in the hills. These tributaries are transient, flowing only during the monsoon season and ceasing to exist in the summer. The region has a semi-dendritic to dendritic drainage system.

Groundwater Level

It is crucial to evaluate the qualitative and quantitative changes in the groundwater regime across time and geography because groundwater is replete and dynamic by nature. In the zone of saturation, groundwater is found in the unconsolidated alluvial material's pore spaces. The depth to water table map was created using information gathered from CGWB and KSNDMC.

Geology

The District is supported by granites, gneisses, schists, laterites and alluvium. The formations mentioned above contain some basic dykes. The majority of the District is composed of granites and gneisses. Schists are mostly found in two locations: the area surrounding the Kolar Gold Fields and the northwest corner of the Gauribidanur Taluk. In the Taluks of Kolar, Srinivaspura and Sidlaghatta, laterites are sparsely distributed. Only river routes include alluvium. Well-defined structural valleys are occupied by fractures or lineaments, the bulk of which trend NE-SW.

METHODOLOGY

15 bore wells around the Mulbagal Taluk have chosen to monitor the water level within the span of four seasons (2019-2020) i.e. Data from the pre-monsoon and post-monsoon seasons for the years 2019 and 2020, respectively. A camera based water level measurement device has been used to record depth to water level throughout pre- and post-monsoon seasons (2019–2020). Data on pre-monsoon water levels were obtained in May of the years 2019 and 2020, respectively, while data on post-monsoon water levels were acquired in November of the years 2019 and 2020, respectively. Secondary data of pre- and post-monsoonal groundwater levels for 13 years (2006 to 2018) in the same study area that is being used for monitoring of groundwater level were collected from KSNDMC. Maps of the slope, geology and drainage maps had done using GIS software such as Arc Map. Base map obtained from the Geological Survey of India. Detailed methodology has been given in the flow chart below.

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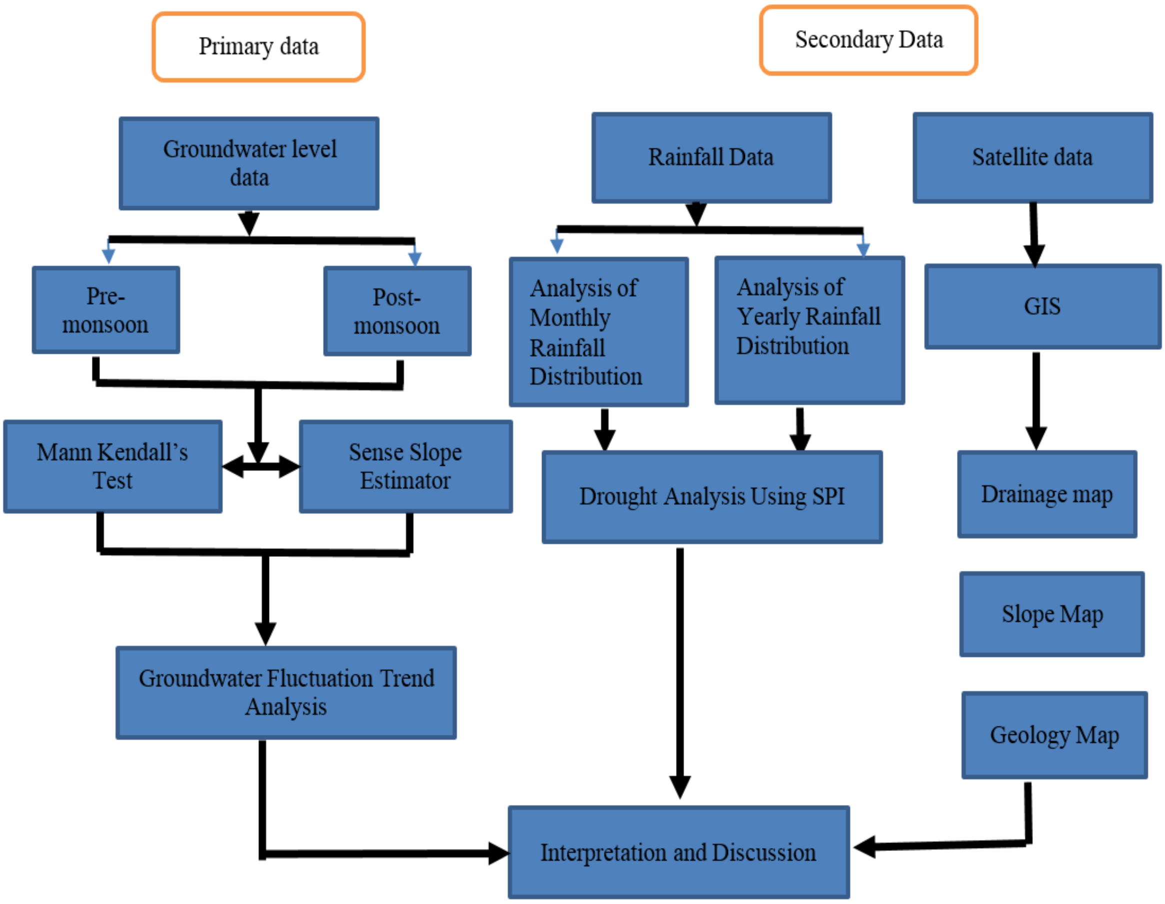

Fig 2: Flow chart of methodology

RESULTS AND DISCUSSIONS

Geology and geological structures

From a geological perspective, the research region's geology is composed of granitoid gneiss, granite, schist, metabasalt, gneiss and dykes. Granitoid gneiss and granites makes up the majority of the study area fig 3. The granitoid gneiss class and granites contains the majority of the monitoring wells. Due to hydrogeological property of granitoid gneiss and granites, these are considered as good aquifers. As the receiving rainfall is very less in the study area and large scale withdrawals of groundwater to wells in these area shows medium to low water level fluctuation. Granitoid gneiss is a high-grade metamorphic rock that was created by the high temperature and pressure metamorphosis of igneous rock. Granite gneiss typically has medium to coarse grains and is hard. Granite gneiss can be fairly permeable material despite having a polished, impervious-appearing because of its tiny crystal structure (S. Chandra et al. 2015). Granitoid gneiss and granites can easily allow infiltrated water to trickle down to shallow

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aquifers due to its excellent porosity. Despite this, the existence of fractures, fissures and other secondary porosity enhances the process of recharging shallow aquifers, causing reduced WLF of related wells.

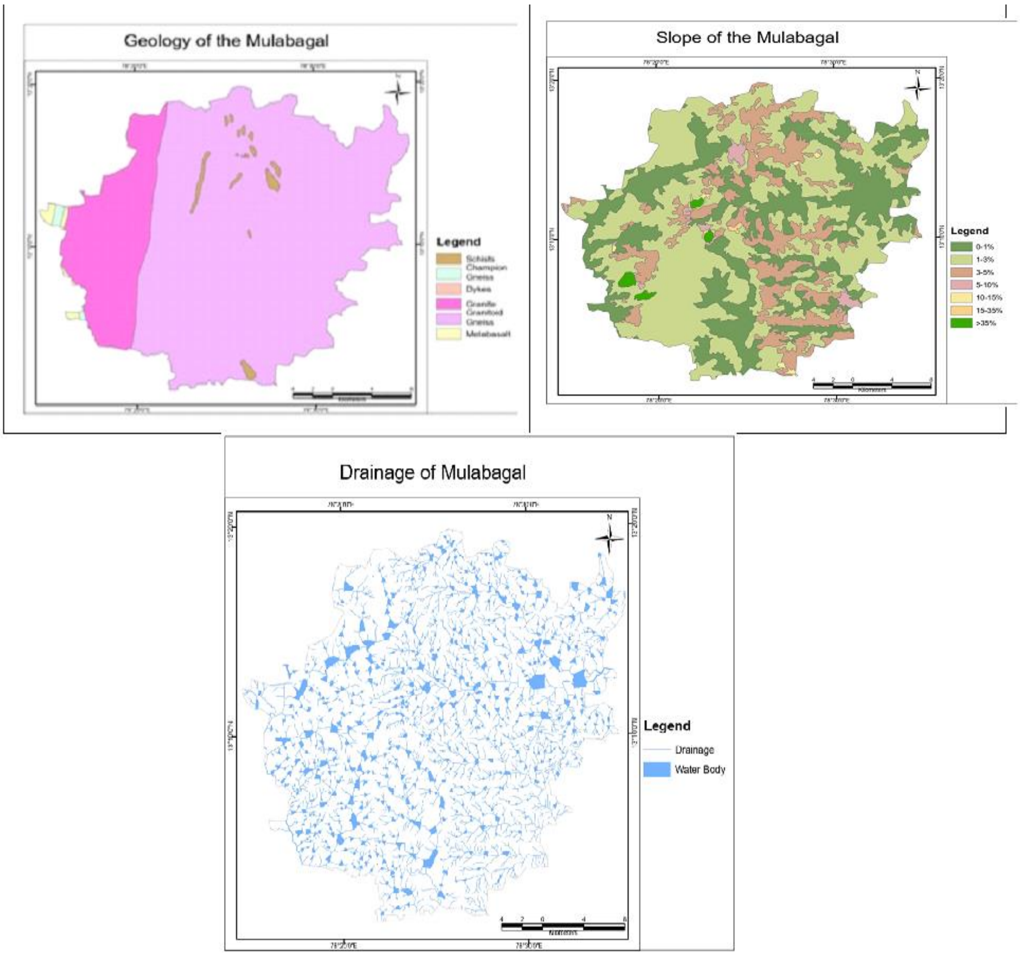

Fig 3: Geology, Slope and Drainage map of the study area

Rainfall analysis

Rainfall data has been collected from the Karnataka state disaster monitoring center Bangalore. The rainfall distributional variance over the region is investigated using statistical parameters of annual and monthly rainfall data. To comprehend the distribution and variability of yearly, seasonal and monthly rainfall in the research locations, statistical studies were carried out. To look for changes in annual rainfall means that were statistically significant, we utilized "Analysis Of Variance" (ANOVA). Table 1 shows the summery of ANOVA for the total period (1997-2020).

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Table 1: Summery of ANOVA

Summary of ANOVA				
Groups	**Count**	**Sum**	**Average**	**Variance**
1997	12	792.72	66.06	3385.246
1998	12	791.54	65.96167	3684.568
1999	12	759.86	63.32167	3076.505
2000	12	777.1	64.75833	3306.295
2001	12	754.1	62.84167	3643.266
2002	12	810.24	67.52	4747.593
2003	12	755.18	62.93167	3242.467
2004	12	704.6	58.71667	2563.78
2005	12	852.56	71.04667	5194.925
2006	12	1106.7	92.225	9606.708
2007	12	766.9	63.90833	3258.308
2008	12	792.62	66.05167	4110.146
2009	12	865.92	72.16	6791.047
2010	12	772.5	64.375	3198.937
2011	12	744.2	62.01667	2948.742
2012	12	629.64	52.47	1921.879
2013	12	744.68	62.05667	3033.724
2014	12	731	60.91667	2910.232
2015	12	770.06	64.17167	3099.567
2016	12	784.6	65.38333	4178.511
2017	12	807.4	67.28333	3939.383
2018	12	731.6	60.96667	2950.612
2019	12	757.2	63.1	3321.082
2020	12	1024.1	85.34167	8372.584

The above summery table explains about the total rainfall received in each year and the average of rainfall in every year and the variance between the months in the same year. As per the summery table, the study area received a highest rainfall of 1106mm in the year 2006 and least rainfall of 629.64mm in the year 2012.

Table 2: Results of ANOVA

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	17940.94	23	780.041	0.194028	0.999987	1.570294
Within Groups	1061347	264	4020.254			
Total	1079288	287				

The above Table shows a results of ANOVA. This table shows if there were any significant differences in the mean yearly rainfall. The findings showed that P value is greater than 0.05 indicating there was a highly significant difference in yearly rainfall during a period of 24 years (1997-2020).

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Annual and seasonal rainfall distribution

As per the rainfall data obtained from the KSNDMC for a period of 24 years (1997-2020). It is observed that the average rainfall in the study area is 792.79mm. The study area received highest rainfall of 1106mm in 2005 and 1024mm in 2020 in a span of 24 years. The annual and seasonal rainfall distribution is shown in the Fig 4.

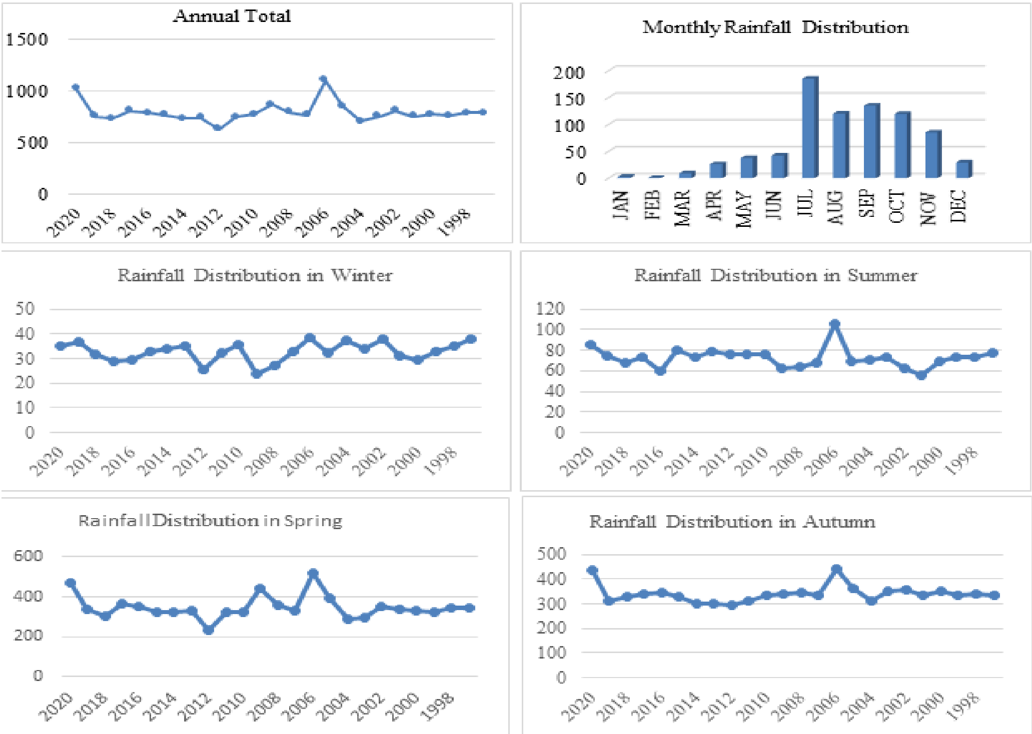

Fig 4: Annual, monthly and seasonal rainfall distribution

Standard Precipitation Index (SPI)

By definition, a drought is a protracted period with exceptionally little rain, particularly one that has a negative impact on the environment or living conditions. Rainfall is to be seen as a sign of the climate's usual wet and dry conditions. It is one of the most significant risks related to water. It significantly affects social, economic, environmental and agricultural systems (Ravi Shah et al., 2015). Table 3 shows the categories of drought based on SPI value. Drought analysis has been carried out in the study using Standard precipitation index (SPI). One of the most popular drought indicators is the standardized precipitation index (SPI), which is used extensively in research on drought analysis and drought forecasting in a variety of domains, including meteorology, agriculture and hydrology (Qianfeng Wang et al., 2022). As per the SPI study it is found that the study area is in extreme drought condition. As the analysis had done for a period of 24 years, majority of the period is under drought condition. Table 4 shows the different categories of drought based on the Standard precipitation index value.

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Table 3: Standard categories of drought based on SPI value

Drought Category	SPI VALUE
Extremely Wet	2.0+
Very Wet	1.5 to 1.99
Moderately Wet	1.0 to 1.49
Near Normal	minus 0.99 to 0.99
Moderately Drought	minus 1.0 to 1.49
Severely Drought	minus 1.5 to 1.99
Extremely Drought	minus 2.0 to less

Table 4: Different categories of drought based on SPI index

Extremely Draught				Normal Draugt			
year	month	SPI	Category	YEAR	MONTH	SPI INDEX	CATEGORY
2002	6	-2.93	Etreme Draugt	1997	2	1.28	Normal Draugt
2009	12	-2.69	Etreme Draugt	1997	6	1.05	Normal Draugt
2012	7	-2.78	Etreme Draugt	1997	8	1.16	Normal Draugt
Severely Draught				1997	12	1.07	Normal Draugt
year	month	SPI	Category	1998	2	1.28	Normal Draugt
2000	5	-1.5	severely Draught	1998	9	1.02	Normal Draugt
2001	3	-1.77	severely Draught	1999	6	1.25	Normal Draugt
2001	4	-1.94	severely Draught	1999	8	1.16	Normal Draugt
2002	5	-1.7	severely Draught	2000	4	1.01	Normal Draugt
2002	8	-1.49	severely Draught	2000	8	1.33	Normal Draugt
2003	8	-1.89	severely Draught	2000	11	1.13	Normal Draugt
2004	8	-1.79	severely Draught	2002	12	1.61	Normal Draugt
2005	4	-1.69	severely Draught	2003	3	1.69	Normal Draugt
2008	5	-1.5	severely Draught	2004	12	1.07	Normal Draugt
2009	3	-1.77	severely Draught	2005	10	1.95	Normal Draugt
2011	3	-1.77	severely Draught	2006	2	1.28	Normal Draugt
2012	3	-1.77	severely Draught	2006	4	2.45	Normal Draugt
2012	12	-1.98	severely Draught	2006	5	2.67	Normal Draugt
2016	4	-1.69	severely Draught	2006	6	2.03	Normal Draugt
Moderately Draught				2006	7	2.31	Normal Draugt
YEAR	MONTH	SPI	CATEGORY	2006	8	1.49	Normal Draugt
1997	1	0.48	Moderately Draught	2006	9	2.74	Normal Draugt
1997	3	0.02	Moderately Draught	2006	10	1.77	Normal Draugt
1997	4	0.08	Moderately Draught	2006	11	1.65	Normal Draugt
1997	5	0.88	Moderately Draught	2006	12	1.34	Normal Draugt
1997	7	-0.33	Moderately Draught	2007	1	1.9	Normal Draugt
1997	9	0.37	Moderately Draught	2007	3	1.69	Normal Draugt
1997	10	-0.21	Moderately Draught	2008	10	1.04	Normal Draugt
1997	11	-0.99	Moderately Draught	2009	7	1.66	Normal Draugt
1998	1	0.48	Moderately Draught	2010	1	1.9	Normal Draugt
1998	3	0.02	Moderately Draught	2010	10	1.59	Normal Draugt
1998	4	0.28	Moderately Draught	2013	2	1.28	Normal Draugt
1998	5	-0.06	Moderately Draught	2013	3	1.69	Normal Draugt
1998	6	0.22	Moderately Draught	2015	4	1.01	Normal Draugt
1998	7	-0.17	Moderately Draught	2015	11	1.04	Normal Draugt
1998	8	0.73	Moderately Draught	2016	11	2.15	Normal Draugt
1998	10	-1.13	Moderately Draught	2017	8	1.57	Normal Draugt
1998	11	-0.78	Moderately Draught	2017	11	1.3	Normal Draugt
1998	12	0.23	Moderately Draught	2019	2	2.24	Normal Draugt
1999	1	-1.31	Moderately Draught	2019	3	1.69	Normal Draugt

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Mann-Kendall's Test

Sen's analysis and the Mann-Kendall (MK) test are the two statistical methods that were used to determine the trend of the research area's groundwater level over the course of the study on a temporal scale to predict the groundwater in the future scenario (Parimita Saikia and Dr. Narayan Chetry 2020). Mann Kendall's test was initially proposed by Mann (1945) and Kendall (1975) later computed the test statistic distribution. The Mann-Kendall test has been extensively used to compare randomness to hydrological trends (Helsel D R et al., 1982). Since it does not require that the data be normally distributed and is still applicable in the case of missing and censored observations in the data pertaining to the time series, the MK test based on rank is among the family of non-parametric statistical tests that is highly recommended for statistically confirming the existence of any significant monotonic upward or downward trend in the hydrological data of interest over time (Brototi Biswas, Sanjay Jain and Sanchita Rawat 2018). The interpolated data were put to the Man-Kendall's test. All the data values are compared to each individual subsequent data value.

Step-1

$$\text{Sign } (x_j - x_k) = 1 \text{ if } (x_j - x_k) > 0$$

$$= 0 \text{ if } (x_j - x_k) = 0$$

$$= \text{-1 if } (x_j - x_k) < 0$$

Step-2

$$S=\sum_{k-1}^{n-1}\sum_{j=k+1}^{n} sign\ (x_j - x_k)$$

The MK statistic 'S' is considered to have a starting value of 0 (i.e. no trend) and it is increased by 1 if a data value from a later period is greater than a data value from an earlier time. However, if a later data value is lower than a previous data value collected earlier, is decreased by 1. The final value of 'S' is the net consequence of all of these increments and decrements.

Step-3

$$Var(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{k=1}^{n} t_k\,(t_k - 1)(2t_k + 5)]$$

Step-4

$$Z_s = \begin{cases} \dfrac{s-1}{\sqrt{var(s)}} if\ s > 0 \\ 0 \qquad\quad if\ s > 0 \\ \dfrac{s+1}{\sqrt{var(s)}} if\ s > 0 \end{cases}$$

Where Z is the final index value, based on which confidence level is determined. The below table 5 Shows the percentage of confidence level based on the Z value.

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Table 5: MK standard table with confidence level and Z-value

Confidence Level	[Z-value]
90%	1.65
91%	1.7
92%	1.75
93%	1.81
94%	1.88
95%	1.96
96%	2.05
97%	2.17
98%	2.33
99%	2.58

Around the study area 15 bore wells have been selected for monitoring of water level for four seasons (2018–2020) viz. post-monsoon data for year 2018 and 2019, respectively and pre-monsoon data for year 2011 & 2020, respectively. Depth to water level has been recorded using a camera-based water level recorder for pre- and post and monsoon periods (2018–2020). Pre-monsoonal water level data has been collected in the month of May in year 2018 and 2019, respectively while post-monsoonal water level data has been collected in the month on November in year 2019 and 2020, respectively. From CGWB 20 years 1997-2017 of groundwater data has been collected and used for the comparison study. Sen's slope estimator and the Mann-Kendall (MK) test (table 6) were used as statistical tools to anticipate the future groundwater situation and to assess the pattern of the research area's groundwater level through time. Each of the neighboring locations' groundwater fluctuations was sampled. As a result, the trend value reflects the overall variation in groundwater (Parimita Saikia and Narayan Chetry, 2020). It is observed that from the pre monsoon data all the observation well locations shows decreasing trend. In the post monsoon location no MBL9 and MBL13 sowed increasing trend rest all the wells sowed decreasing trend.

Table 6: Trending results of Mann Kendall's and Sens slope analysis

	PRE-MONSOON 2018-2020			POST MONSOON 2018- 2020		
OBSERVATION WELL LOCATION	MANN KANDALL'S	SEN'S SLOPE	TREND	MANN KANDALL'S	SEN'S SLOPE	TREND
MBL1	-0.04447	-0.421	DECREASING	-0.82355	-0.393	DECREASING
MBL2	-0.75443	-0.067	DECREASING	-0.63014	-0.047	DECREASING
MBL3	-0.13165	-0.077	DECREASING	-0.00588	-0.061	DECREASING
MBL4	-0.12942	-0.162	DECREASING	-0.64052	-0.121	DECREASING
MBL5	-0.13165	-0.301	DECREASING	-0.20588	0.276	DECREASING
MBL6	-0.50887	-0.121	DECREASING	-0.00588	-0.105	DECREASING
MBL7	-0.13277	-0.137	DECREASING	-0.00588	-0.119	DECREASING
MBL8	-0.75369	-0.199	DECREASING	-0.83014	-0.186	DECREASING
MBL9	0.37684	-0.174	DECREASING	0.12133	0.195	INCREASING
MBL10	-0.75295	-0.096	DECREASING	-0.63531	-0.071	DECREASING
MBL11	-0.75369	-0.176	DECREASING	-0.63014	-0.135	DECREASING
MBL12	-0.75443	-0.089	DECREASING	-0.85441	-0.059	DECREASING
MBL13	0.75295	-0.031	DECREASING	0.00588	0.073	INCREASING
MBL14	-0.75295	-0.079	DECREASING	-0.63014	-0.052	DECREASING
MBL15	-0.75147	-0.091	DECREASING	-0.25441	-0.079	DECREASING

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CONCLUSION

Sen's slope estimator and the nonparametric Mann Kendall's test, two commonly used methods were utilized for trend analysis. ANOVA is used to study the significant difference in the rainfall pattern and graphically represented the annual and seasonal rainfall distribution in the study area. From the SPI study it is found that the Mulbagal Taluk is undergone in to severely drought to extreme drought category, since the receiving rainfall is less than the discharge of groundwater from the aquifers. Supporting to the SPI drought results, Mann Kendall's analysis also showed a decreasing trend in groundwater table level in both pre and post monsoon seasons. From the overall study it is found that groundwater level decreased to an extreme levels, where the study area is falling under the critical zone which may need extensive water conservation methods need to be adopted to overcome from the current situation.

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