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Premonsoon Groundwater Trends for Nanjangud Taluk, India: A Spatio-Temporal Analysis

M.C. Manjunatha
DBT-BUILDER, JSS AHER, Sri Shivarathreeswara Nagar, Mysuru-570 015, India
E-mail: mcmanju1@gmail.com

Abstract: Groundwater is a crucial natural resource that plays a vital role in providing drinking water and supporting various industries and ecosystems. The study investigates the trends in premonsoon groundwater levels in southern Karnataka state, focusing on understanding fluctuations before the monsoon season (Jan-May). The analysis reveals a predominant decreasing trend in groundwater levels, with varying rates of decline observed across monitoring wells. The spatial distribution of groundwater trends was analysed by statistical methods and IDW tool of GIS software. More than 46% of the studied region indicated a declining trend and falling from south-east to eastern parts between 2003 and 2019. The output results contribute to a comprehensive understanding of premonsoon groundwater dynamics and their implications for water resource management by analyzing decadal fluctuations in groundwater depths.

Keywords: Premonsoon, Groundwater trends, Nanjangud, GIS

Groundwater is essentially important for rural communities, where about 90% of drinking water is sourced from groundwater (Dubey et al 2022). It is estimated that as much as 50% of the global population relies on groundwater for their drinking water needs, with approximately 43% of all water used for irrigation coming from groundwater sources (Johnson et al 2022, Van Loon et al 2024). This hidden water source, stored in aquifers beneath the Earth's surface, makes up 99% of the Earth's liquid fresh water and significantly contributes to the water cycle, impacting rivers, lakes, wetlands, and other surface water bodies (Poeter et al 2020). Hot spots of groundwater depletion have been identified in arid and semiarid regions worldwide, with significant depletion has been observed in countries like India, the United States, China, Iran, Mexico, and Saudi Arabia, which collectively account for a substantial portion of global annual water extraction. This issue poses challenges such as reduced flows in streams and wetlands, land subsidence, water quality degradation (Jakeman et al 2016), and increased pumping costs, highlighting the urgent need for sustainable groundwater management practices on an international scale. Groundwater also plays a critical role in stabilizing water levels in rivers, lakes and wetlands during drier months, providing a sustainable water source for wildlife and plants in these environments.

The spatial and temporal analyses of rainfall and groundwater levels show a declining trend in the pre-monsoon groundwater levels (Halder et al 2021), with rates of decrease varying across wells in Nanjangud taluk. The decrease in pre-monsoon groundwater levels can have adverse effects on irrigation practices in the taluk, as it reduces the availability of water for agricultural purposes, impacting crop growth and productivity. Additionally, declining groundwater levels can affect domestic water supply, leading to water scarcity for households relying on groundwater sources for daily use. Sustainable management of groundwater resources is crucial to maintain a balance between water availability and demand for various purposes, especially in regions where groundwater serves as a primary source of water for agriculture, drinking, and industrial activity (Li et al 2021).

Research has shown that premonsoon water levels can vary significantly between years, impacting water availability for various uses such as agriculture, drinking water, and industry (Vaibhav Deoli and Deepak Kumar 2020). Monitoring these trends is essential for assessing changes in water availability, especially in regions heavily reliant on groundwater. Factors like rainfall patterns, land use changes, and groundwater pumping practices play a significant role in influencing premonsoon groundwater trends. Sustainable management of groundwater is paramount, especially with the expected increase in the global population by 2100, as overexploitation and pollution threaten this finite resource. Historically the groundwater was mostly used by agriculture and irrigational activities in the taluk earlier, but since last few decades its utilization was noticed by various industrial and factories observed next to Perennial River Kapila. This would immensely impact on groundwater resource management in the vicinity near future. The present aims to understand the dynamics of premonsoon groundwater levels using GIS tool in Nanjangud taluk mainly focusing on the long-term groundwater sustainability.

MATERIAL AND METHODS

Description of the Study area: The taluk of Nanjangud is measured an area of 983.95 sq km and situated between 72^0 26' and 76^0 56' E longitude and 11^0 51' and 12^0 13' N latitude (Fig. 1). The general altitude is 600-700 ft above MSL covering 184 villages (Manjunatha and Basavarajappa 2021). With the exception of a few scattered hillocks to the south and west, this forms practically a plain boundary. The highest point, 3111 ft above MSL, is located in the southwest corner and the overall slope is north to south, with a narrow but gradually expanding depression located in the Kapila river basin.

Data used and analysis: The taluk boundary was freely downloaded from K-GIS, Govt. of Karnataka website and the groundwater level data was acquired from District Groundwater Board, Mysuru, Govt. of Karnataka for a period of 16 years (2003-19) from 10 observation groundwater well points (Table 1). Spatio-temporal maps were generated by calculating depths, and drawing contours using methods like Inverse Distance Weighted (IDW) tool in ArcGIS software (Manjunatha et al 2023). IDW tool was processed on groundwater level analyses (meters, bgl) for pre-monsoon seasons (Jan-May) on four year fluctuation (2003-07, 2007-11, 2011-15, 2015-19) and long-term fluctuation study (2003-19). This study specifically focusing on premonsoon periods between Januarys to May to avoid seasonal recharge effects from rainfall.

RESULTS AND DISCUSSION

Groundwater trend analysis: The fluctuations of groundwater level yield a precise geological formation that increases the point value of recharge, which is computed from the rise in a well's water level. Over a 16-year period (2003-2019), 10 representative observation bore well points were taken into consideration in order to analyse the fluctuations in groundwater levels from January to May (pre-monsoon season) (Table 1, Fig. 2) (Manjunatha et al 2020). The deeper water levels were recorded as 29.96 m at Hanumanapura observation well measured below ground level (bgl). Groundwater levels were showing declining patterns from the south-eastern (2003) to east (2019) (Table 3, Fig. 3).

Over-exploitation of subsurface water through pumping wells was noticed in eastern parts contributing to groundwater declining levels (Table 2, Fig. 2). Bar graphs of groundwater data revealed the groundwater trend analyses over a period of 16 years (2003-19) (Table 1, Fig. 4). Prominent lineament structures like dykes and fractures are noticed along the NS, NE-SW, and NW-SE directions that control regional subsurface water flow and help in natural recharge of groundwater along various streams, rivers and ponds. More than 46% (461.92 sq km) of the study area showed declined trend from 2003-2019 in groundwater depth (Table 4). Most parts of eastern Nanjangud showed higher demands of groundwater resources, especially for domestic and agricultural activities during summer months. Inclining trend of groundwater levels in all observation well points were observed due to flash floods and heavy rainfall occurred during August 2018 in Wayanad region of Kerala state (Manjunatha and Basavarajappa 2022). More water intensive crops such as paddy, cotton, sugarcane and others could be avoided in critical and over-exploited areas. Artificial recharge structures (ARS) are the best techniques to recharge aquifers within town limits for reducing the load on urban water supply systems. Roof top Rain Water Harvesting (RRWH) structures would be most suitable for larger industrial structures to overcome their demand of groundwater.

Premonsoon groundwater fluctuations in India are

Table 1. Average pre-monsoon groundwater level meters (2003-2019)

Station name	Latitude	Longitude	2003	2007	2011	2015	2019
Deburu	12.11385	76.61656	5.24	5.37	4.81	4.52	4.14
Hanumanapura	12.06005	76.82569	0.4	13.21	21.28	29.96	27.27
Hullahalli	12.09455	76.55575	12.41	11.2	9.61	9.22	0.1
Hura	12.00258	76.54400	9.27	5.94	7.97	11.73	9.93
Kalale	12.07446	76.66335	9.26	7.84	6.86	7.7	5.31
Kothanahalli	11.90696	76.53156	6.03	6.05	7.02	7.07	4.45
Kowlande	12.03232	76.79744	17.33	19.36	18	13.09	13.97
Nanjangud	12.11626	76.67928	3.94	2.65	3.41	3.32	2.66
Sindhuvallipura	12.03095	76.63965	10.38	12.03	10.74	12.73	9.28
Thagaduru	12.09297	76.80928	0.7	17.95	7.22	17.16	23.3

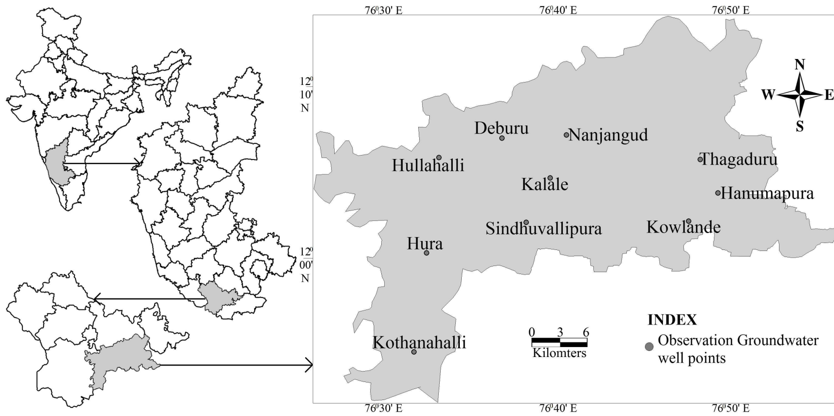

Fig. 1. Groundwater well points map of Nanjangud taluk

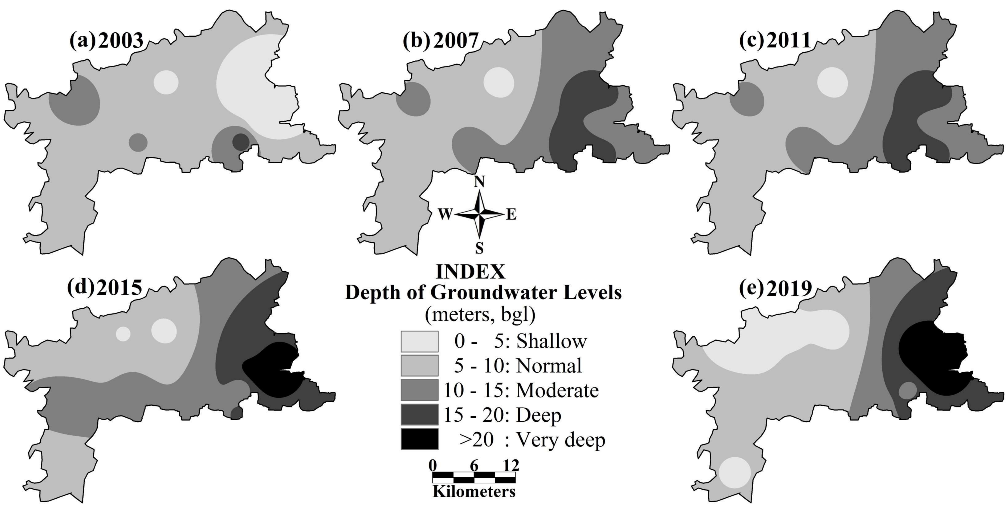

Fig. 2. Premonsoon Groundwater Depths maps for the years (a) 2003, (b) 2007, (c) 2011, (d) 2015 and (e) 2019

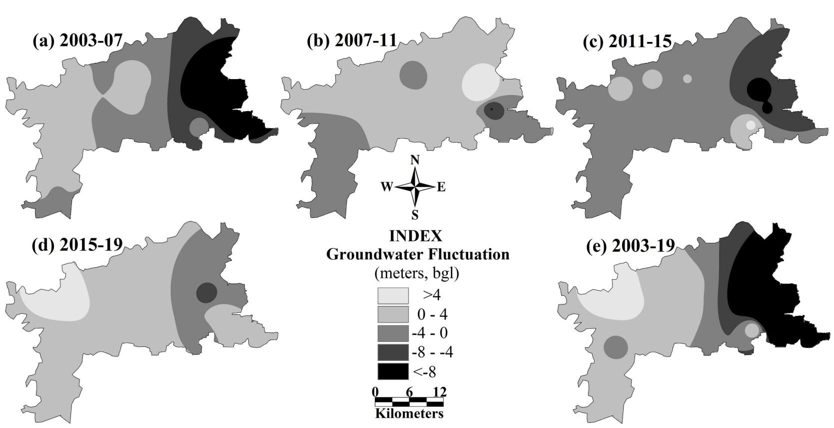

Fig. 3. Premonsoon Groundwater level fluctuation maps for various years (a) 2003-07, (b) 2007-11, (c) 2011-15, (d) 2015-19 and Long-term fluctuation for (e) 2003-19

influenced by various factors, including climate conditions, human activities, and geological characteristics (Vinod Kumar and Vipin Kumar 2020). Studies indicates that around 23% of areas in India experienced a decline in groundwater levels from 1996 to 2016 during the premonsoon period (Gopal Krishan et al 2015). Groundwater based study is a much necessary task in major towns of Karnataka due to many uprising issues of rapid increase of population, water supply & demand in various fields of major industries, factories, urbanization, mining areas and others (Urvashi Sharma et al 2020). Recent studies indicated that some northern Karnataka regions experienced a rise in groundwater levels, while southern regions often face declines. The depth of groundwater levels during the premonsoon season has been recorded between 7 to 22 mts bgl in various districts (Surender Kumar et al 2020). Insufficient premonsoon rainfall often leads to a decline in water levels due to increased evaporation and higher extraction for irrigation purposes. Agricultural practices play a pivotal role in groundwater dynamics. The extensive use of tube wells for irrigation contributes to the depletion of groundwater resources, particularly in regions dependent on monsoon rains for crop cultivation. For instance, fluctuations can range dramatically from below 2-6 mts depending on local geological conditions and rainfall distribution.

The final output maps were generated in analyzing the pre-monsoon groundwater trend using a period of 16 years (2003-19) of observation bore-well point's data. The groundwater levels of Nanjangud taluk were heavily being withdrawn through pumping wells in eastern parts due to the existence of various major, medium and minor industries contributing to groundwater decline. The presence of numerous industries in the area, such as distilleries and other manufacturing units, lead to the discharge of effluents and sewage directly into the Kapila River, which flows through the industrial zones. This pollution contributing to an increase in nutrients in the sediments, affecting the overall water quality and ecosystem health (Mohammad Amin et al 2016).

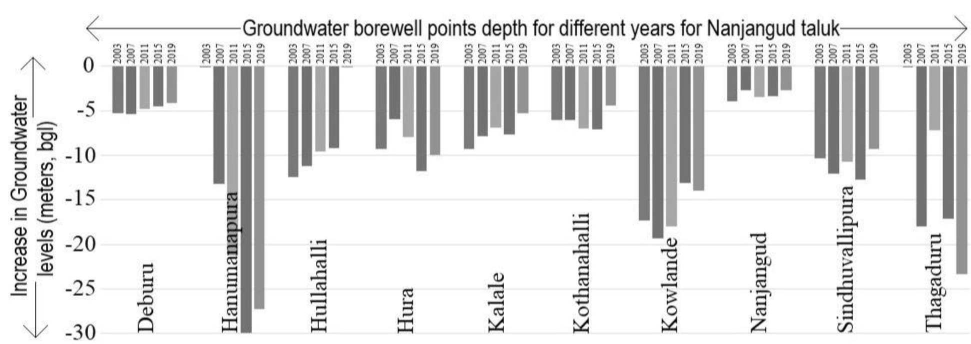

Fig. 4. Bar graph depicting groundwater fluctuations for various years (2003-19)

Table 2. Area under different groundwater depth zones in various years

Depth of groundwater levels (m, bgl)	2003	2007	2011	2015	2019
0 – 5	169.76	20.72	21.46	18.89	181.93
5 – 10	719.73	514.81	657.96	403.13	422.58
10 - 15	87.84	333.69	203.83	344.58	130.87
15- 20	6.62	114.73	96.67	154.82	146.06
>20	Nil	Nil	4.03	62.53	102.51

Table 3. Area under different groundwater depth fluctuation in various years

Fluctuation in depth to water levels (m, bgl)	Area (km^2)				Trends in fluctuation
	2003 – 07	2007 – 11	2011 – 15	2015 – 19	
<4.0	-	45.68	2.91	95.38	Inclination
0.0 – 4.0	365.47	637.07	61.47	658.13	
-4.0 – 0.0	282.71	289.38	732.33	216.29	Declination
-8.0 – -4.0	147.62	11.69	163.57	14.15	
> -8.0	188.15	0.13	23.67	-	

Table 4. Area under long-term fluctuation from 2003 to 2019

Fluctuation in depth to water level (m, bgl)	2003 - 19	Trend in fluctuation
<4.0	91.27	Inclination
0.0 – 4.0	430.76	
4.0 – 0.0	137.59	Declination
-8.0 – -4.0	78.97	
> -8.0	245.36	

Geospatial approach showed a better illustrations in continuous monitoring of groundwater levels using observation wells which is crucial for assessing trends over time. This has been very critical for successful analysis, prediction, validation and involves developing models that can guide environmental and socioeconomic planning related to groundwater resources.

CONCLUSIONS

Nanjangud taluk showed a wide variation of 29 mts in groundwater fluctuations at Hanumanapura observation well point due to natural and anthropogenic activities. Industrial activities in Nanjangud taluk showed a significant impact on groundwater quality and availability. Integrating GIS tools with statistical groundwater data would better portray the groundwater dynamics, availability and sustainability especially for the industrial town in India. Regular analysis provides valuable insights for policymakers to improve groundwater levels, aquifer-recharge potential, and regular monitoring of over-dependency regions of groundwater resources across the state. Implementing GIS based monitoring, mapping high-potential areas, community engagement and integrated water resource management can help in predicting water availability, and efficient water use practices to create a comprehensive groundwater management plan. The outcome of this study can help the farmers to take necessary steps in their crop rotation and cultivation who depend only on shallow groundwater levels. Utilizing GIS techniques in Nanjangud taluk offers a robust framework for understanding and managing premonsoon groundwater fluctuations. By focusing on aquifer characteristics, drainage patterns, and potential zones identified through GIS, stakeholders can make informed decisions to ensure sustainable groundwater use in the region.

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