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Precipitation Disparity's Impact on Groundwater Fluctuation Using Geospatial Techniques in the Ranipet District of Southern India

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Abstract: The influence of precipitation differential on groundwater level fluctuation was investigated using geospatial approaches in the Ranipet area of Tamil Nadu, India. There are nine rain gauge stations in the research area, seven of which receive more precipitation than the state's average annual precipitation (1035 mm), namely Panapakkam, Kaveripakkam, Ranipet, Kalavai, Arakkonam, Arcot, and Sholinghur. The other two stations, Walajahpet and Palar, get less than 1035 mm of rain each year. The research area's average annual precipitation is 977.31 mm. During the southwest and northeast monsoon seasons, all five rain gauge sites get more than 100 mm of precipitation. The greatest monthly precipitation is generally recorded in November, while the smallest precipitation is usually recorded in February. Pre-monsoon precipitation in the study region is roughly 59.8 mm, which is essentially non-existent. The following seasons provide precipitation in the order of monsoons: Northeast> Southwest > Post > Pre. The intensity of average annual, pre-monsoon, and post-monsoon precipitation rises westward in the study region, according to the geographic disparity research. Precipitation intensity is higher in the northern region during the SW monsoon season and higher in the southern section during the NE monsoon season. In this region, the lowest, mean, and highest depths of occurrence of groundwater are 0.96, 6.64, and 36.25m, respectively. The regional groundwater level lowers from December to June due to less precipitation during the non-monsoon season. Monsoon precipitation (including SW and NE monsoons) recharges groundwater from June to December, with the highest recharge occurring in December.

Key words: Precipitation, groundwater, GIS, Ranipet, South India.

Introduction

Water is an essential and replenishing resource for life on Earth. Due to rising demand for water for a variety of applications, water shortage occurs in many places of the world. Precipitation distribution and variations influence temperature fluctuation, which influences agricultural productivity in various areas (Aishwarya et al., 2014a, 2014b). Droughts and floods are further exacerbated in many regions by erratic fluctuations in precipitation over time and space. Many planning activities require an understanding of the precipitation disparity (Aishwarya et al., 2023; Brown et al., 1970; Clesceri et al., 1998; Davina et al., 1999). There are also insufficient surface water sources in many regions to sustain daily activities. As a result, groundwater resources are often harvested and exploited for agriculture, industry, and human consumption (Dhamodharan et al., 2016; Elangovan and Dharmendirakumar, 2013; Etier et al., 2020). This draws attention to the presence of groundwater and its varying location, time, and depth. The World Health Organisation (WHO) predicts that India will confront

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water scarcity in the future. As a result, research on groundwater management, knowledge of groundwater level variation, and rainfall analysis are critical to addressing India's water shortage concerns (Govindaraj et al., 2022, 2023a, 2023b).

Necessity of the Study

The study aims to elucidate the intricate relationship between precipitation patterns and groundwater levels in Tamil Nadu's Ranipet district, India, where water scarcity poses a significant challenge. Specifically, the research seeks to address the following objectives:

1. **Assessing Precipitation Variability**: To analyse the spatial and temporal variability of precipitation across the study area over distinct monsoon seasons.
2. **Investigating Groundwater Response**: To examine how fluctuations in groundwater levels correspond to variations in precipitation patterns, particularly during different monsoon seasons.
3. **Understanding Recharge Mechanisms**: To elucidate the impact of regulated flow in the Palar River, resulting from check dams erected by the government of neighbouring Andhra Pradesh, on groundwater recharge dynamics.

Based on these objectives, the following hypotheses guide the study:

1. **H1**: There is a significant correlation between seasonal and monthly variations in precipitation and corresponding fluctuations in groundwater levels across distinct locations within the study area.
2. **H2**: The regulation of the Palar River's flow by check dams influences groundwater recharge processes, leading to observable changes in groundwater levels during different monsoon seasons.

Experimental Section

Study Area

The research area is in the northern section of Tamil Nadu, a South Indian state. The research region is the Ranipet district of Tamil Nadu, which is located between latitudes 12° 35′ 00″ and 12° 55′ 00 ″N and longitudes 78° 30′ 00″ and 78° 50′ 00″E (Figure 1). 2234 km^2 is the total geographical area. According to the 2011 Census,

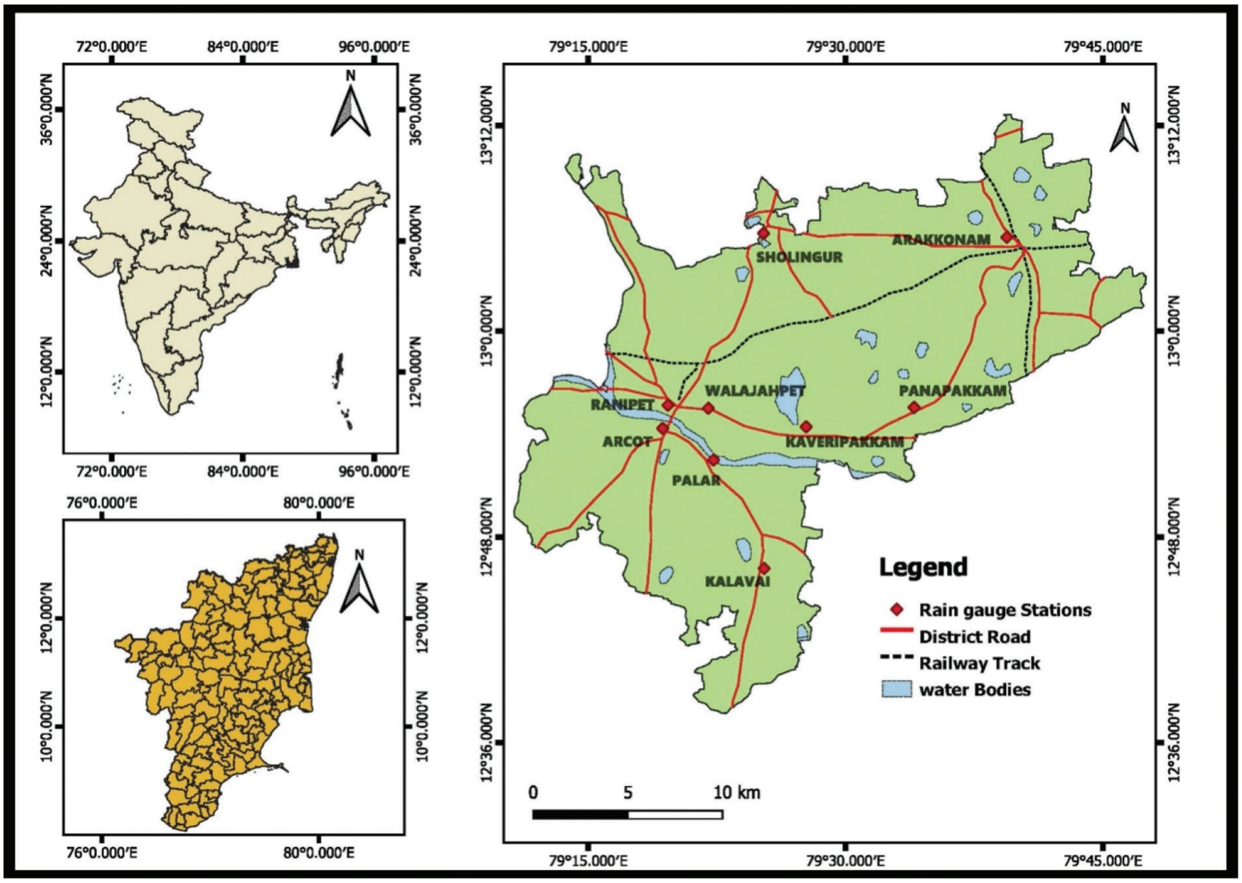

Figure 1: Study area map.

the study region comprises 288 significant communities and a total population of 1,210,277 people.

Materials and Methods

The Institute for Water Studies (IWS), Taramani, Chennai, Tamil Nadu, India, supplied monthly precipitation data for all 9 rain gauge stations from 2012 to 2021 in order to examine the monthly and seasonal fluctuations in precipitation throughout the research region. The research area's 10-year average yearly precipitation was also calculated (Govindaraj et al., 2023c; Karunanidhi et al., 2021; Kavita et al., 2023; Mohamed Sheriff and Zahir Hussain, 2012; Ramesh et al., 2002; Ravishankar and Poogothal, 2008). The past ten years' average annual precipitation for the study region was also calculated.

The GIS method Inverse Distance Weighted (IDW) interpolation was used to illustrate the changes in groundwater levels and precipitation over time. The scatter diagrams and histograms were used to examine the frequency variation in precipitation as well as the monthly, seasonal, and seasonal disparities.

The Institute for Water Studies (IWS), Taramani, Chennai, Tamil Nadu, India, submitted monthly precipitation data for each of the 9 rain gauge stations for a 10-year period (2012-2021) in order to quantify monthly and seasonal precipitation changes throughout the research region. The investigation's entire methodology flowchart is depicted in Figure 2. The research area's 10-year average annual precipitation was also calculated (Siosemarde et al., 2010; Trivedy and Goel, 1986).

Results and Discussion

The nation's expanding need for water resources is one of its most pressing and complicated issues. In response to these challenges, the Tamil Nadu government implemented various initiatives aimed at addressing water scarcity. For instance, laws were enacted requiring the installation of rainwater collection equipment in all homes to augment water resources (Venkatesan et al., 2018, 2019, 2020c). Additionally, to cater to the demand for drinking water, the government constructed two desalination plants in the Ranipet area. Despite these measures, it's crucial to acknowledge that groundwater levels can be influenced by various factors beyond the scope of direct interventions. Factors such as land use changes and hydrological processes play significant roles in shaping groundwater dynamics. The Government Water Act of 2003 was enacted to protect groundwater resources, recognizing the vulnerability of Ranipet's water supply due to uncontrolled extraction (Venkatesan et al., 2022a, 2022b).

Monthly Disparity in Precipitation

The average monthly precipitation acquired from nine rain gauge sites was studied in order to better understand the variance in monthly precipitation over a ten-year period (2012-2021). The 10-year precipitation data for

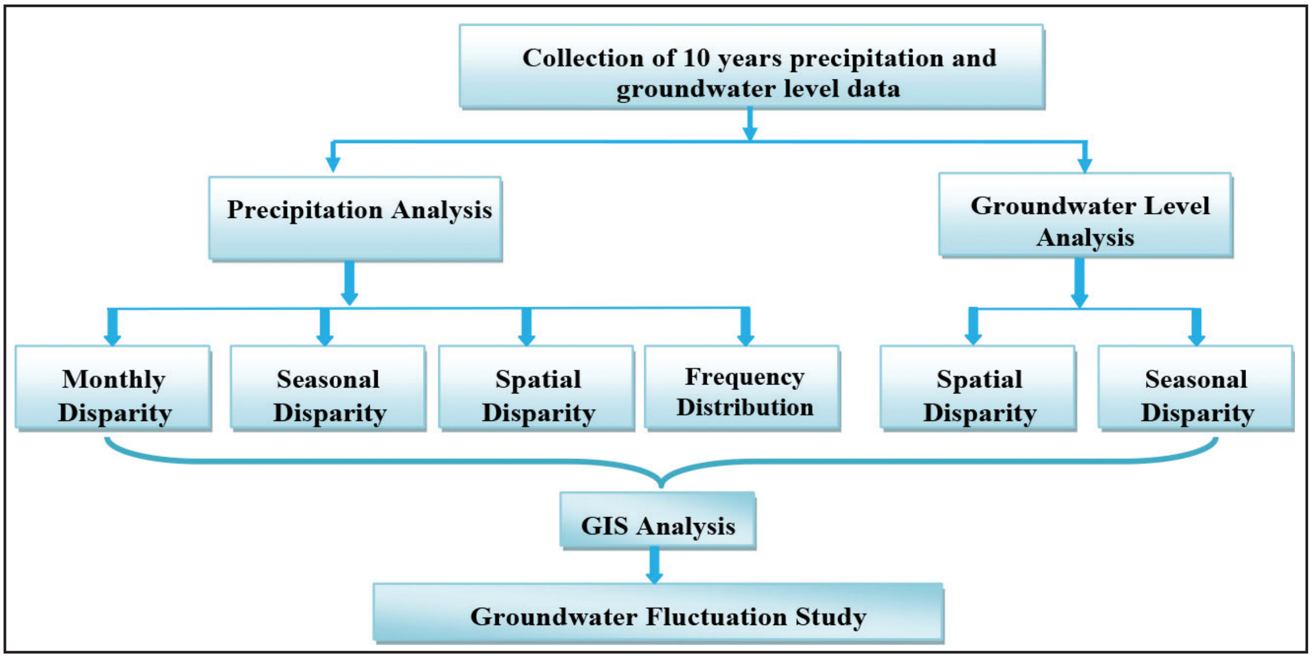

Figure 2: The study's methodology flowchart.

each rain gauge location were shown separately (Figure 3). At seven rain gauge stations: Arakkonam, Kalavai, Kaveripakkam, Palar, Panapakkam, Sholinghur, and Walajahpet, November has the most precipitation (Venkatesan et al., 2023). In July, August, and September, roughly identical amounts of precipitation were reported at the Kalavai rain gauge station. At the Panapakkam rain gauge station, November got the greatest precipitation.

Seasonal Disparities

From 2012 to 2021, the seasonal difference of precipitation demonstrates a similar pattern of precipitation at each of the nine rain gauge locations. Pre-monsoon season accounts for 3 to 17% of precipitation, whereas post-monsoon season accounts for just 1 to 2%. Table 1 shows the percentage contributions to precipitation throughout numerous monsoon seasons. Figure 4 displays the seasonal

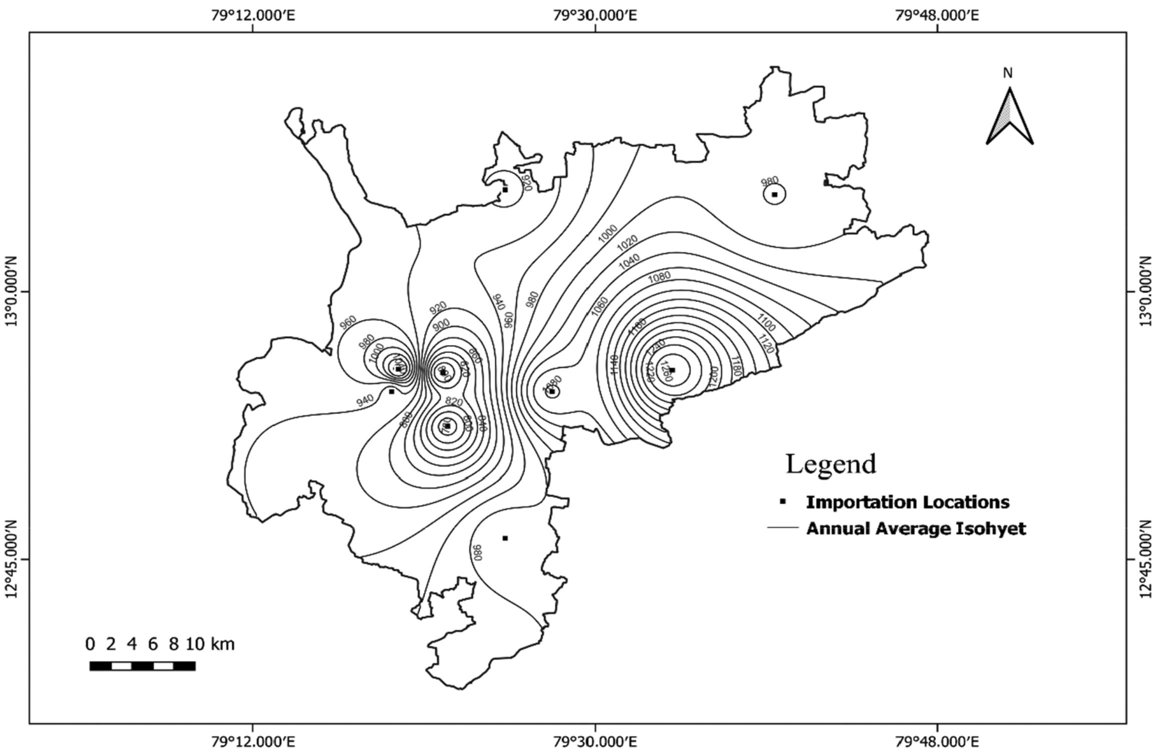

Figure 3: Spatial disparity of average annual precipitation.

Table 1: Average yearly precipitation reported at different Station Rain gauge stations

Rain gauge stations	*Postmonsoon season (mm)*	*Percentage contribution*	*Premonsoon season (mm)*	*Percentage contribution*	*Southwest monsoon season (mm)*	*Percentage contribution*	*Northeast monsoon season (mm)*	*Percentage contribution*
Arakkonam	8	1%	21	3%	120	15%	140	17%
Arcot	5	1%	27	3%	120	16%	120	15%
Kalavai	10	1%	26	3%	116	14%	145	17%
Kaveripakkam	8	1%	26	3%	145	16%	137	15%
Palar	3	0.5%	19	3%	91	14%	114	18%
Panapakkam	9	1%	23	2%	170	16%	169	16%
Ranipet	6	1%	31	4%	134	15%	138	15%
Sholingur	4	0.5%	21	3%	109	14%	138	18%
Walajahpet	7	1%	24	4%	96	15%	102	16%

Table 2: Average precipitation incidence at various rain gauge locations throughout several monsoon seasons

Sl. No.	*Rain gauge stations*	*Average annual precipitation (mm) (10 years)*
1	Arrakkonam	979
2	Arcot	931
3	Kalavi	994
4	Kaveripakkam	1082
5	Palar	769
6	Panapakkam	1275
7	Ranipet	1068.
8	Sholinghur	917
9	Walajahpet	779.5
Average		977

variation in precipitation for many rain gauge sites in the research region. Table 2 depicts the Average precipitation incidence at various rain gauge locations throughout several monsoon seasons.

Spatial Disparity in the Precipitation

A geographic information system (GIS) was used to create isohyetal maps for several seasons and the average yearly rainfall to investigate the regional variation of precipitation. GIS is commonly used to construct contour maps that show how precipitation varies spatially in a certain location. The average annual precipitation spatial difference map (Figure 5) shows that precipitation intensity in the research region continuously increases to the west. The northern portion of the research region receives the most rainfall, followed by the western section, according to a regional disparity map of southwest monsoon precipitation. During the northeast monsoon season, however, the intensity of the precipitation increases southward (Figure 6).

Frequency Distribution of Precipitation

Table 4 shows the precipitation frequency distributions for yearly, monsoon (SW and NE combined), and non-monsoon (pre and post) conditions. It is also shown as histograms for each station with a rain gauge (Figure 7). Precipitation data covering 10 years, from 2012 to 2021, was used to construct the frequency distribution graphs. In the precipitation range of >1000 mm, the average annual precipitation frequency distribution figure reveals that Arakkonam, Arcot, Kalavai, Kaveripakkam, Palar, Ranipet, Sholinghur, and Walajahpet had the greatest frequencies of 5, 4, 3, 6, 1, 6, 4, and 1, respectively (Figure 7).

Physiography

The Ranipet district is mostly flat, with a few minor hills strewn around. Regionally, the study region slopes

Figure 4: Monthly disparity in the Precipitation at different rain Gauge station.

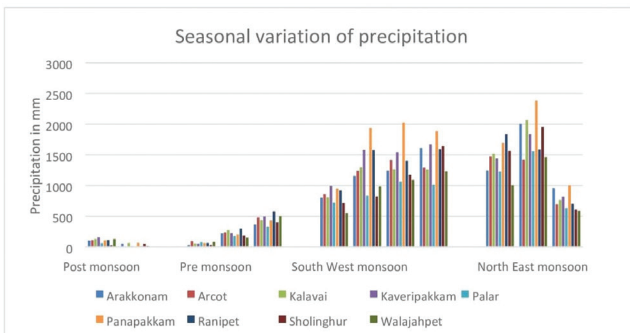

Figure 5: Seasonal variance in precipitation at several rain gauge sites in the research region.

Table 3: Average, maximum, and lowest precipitation occurrences at various rain gauge sites throughout distinct monsoon seasons

Monsoon seasons	*Average contribution (2012 to 2021)*		*Maximum occurrence*			*Minimum occurrence*		
	(mm)	*Percentage*	*Year*	*(mm)*	*Percentage*	*Year*	*(mm)*	*Percentage*
Arakkonam								
Post-monsoon season	8	1%	2013	52	34%	0		
Pre-monsoon season	21	3%	2015	154	25%	2013	7	1%
Southwest monsoon season	120	15%	2019	348	7%	2016	21	1%
Northeast monsoon season	140	17%	2021	353	8%	0		
Arcot								
Post-monsoon season	5	1%	2017	76	71%	0		
Pre-monsoon season	27	3%	2015	193	24%	0		
Southwest monsoon season	120	16%	2014	269	6%	2015	7	1%
Northeast monsoon season	120	15%	2017	359	10%	2014	9	1%
Kalavai								
Post-monsoon season	10	1%	2017	105	54%			
Pre-monsoon season	26	3%	2014	165	22%	0		
Southwest monsoon season	116	14%	2017	276	6%	2014	19	1%
Northeast monsoon season	145	17%	2015	708	16%	2020	48	1%
Kaveripakkam								
Post-monsoon season	8	1%	2017	75	28%	0		
Pre-monsoon season	26	3%	2016	145	18%	2013	6	1%
Southwest monsoon season	145	16%	2017	358	6%	2016	29	1%
Northeast monsoon season	137	15%	2015	675	16%	2014	10	1%
Palar								
Post-monsoon season	3	1%	2017	41	65%	0		
Pre-monsoon season	19	3%	2015	24	24%	2013	6	1%
Southwest monsoon season	91	14%	2013	203	6%	2015	8	1%

Northeast monsoon season	114	35%	2015	560	18%	0		
Panapakkam								
Post-monsoon season	9	2%	2013	53	30%	2021	6	3%
Pre-monsoon season	23	17%	2014	137	20%	2015	10	1%
Southwest monsoon season	173	45%	2020	422	6%	2021	37	1%
Northeast monsoon season	169	35%	2015	830	16%	2014	29	1%
Ranipet								
Post-monsoon season	6	1%	2017	58	47%	0		
Pre-monsoon season	31	4%	2015	179	19%	2013	9	1%
Southwest monsoon season	134	15%	2012	372	7%	2015	28	1%
Northeast monsoon season	138	15%	2012	655	46%	2018	22	2%
Sholinghur								
Post-monsoon season	4	1%	2013	46	65%	2021	2	3%
Pre-monsoon season	21	3%	2019	153	25%	0		
Southwest monsoon season	109	14%	2017	359	8%	2016	7	1%
Northeast monsoon season	138	18%	2015	497	12%	2014	42	1%
Walajahpet								
Post-monsoon season	7	1%	2017	99	70%	0		
Pre-monsoon season	24	4%	2013	138	19%	2013	12	2%
Southwest monsoon season	96	15%	2021	297	55%	2015	14	1%
Northeast monsoon season	102	16%	2021	622	20%	2014	7	1%

northeastward. The Palar River is an ephemeral body of water. Because the river has recently ceased transporting water, the groundwater level has been trending lower. The topography is mostly rocky, with the bulk of the rocks being charnockite, Peninsular gneiss, and alkali rocks. Table 3 depicts the Average, maximum, and lowest precipitation occurrences at various rain gauge sites throughout distinct monsoon seasons.

Effect of Climate Change in Groundwater

It is unknown how climate change will affect groundwater. Recent research has looked at the links between ground water levels and climate change in several places of the world. In India, several publications have published studies on groundwater and climate change. Rainfall is a common occurrence that has a considerable impact on groundwater levels and assists the agriculture business in particular.

Variation of Groundwater Levels with Respect to Space, Season, and Depth

Groundwater level data for 48 places are available for the last ten years. Figures 8 and 9 examine the various seasonal and regional patterns of changes in

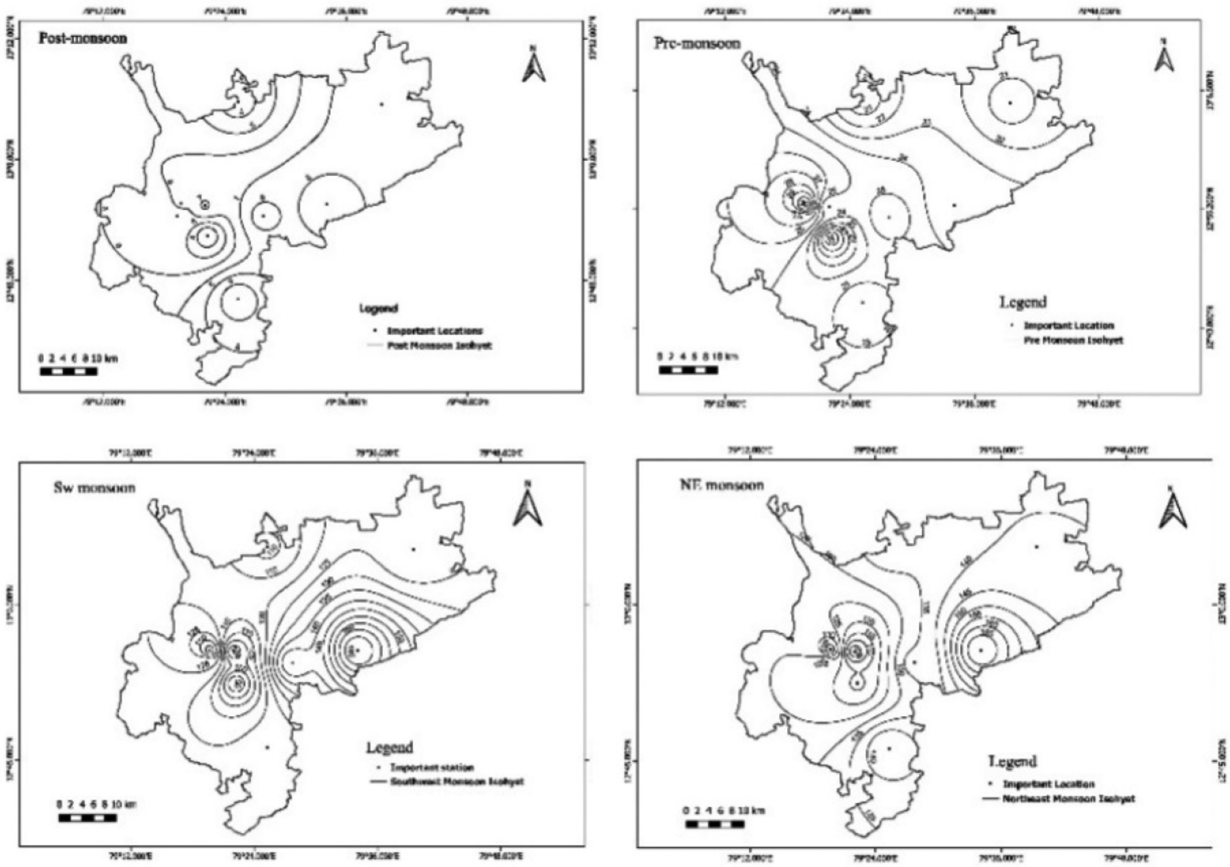

Figure 6: Spatial disparity of different monsoon precipitation.

groundwater level. The height of each well was recorded using GPS to establish the groundwater head in relation to mean sea level.

Conclusions

- Long-term precipitation and groundwater fluctuation investigations in a semi-arid area of southern India assisted in comprehending aquifer storage fluctuations. The investigation generated the following results:
- The Rainpet district in the Indian state of Tamil Nadu receives less precipitation in comparison to the state's average annual precipitation (987 mm). Four of the nine rain gauge stations in the research region get more than 987 millimetres of precipitation each year: Panapakkam, Kaveripakkam, Ranipet, and Kalavi. Table 5 depicts the depth of groundwater in wells during various monsoon seasons.
- At its peak, the Panapakkam area receives 1275 mm of rain. The yearly precipitation at the other five stations, Arrakkonam, Arcot, Sholinghur, Walajahpet, and Palar, is less than 987 mm. This area's total average annual precipitation is 977 mm, which is less than the state of Tamil Nadu's average annual precipitation (977 mm).
- During the SW and NE monsoon seasons (May to December), all five rain gauge locations consistently report more than 200 mm of precipitation, according to monthly variance in the precipitation pattern. November has the greatest monthly precipitation total.
- There are four monthly precipitation patterns in the research region: an increasing trend from January to May, a decreasing trend from May to June, a rising trend from June to November, and a decreasing trend from November to January. There are no records of precipitation totals greater than 20 mm from January to March.

Recommendation to Improve the Present Scenario

Sustainable Water Management

- Improving water infrastructure should be a top priority since sustainable water management is dependent on efficient and effective water usage. Intelligent irrigation and solar desalination are two

Table 4: Based on the frequency distribution of precipitation

Station name	*Annual precipitation intensity (mm)]*					*Monsoon precipitation intensity (mm)]*					*Non-monsoon precipitation intensity (mm)]*				
	<250	*250-500*	*500-750*	*750-1000*	*>1000*	*<250*	*250-500*	*500-750*	*750-1000*	*>1000*	*<250*	*250-500*	*500-750*	*750-1000*	*>1000*
Arakkonam	0	1	1	3	5	0	1	2	5	2	10	0	0	0	0
Arcot	0	0	2	4	4	0	0	3	5	2	9	1	0	0	0
Kalavai	0	0	2	5	3	0	0	3	5	2	10	0	0	0	0
Kaveripakkam	0	0	3	1	6	0	0	4	1	5	10	0	0	0	0
Palar	0	2	6	1	1	0	2	5	1	2	9	1	0	0	0
Panapakkam	0	0	1	1	8	0	0	2	1	7	10	0	0	0	0
Ranipet	0	0	2	1	6	0	0	3	4	3	9	1	0	0	0
Sholinghur	0	2	2	2	4	1	1	3	1	4	10	0	0	0	0
Walajahpet	0	2	6	1	1	0	3	5	1	1	10	0	0	0	0

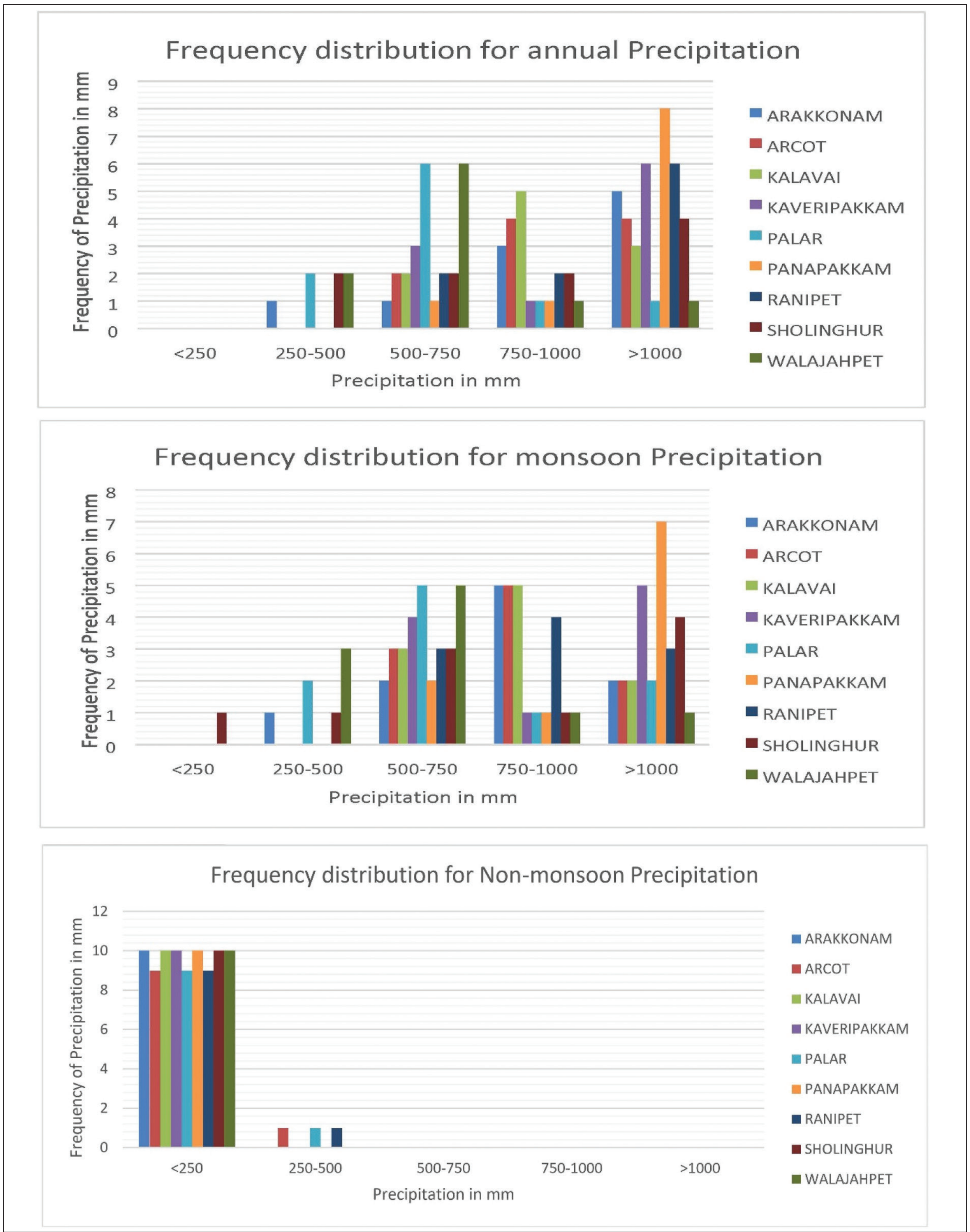

Figure 7: Precipitation frequency distribution at several rain gauge stations.

Table 5: The depth of groundwater in wells during various monsoon seasons

	Lowest for below ground level	*Highest concerning below ground level*
Post-monsoon season	0.96 (2012)	35.32 (2015)
Pre-monsoon season	0.44 (2013)	35.9 (2014)
Southwest monsoon season	0.14 (2013)	34.8 (2015)
Northeast monsoon season	0.39 (2015)	34.1 (2013)

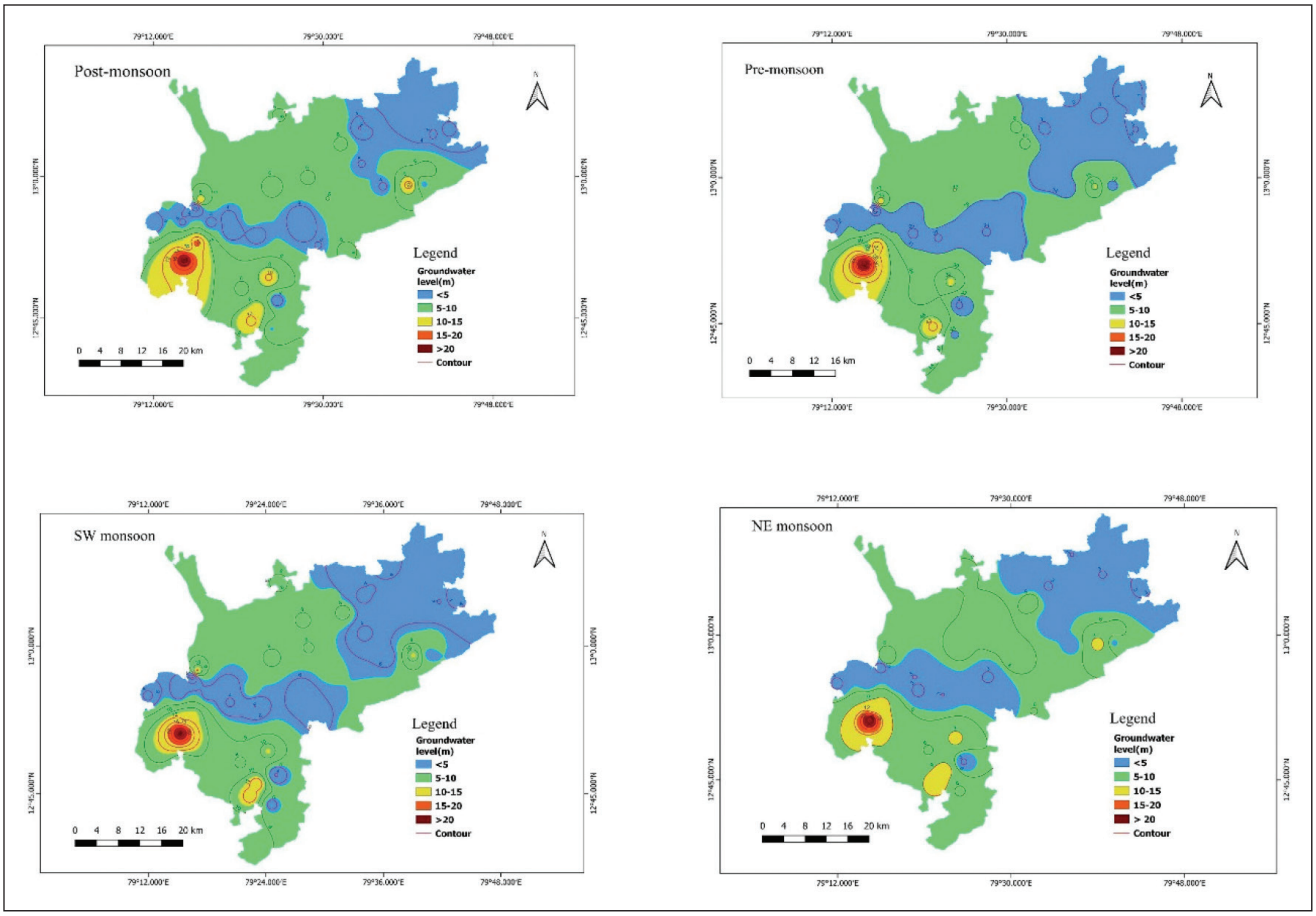

Figure 8: Spatial disparities in the groundwater level during different monsoon season.

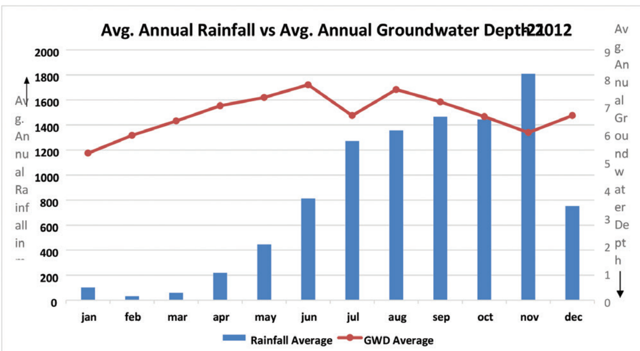

Figure 9: Variation in regional groundwater levels versus precipitation differential.

good examples of environmentally friendly water management technology. This is especially true for agriculture and farming, as these are the industries with the highest water use.

Reclaimed Water

- Groundwater and other natural water sources may be less strained as a result of recycled wastewater and rainwater collecting. Groundwater recharge, which permits water to flow from surface water to groundwater, is widely recognised as one technique for preventing water scarcity.

Pollution Control & Better Sewage Treatment

- Water gets dirty and hazardous to drink when there is insufficient sanitation. As a result, addressing pollution as well as measuring and monitoring water quality are crucial. Another approach for preventing the water shortage from increasing is to upgrade sewage systems in certain locations.

Author Contributions

VG: Writing-original draft, conceptualization, investigation, resources, software and formal analysis, methodology and supervision, Data curation. JG: Writing-original draft, software and formal analysis. JS: Data collection and manuscript writing.

Conflict of Interest

The authors state that they have no known conflicting financial interests or personal ties that might have influenced the work presented in this study.

Appendix A – Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2021.111238.

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