Seasonal Water Quality Assessment in Coastal Aquifers Using GIS: Pre-Monsoon and Post-Monsoon Perspectives

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Abstract**:** *The assessment of groundwater quality in coastal areas is essential because of the excessive drafting of groundwater due to insufficient surface water supplies. This study was aimed to assess the groundwater quality in a coastal district of Maharashtra, India. Samples of groundwater were obtained from 37 observation wells situated in three major coastal Talukas of Sindhudurg district during the pre- and post-monsoon seasons. Samples were analyzed for chemical properties in the laboratory using the standard methods given by the Indian Standard 10500. The geographic information system-based spatial distribution maps of various water quality parameters viz. pH, Turbidity, Total Dissolved Solids, Hardness, Sodium, Potassium, Iron, Zinc, Chlorine, Calcium, Chloride, Nitrates etc. has been prepared using Inverse Distance Weighted (IDW) method in QGIS 3.22.1 Software. The maps of water quality index (WQI) have been used to classify water samples in study area, ranging from excellent to unfit for consumption. The analysis revealed that maximum no wells were contaminated with TDS, Chlorine, Calcium, and Hardness level in certain areas during the pre-monsoon season. Pre-monsoon and post-monsoon average TDS range values have been observed between 27 and 1827 mg/l & 26 to 1495 mg/l, respectively. The Spatio-temporal analysis using IDW method indicated that in the pre-monsoon season, a greater concentration of hardness was there in 25% of the study area, while in post-monsoon season, this was observed in 14% of area under study. In the pre-monsoon season, WQI values were higher across an expanse of nearly 190 km^2, whereas in the post-monsoon season, this trend was observed over an area of 85 km^2. The highest water quality index value was found in Vengurla Taluka. Ultimately, the study finds that human activity has a negative impact on the quality of groundwater, and that a good management plan is needed to protect Vengurla Talukas groundwater resources.*

Keywords: coastal area, GIS, groundwater quality, spatial interpolation, WQI.

Introduction

Coastal aquifers are crucial freshwater resources, particularly in regions facing surface water scarcity. However, the increasing reliance on groundwater in these areas often leads to over-extraction and, consequently, the deterioration of groundwater quality (Verma et al., 2020). Understanding the spatial and temporal variations in groundwater quality is essential for effective management and sustainable use of these vital resources (Aheto, 2011), (Mishra & Nagarajan, 2011). This study aims to assess the seasonal variations in groundwater quality in a coastal district of Maharashtra, India, using GIS-based techniques (Rawat & Singh, 2018), (Ravish et al., 2020), (Selvam et al., 2014), (Vengadesan & Lakshmanan, 2018).

The coastal areas of India are facing various challenges related to water quality and availability (Jha et al., 2020). The excessive withdrawal of groundwater in these regions has led to the intrusion of saltwater and the contamination of aquifers with various pollutants (Kushe et al., 2024), (Agoubi, 2021). The overexploitation of groundwater resources, along with the impact of climate change, has exacerbated the water quality and availability issues in coastal areas (Alfarrah & Walraevens, 2018), (Bouderbala et al., 2016). The quality of groundwater is affected by various natural and anthropogenic factors, such as geological formations, saltwater intrusion, agricultural activities, and industrial effluents (Chatterjee et al., 2010), (Milovanovic, 2007). Spatial analysis of groundwater quality parameters using GIS can help in the identification of contaminated zones and the development of appropriate management strategies (Kaliraj et al., 2015), (Asadi et al., 2007), (Nas & Berktay, 2010). This study focuses on the Sindhudurg district of Maharashtra, a coastal region characterized by a complex hydrogeological setting and increasing groundwater exploitation (R. Aher et al., 2020). The objectives of this study are: to assess the spatial and temporal variations in groundwater quality during the pre-monsoon and post-monsoon seasons to identify the factors influencing groundwater quality, and to delineate the areas of concern for groundwater management (Gaikwad et al., 2010), (Jinwal & Dixit, 2008), (Priyadharshini & Aruchamy, 2015). This study focuses on assessing the groundwater quality in a coastal district of Maharashtra, India, characterized by significant groundwater dependence (Jha et al., 2020), (Sharma et al., 2022).

By examining the groundwater quality dynamics in this coastal region, this study provides valuable insights for policymakers, water resource managers, and local communities to develop sustainable groundwater management strategies and ensure the long-term availability of this critical resource.

Study Area

A region of study for this research project is the Sindhudurg District in Maharashtra, India. Figure 1 depict the region's arid coastline conditions. Between latitudes 15°40' and 16°44' North and longitudes 73°19' and 74°13' East is where the research area is situated. Rainfall averages 4234 mm per year over the 1,750 Km^2 overall geographic areas. 300–400 meters above mean sea level is the elevation of the basin's landscape. At 39.5°C, May is the month with the highest average high temperature, and December is the month with the lowest average low temperature. For study, groundwater samples are taken from 37 well locations throughout pre-monsoon & post-monsoon seasons.

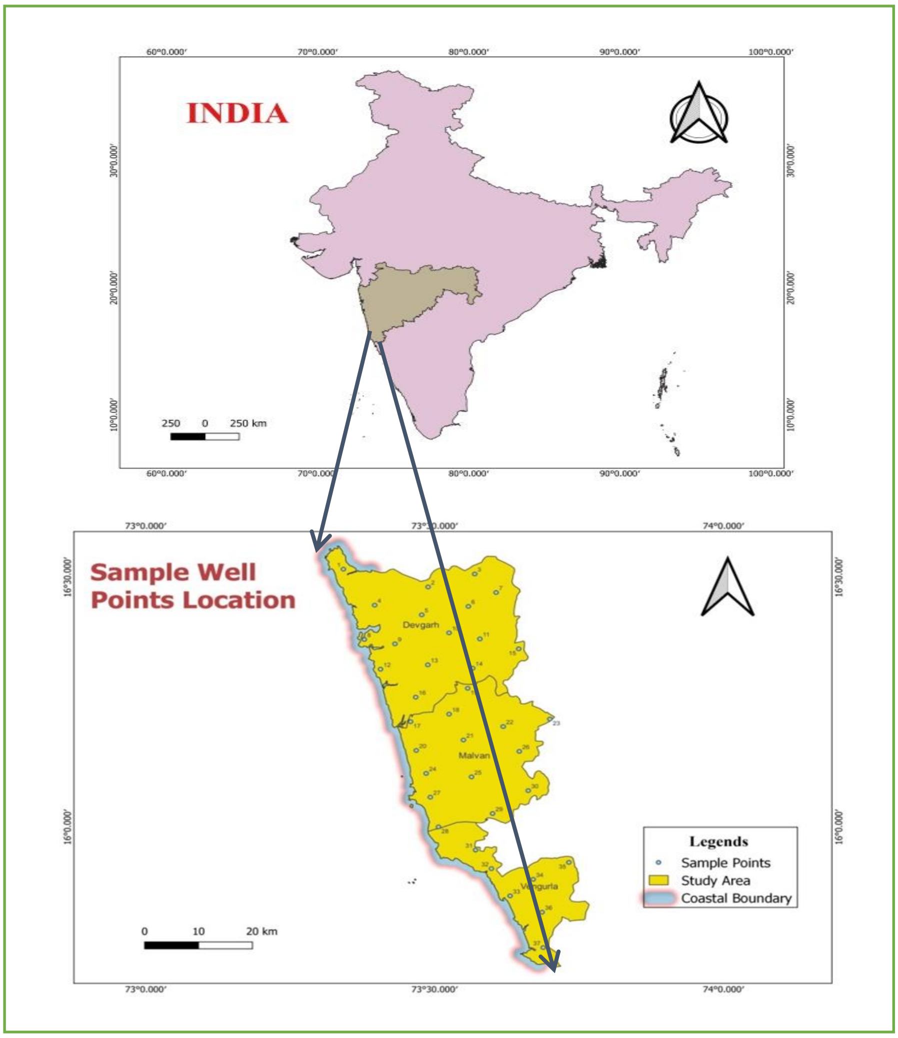

Figure 1: Location map of Study area with sample well points.

Materials and Methods

37 observation wells provided water samples for collection during the pre-monsoon (February 2023 to May 2023) and post-monsoon (October 2022 to January 2023) seasons. Groundwater samples were collected following standard procedures, which involved utilizing bottles made of plastic after being acid-washed, to avoid unanticipated changes in features. The water quality index was computed by looking at various water quality characteristics, including TDS, turbidity, K, pH, Zn, Ca, Alkalinity, Hardness, Na, Fe, Cl,

Cl-, & NO3. The next sections outline the thorough technique used in this investigation, which is also depicted in Figure 2.

a. Collection of samples:

37 separate groundwater samples were collected from the research area during the pre-monsoon season (February 2023 to May 2023) and the post-monsoon season (October 2022 to January 2023). A random sampling technique was applied to gather samples of groundwater from the research region. Thirteen samples of groundwater were collected from Malvan Taluka, sixteen from Devgad Taluka and seven from Vengurla Taluka.

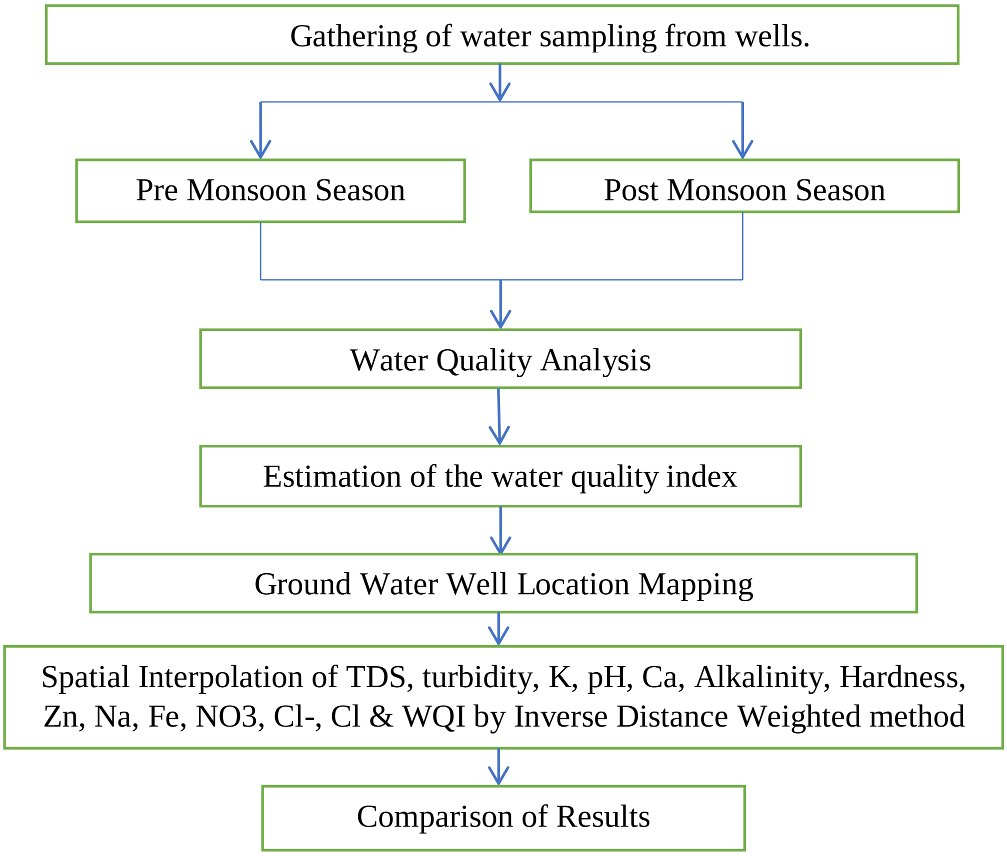

Figure 2: Methodology Flow chart.

b. Water quality samples Analysis:

Using standard procedures, plastic bottles that acid washed were used to collect groundwater samples. The subsequent water quality aspects were examined at: TDS, turbidity, K, Zn, Ca, Alkalinity, Fe, Hardness, pH, Na, Cl, Cl-, & NO3 to estimate water quality index (Singh & Khan, 2011). The Standard values of the parameters are displayed in Table 1 in accordance with the Indian Drinking Water Recommendations (IS: 10500, 2012). (Herschy, 2012), (BIS, 2012).

Table 1: The parameters' standard values are based on (IS: 10500, 2012).

Sr. No.	Parameter	Standard Values
1	Alkalinity	200
2	Turbidity	5
3	Chlorine	4
4	Nitrates	10
5	Calcium	75
6	Potassium	100
7	Chlorides	1000
8	Iron	1
9	Hardness	600
10	Zinc	0.5
11	pH	8.5
12	Sodium	20
13	TDS	500

c. Water Quality Index:

To calculate Water Quality Index (WQI), Horton in 1965 employed 10 of most commonly used water quality variables, including alkalinity, pH, dissolved oxygen (DO), & chloride. It has now been widely accepted & utilized in countries throughout Asia, Africa, and Europe. The given weight has a substantial impact on the index and indicates how important a parameter is for a particular objective. Furthermore, in 1970, the Brown group developed a new WQI that was similar to Horton's index and was based on weights to particular criteria. Several experts and scientists have recently suggested numerous modifications to the WQI concept (Kuttimani et al., 2017), (Khan Adnan & Rehman Yusra, 2017).

The phrase "water quality index" (WQI) describes a ranking system that illustrates how various water quality criteria work together to affect the overall water quality. Human consumption is taken into account while estimating it (Rawat & Singh, 2018). The water's quality and appropriateness for drinking can be assessed using the quality index. WQI was computed with consideration for drinking norms (BIS, 2012). Weighted averages of the linked parameters are assumed to be inversely proportional to the specified standards, according to this technique (Batabyal & Chakraborty, 2015). The computation requires steps listed in equation 1, 2 & 3.

First, ascertain weight of i^{th} parameter. Quality rating for each parameter associated with water quality is calculated using the second equation, and the overall index is obtained by adding up all of these sub-indices in the third equation (Kamble & Vijay, 2011), (Kumar & Krishna, 2021).

The i^{th} parameter's weight,

$$Wi = k/Si \quad (1)$$

Where Wi is the unit of weightage and Si is the recommended level for the ith parameter (i = 1-6), and k is the proportionality a constant.

The term gives each item a quality rating,

$$Qi = 100\ Vi/Si \quad (2)$$

Where Vi is the measured quantity of the ith parameter in µg/l, Si is the standard or permissible limit for the i^{th} parameter, and Qi is the i^{th} parameter's sub-index.

Water Quality Index (WQI) is determined as:

$$\mathrm{WQI} = \sum_{i=1}^{n}(\mathrm{QiWi}) \Big/ \sum_{i=1}^{n}(\mathrm{Wi}) \quad (3)$$

Where, Qi is the sub-index of the i^{th} parameter. Wi is the unit weightage for the i^{th} parameter, and n is the total number of parameters taken into account. (Rawat & Singh, 2018).

d. Spatial Interpolation of Water Quality Index (WQI):

Using inverse distance weighted (IDW) method in QGIS software, different maps for TDS, Cl, turbidity, K, pH, Zn, Fe, Ca, Alkalinity, Hardness, Na, Cl-, & NO3 have been created (Dhilleswara Rao et al., 2019). The groundwater parameter point-wise data were spatially interpolated using Inverse Distance Weighted (IDW) method, a multivariate predictable interpolation method that uses known scattered gathering of point for well in study region. The IDW approach, which takes weighted values found at known sites, is used to determine values allocated to unknown point (Aheto, 2011).

Cell values are created by combining a series of the sample point with linear weight. These values are subsequently utilized in precise & convex IDW interpolation procedure. This is based on hypothesis that a variable's effect diminishes with raising distance from sampling location. An important characteristic is that all expected values of the IDW interpolation lie between maximum and minimum values of the known locations (le Roux et al., 2023). Table 3 describes the sampling sites' locations as well as their latitude and longitude.

An IDW approach in general is shown in Equation 4:

$$Zo = \frac{\sum_{i=0}^{s} Zi\left(1/d_i^k\right)}{\sum_{i=0}^{s}\left(1/d_i^k\right)} \quad (4)$$

Zi is the Z value of known point i, di is the distance of known point i and Zo is the predicted value of point o. Here, k is indicated power and s is the number of known points used. Power k determines how big local influence is. The change in data increase at certain point & level out away from it, according to power of 2.0 or above. The known number of points included in the estimate has an impact on the local effect as well.

Results and Discussion

a. Explanation, Comparison of water quality parameters in pre & post monsoon season:

The statistical analysis of water quality parameters for pre monsoon and post monsoon season is indicated in Table 2. The study revealed that groundwater's pH ranged from 6.6 to 8 & 6.1 to 8.7 acidic to alkaline in pre monsoon & post-monsoon season respectively in the study area. There were sample places where the TDS was of low quality, with values exceeding 1000 mg/l, range of TDS was 26 mg/l to 1495 mg/l in post monsoon season and 26 mg/l to 1827 mg/l in pre monsoon season. Sodium ranged from 8 to 18 mg/l in pre monsoon & 8.51 to 17.31 mg/l in post monsoon & below permissible level in both seasons. Potassium ranged within desirable limit. Higher turbidity was discovered in a few places in Vengurla Taluka and levels ranged from 0.70 NTU to 8.70 NTU & 0.30 NTU to 8.10 NTU in pre monsoon and post monsoon season respectively. The pH range of the water samples from the research region was 6.1 to 8.7. The water at Shriramvadi is extremely alkaline, having a pH of 8.7, which is caused by weathering of minerals and rocks in post monsoon season. Most of the sites had chloride concentrations within permissible limits, with exception of Huda station in Vengurla Taluka, which has 669 mg/l. With 1827 mg/l in pre-monsoon and 1495 mg/l in post-monsoon, Huda had the highest levels of total dissolved solids due to its densely populated residential area and subpar agricultural practices. Due to its use for agriculture in post-monsoon season, Huda station with 392 mg/l has more concentration of total hardness. The other nearby places showed a moderate range of hardness levels because weathering, salty seeping in groundwater & substantial human activities.

Table 2: Statistics for chemical parameters

Sr. No.	Parameters	Pre Monsoon Season				Post Monsoon Season			
		Mean	**Standard Deviation**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
1	TDS	184.6	284	26	1827	131.6	246.5	26	1495
2	pH	7.2	0.4	6.6	8	7	0.5	6.1	8.7
3	Na	12.6	3	8	18	12.9	2.4	8.5	17.3
4	K	5.1	2.1	2	10	4.7	2.4	1	10
5	Fe	0.1	0.1	0.02	0.3	0.08	0.08	0.02	0.49
6	Zn	0	0	0.01	0.08	0.02	0.02	0.01	0.08
7	Cl	1.6	0.6	1	3	1.3	0.5	1	3
8	Ca	11.7	17.4	3	112	9.1	13.6	2	80
9	Cl-	36.6	149	2	920	28.2	109	2	670
10	NO3	1.5	0.5	1	2	1.5	0.5	1	2
11	Alkalinity	39.3	26.9	4	160	27.1	25.7	4	132
12	Hardness	53.2	87.6	8	560	38.1	64	8	392
13	Turbidity	1.5	1.8	0.7	8.7	1.6	1.7	0.3	8.1

The findings of a correlation matrix-based assessment of correlation between chemical parameters during post-monsoon season are presented in Table 3. The correlation values fell into three categories: low (0.30 to 0.50), strong (0.75) & moderate (0.50 to 0.75). The correlation data indicates that there is highly significant positive link between TDS & Cl- (0.97), Hardness & TDS (0.99), and Hardness & Cl- (0.96) during post-monsoon season. There was relatively favourable relationship between TDS & alkalinity (0.57), pH & alkalinity (0.62), Cl & NO3 (0.53), and Ca & Hardness (0.99) during post-monsoon season.

Table 3: Correlation matrix of various groundwater parameters for post monsoon season.

	Turbidity	Alkalinity	Cl-	Zn	K	TDS	Hardness	NO3	pH	Na	Fe	Cl	Ca
Turbidity	1												
Alkalinity	0.05	1											
Cl-	-0.04	0.34	1										
Zn	0.55	0.09	0.22	1									
K	-0.32	0.07	0.16	-0.34	1								
TDS	-0.03	0.57	0.97	0.20	0.16	1							
Hardness	-0.04	0.56	0.96	0.20	0.16	0.99	1						
NO3	-0.06	0.10	-0.15	-0.35	-0.14	-0.09	-0.10	1					
pH	0.05	0.62	0.21	-0.10	0.20	0.36	0.34	0.00	1				
Na	0.01	-0.14	-0.16	-0.19	0.40	-0.17	-0.17	0.10	0.16	1			
Fe	0.24	0.04	0.05	0.83	-0.34	0.04	0.05	-0.27	-0.22	-0.24	1		
Cl	-0.10	0.10	-0.08	-0.23	0.02	-0.04	-0.09	0.53	0.18	0.01	-0.19	1	
Ca	-0.05	0.64	0.92	0.18	0.19	0.98	0.99	-0.07	0.36	-0.17	0.04	-0.11	1

The findings of a correlation matrix-based assessment of correlation between chemical parameters during pre-monsoon season are presented in Table 4. The correlation values fell into three categories: low (0.30 to 0.50), moderate (0.50 to 0.75), & strong (0.75). The correlation data indicates that there is highly significant positive link between Hardness & Cl- (0.98), Hardness & TDS (0.87), and TDS & Cl- (0.86) during pre-monsoon season. From the above explanation, it can be seen that groundwater may frequently get its calcium, hardness, and alkalinity from the dissolving of minerals like gypsum.

Using the WQI equation, the WQI values for the study region for the pre-monsoon and post-monsoon samples were determined independently. The findings showed that 86.48% of samples (32 out of 37) had excellent to good water quality prior to the monsoon, and 94.59% of samples (35 out of 37) had excellent to good water quality after the monsoon. Nonetheless, 5 (13.51%) of the groundwater samples are extremely poor during the pre-monsoon seasons. After monsoon, only two (5.40%) groundwater samples exhibit extremely low quality.

Using the computed WQI values for every sample point, the IDW interpolation method was used to create the WQI map for both seasons. In the research region, the WQI ranges from 8.4 to 32.9 during the pre-monsoon and from 5.45 to 26.23 during the post-monsoon Fig. 3.

Table 4: Correlation matrix of various groundwater parameters for pre monsoon season.

	Turbidity	Alkalinity	Cl-	Zn	K	TDS	Hardness	NO3	pH	Na	Fe	Cl	Ca
Turbidity	1												
Alkalinity	-0.06	1											
Cl-	-0.02	0.78	1										
Zn	0.62	0.22	0.21	1									
K	-0.16	0.27	0.32	0.01	1								
TDS	0.02	0.76	0.86	0.23	0.24	1							
Hardness	-0.02	0.87	0.98	0.22	0.32	0.87	1						
NO3	-0.32	-0.19	-0.17	-0.41	0.21	0.29	-0.20	1					
pH	0.00	0.07	0.11	0.16	-0.24	0.20	0.09	-0.16	1				
Na	0.04	0.23	0.14	-0.11	0.33	0.13	0.13	0.05	-0.33	1			
Fe	0.71	0.06	0.07	0.71	-0.13	0.21	0.08	-0.57	0.21	-0.23	1		
Cl	0.34	-0.01	0.11	0.36	0.23	0.07	0.07	-0.10	0.12	0.30	0.16	1	
Ca	-0.01	0.86	0.98	0.22	0.31	0.88	0.99	-0.22	0.11	0.16	0.08	0.09	1

Using the WQI equation, the WQI values for the study region for the pre-monsoon and post-monsoon samples were determined independently. The findings showed that 86.48% of samples (32 out of 37) had excellent to good water quality prior to the monsoon, and 94.59% of samples (35 out of 37) had excellent to good water quality after the monsoon. Nonetheless, 5 (13.51%) of the groundwater samples are extremely poor during the pre-monsoon seasons. After monsoon, only two (5.40%) groundwater samples exhibit extremely low quality.

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b. Spatial Variation of Water quality Index in pre monsoon and post monsoon season:

As stated in the methodology section, the spatiotemporal mapping of water quality aspects & water quality index for the pre-monsoon and post-monsoon seasons was completed. According to the evaluation, the research area's ground water quality ranged from outstanding to good. During both seasons, the study area's observed turbidity levels were below the desired limit, with the exception of Vadakhol & Math in Vengurla Taluka. The turbidity levels at these two places were unacceptable Fig 4 (a & b). The pH is acidic to alkaline Fig. 4 (c & d). According to the maps, the research area's acceptable levels for alkalinity, zinc, potassium, calcium, nitrates, and iron are met during both seasons. [e,f,g,h,i,j,k,l,m,n,s,t,u,v,w,x,y,z] is Fig. 4. At Huda in Vengurla Taluka, the observed total dissolved solids levels were unsatisfactory (Fig. 4 (o & p). Although the sodium level was within the allowable limit, it was at the highest allowable limit in the pre-monsoon season at 8 and 7 sites, respectively. Fig 4 (q & r).

The pH level was neutral over whole research area, with the exception of 2 stations (Tendoli & Mahalunge), where it was alkaline & 1 station, where it was acidic in both seasons, according to spatially interpolated map of groundwater quality parameters. In research region, post-monsoon season TDS concentration was determined in poor to unsatisfactory level about 50 Km^2. Throughout study area, the levels of K, Na, NO3, Fe, Alkalinity, Cl, & Zn within allowable bounds throughout both the pre-monsoon and post-monsoon seasons. Where there is a chance of seawater intrusion, the hardness and turbidity levels in the research region were not allowed to be limited to around 45 Km^2.

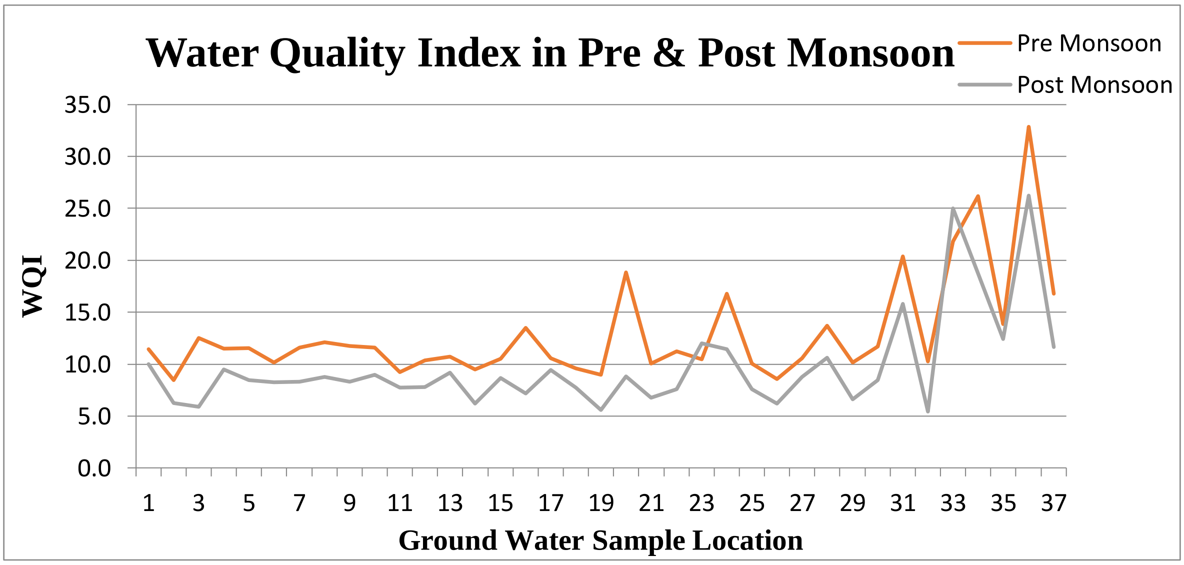
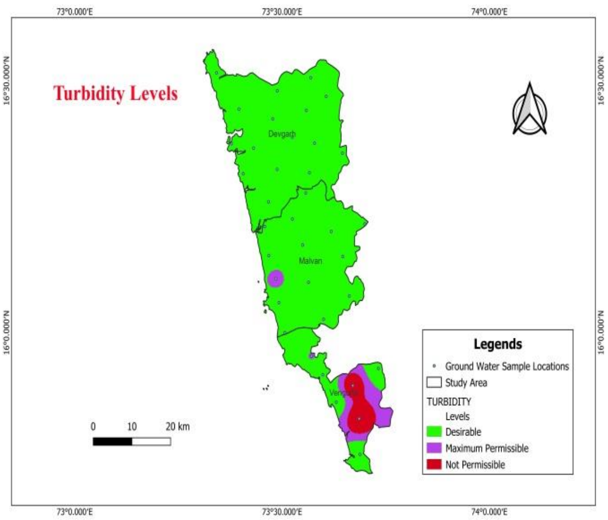


Figure 3: Pre-monsoon and post-monsoon water quality index.

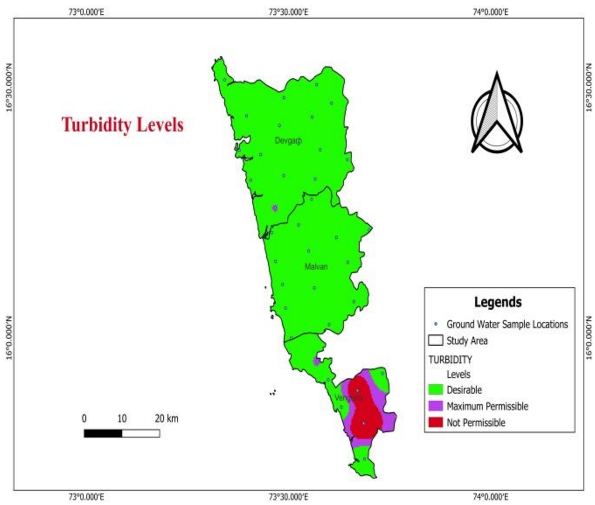
The Indian Standard (IS) 10500:2012 was used to estimate the weights of several water quality characteristics to generate Water Quality Index (WQI), as Table 5 illustrates. Water samples in the research region ranged in terms of quality from excellent to good, according to WQI analysis. Math and Vadakhol were found to have WQI scores of 26.2 and 32.9, respectively in pre monsoon season (Fig. 5 a) & Vengurla and Vadakhol were calculated as 25 and 26.23, respectively in post monsoon season (Fig. 5 b). The elevated concentrations of sodium, TDS, turbidity, zinc, and iron in the groundwater were ascribed to the elevated WQI values observed at these sites. Seawater intrusion in that location was substantially correlated with the greater TDS and turbidity.

Table 5: Unit weighting of variables based on India's drinking water standard (IS: 10500, 2012).

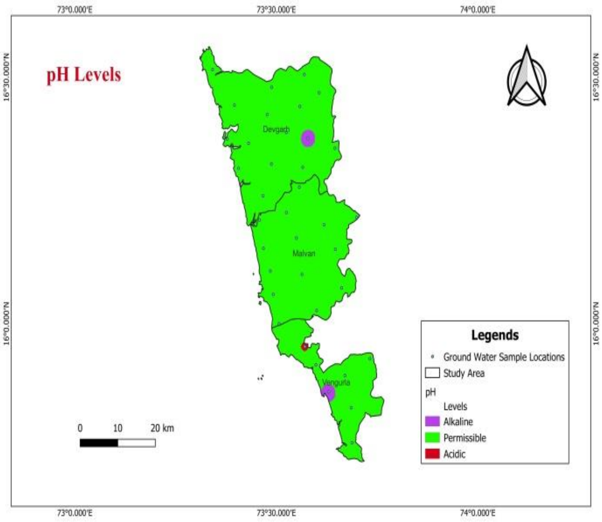
Sr. No.	**Parameter**	**Wi=K/Sn**
1	pH	0.031367
2	Iron	0.266621
3	Sodium	0.013331
4	Potassium	0.002666
5	Chlorine	0.066655
6	Zinc	0.533241
7	Nitrates	0.026662
8	Calcium	0.003555
9	Chlorides	0.000267
10	Hardness	0.000444
11	Alkalinity	0.001333
12	TDS	0.000533
13	Turbidity	0.053324



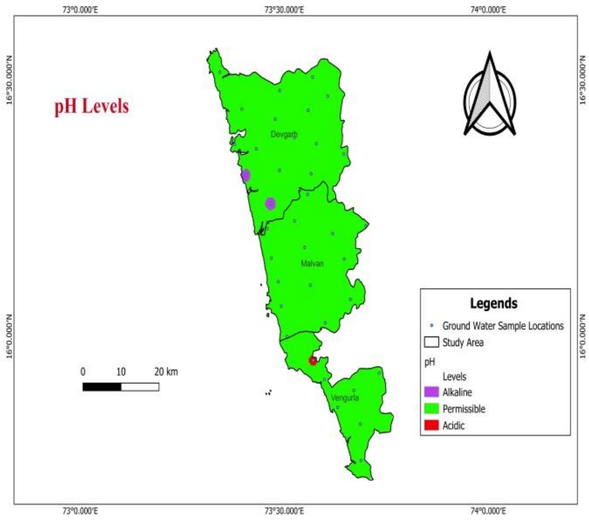
a) Turbidity levels in Post Monsoon



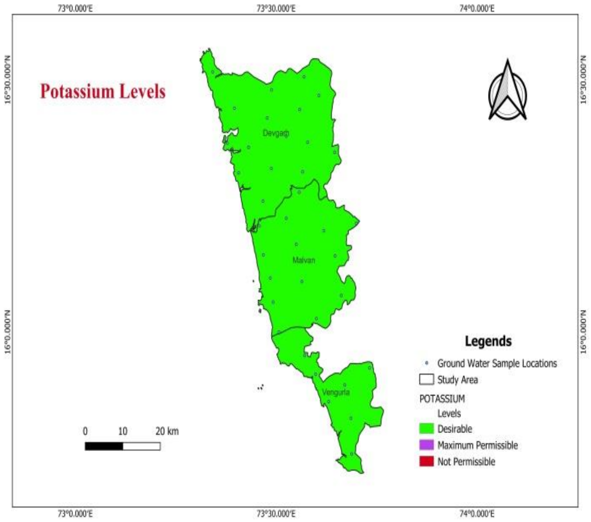
b) Turbidity levels in Pre Monsoon



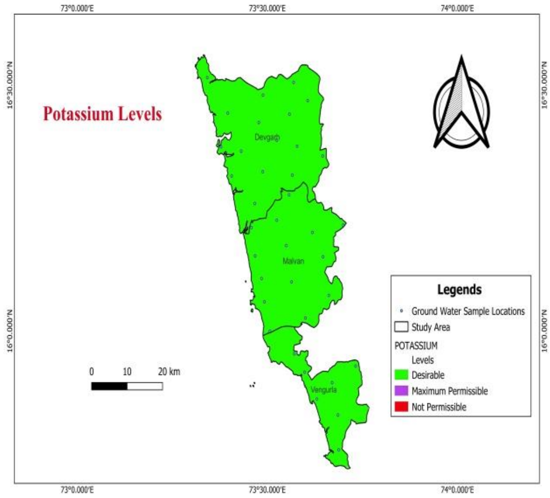
c) pH levels in Post monsoon



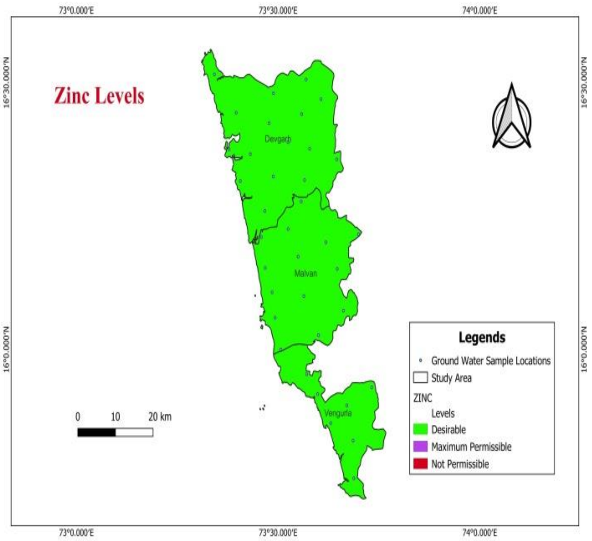
d) pH levels in Pre monsoon



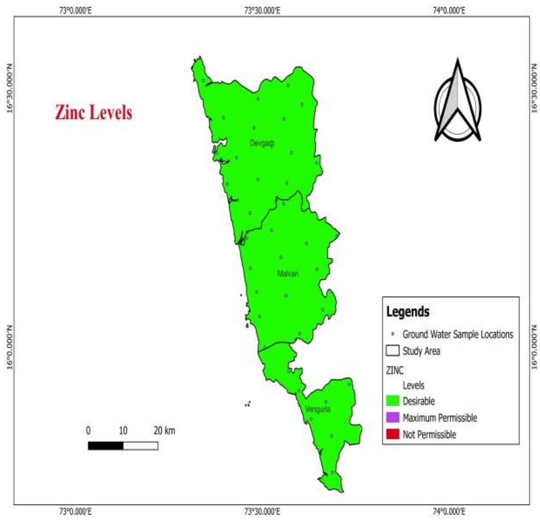
e) Potassium levels in Post Monsoon



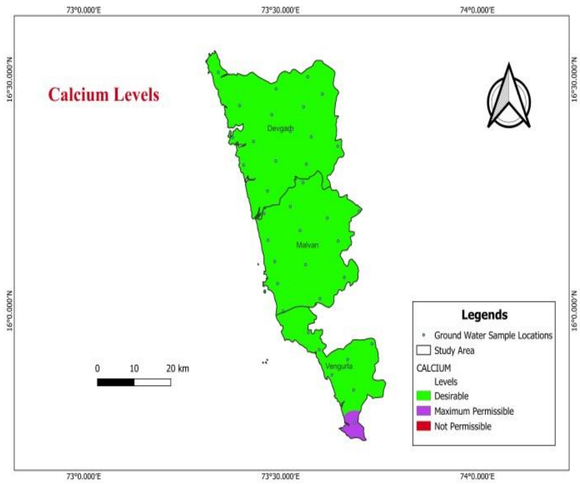
f) Potassium levels in Pre Monsoon



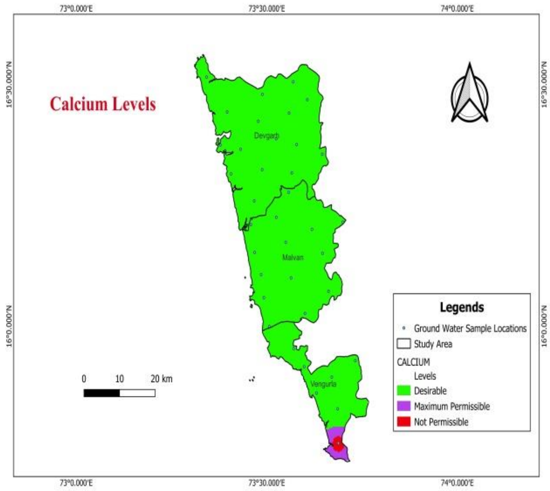
g) Zinc levels in Post Monsoon



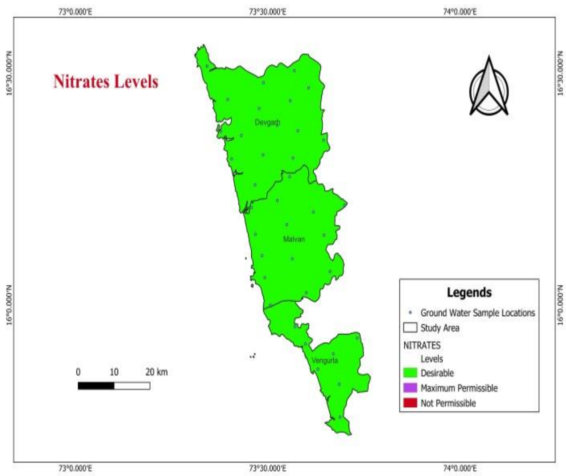
h) Zinc levels in Pre Monsoon



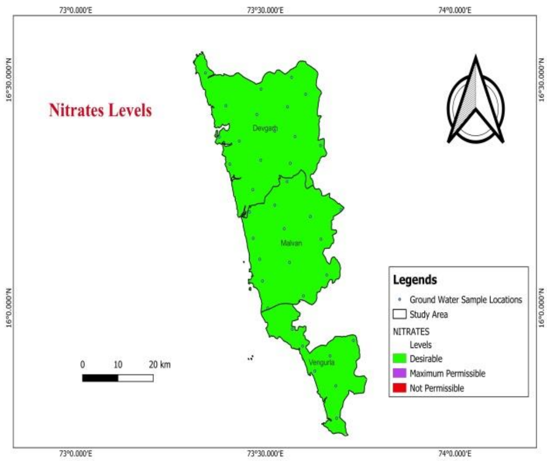
i) Calcium levels in Post Monsoon



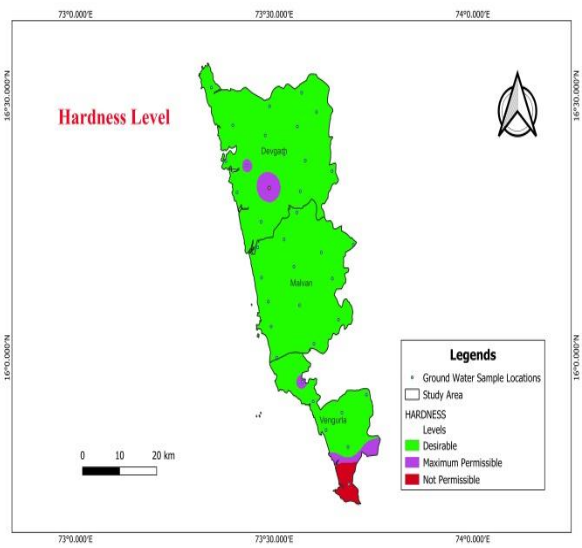
j) Calcium levels in Pre Monsoon



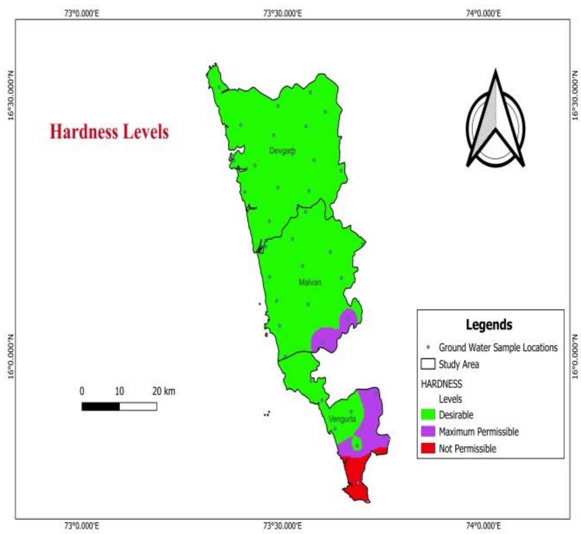
k) Nitrates levels in Post Monsoon



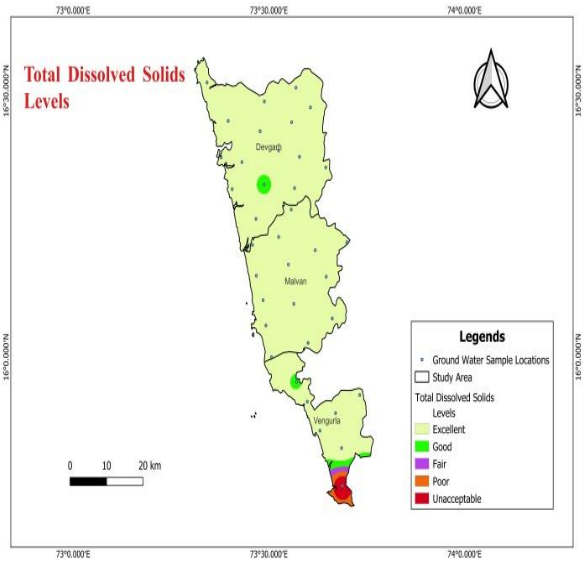
l) Nitrates levels in Pre Monsoon



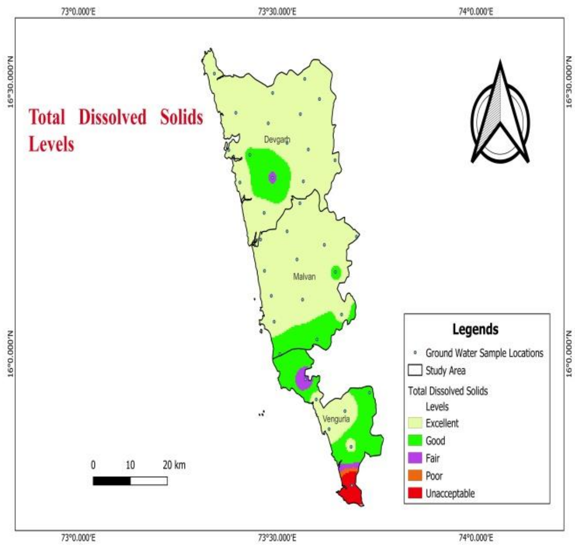
m) Hardness levels in Post Monsoon



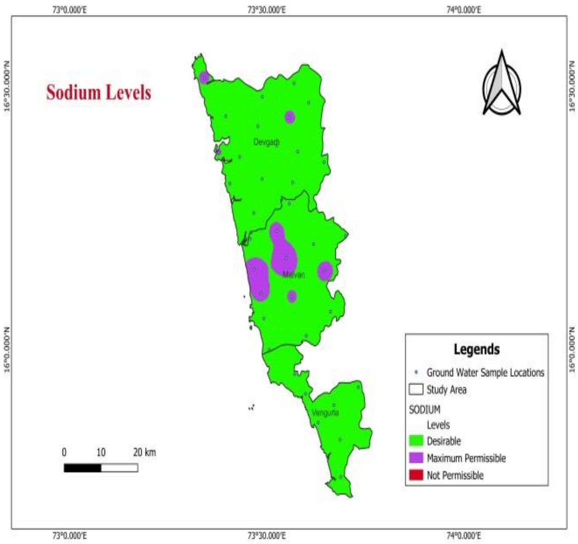
m) Hardness levels in Pre Monsoon



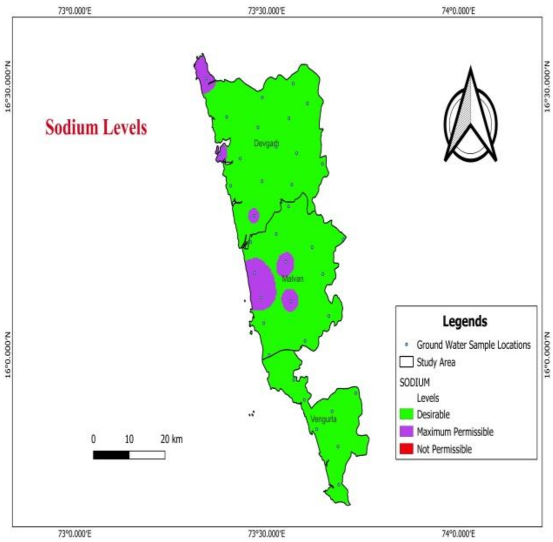
o) TDS levels in Post Monsoon



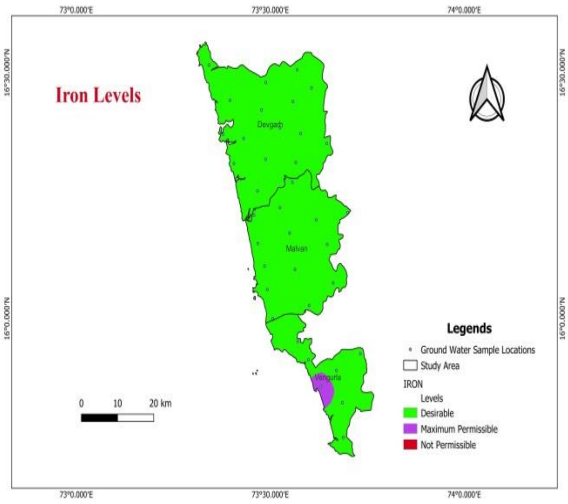
p) TDS levels in Pre Monsoon



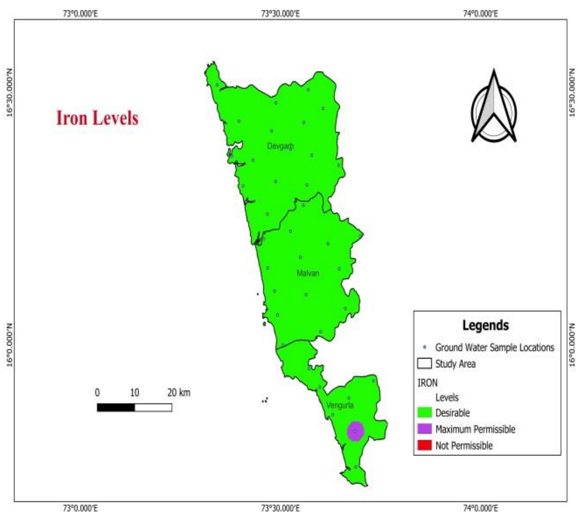
q) Sodium levels in Post Monsoon



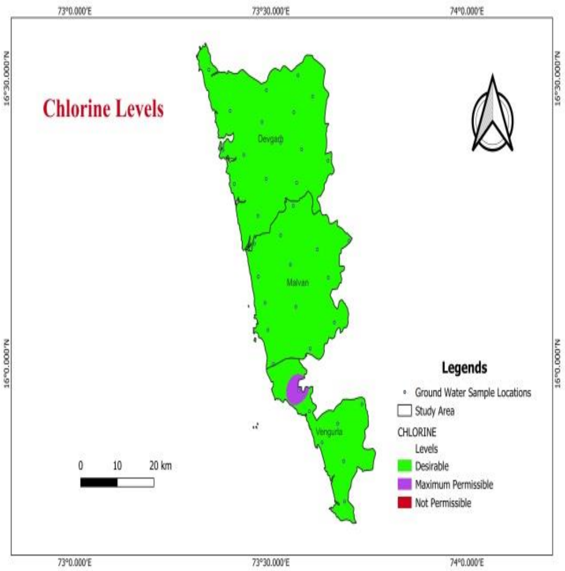
r) Sodium levels in Pre Monsoon



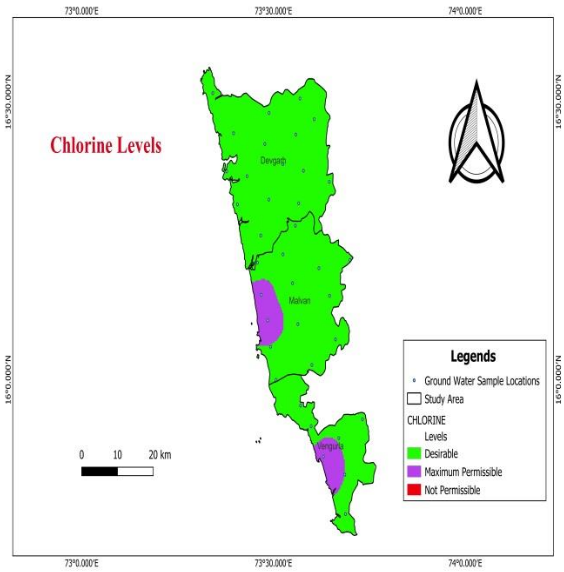
s) Iron levels in Post Monsoon



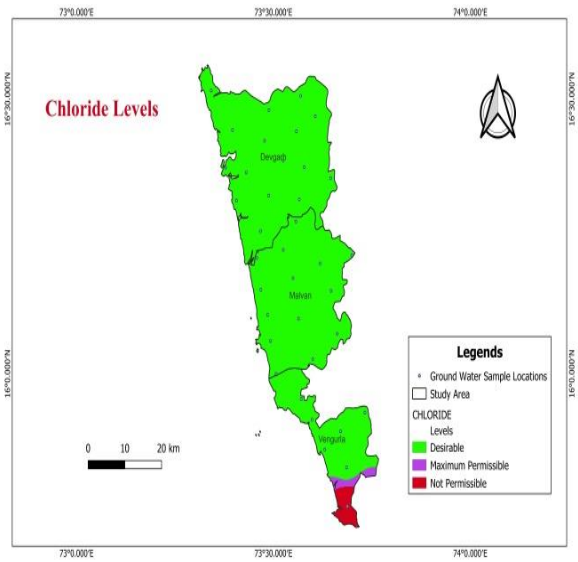
t) Iron levels in Pre Monsoon



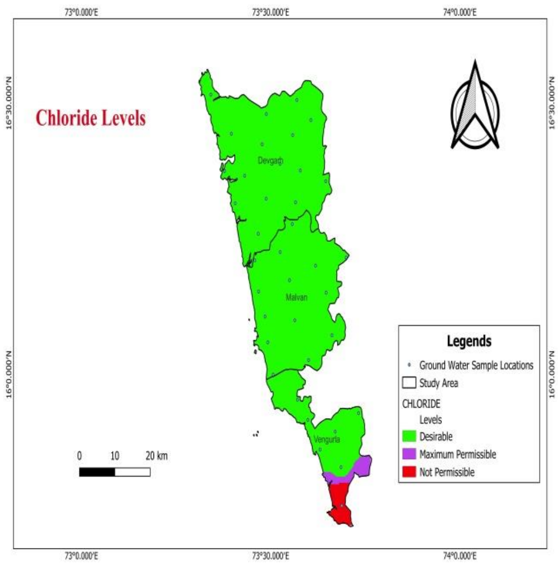
u) Chlorine levels in Post Monsoon



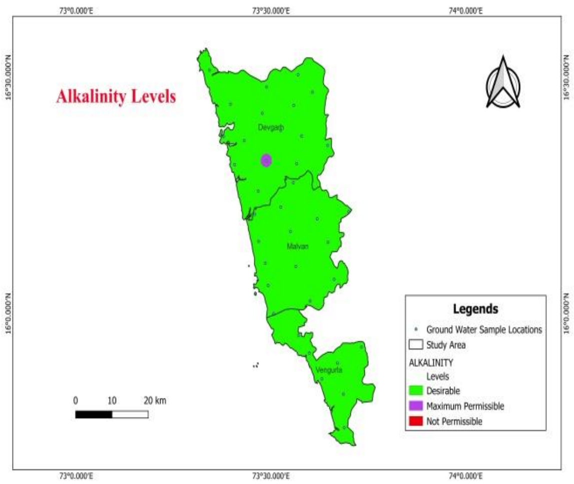
v) Chlorine levels in Pre Monsoon



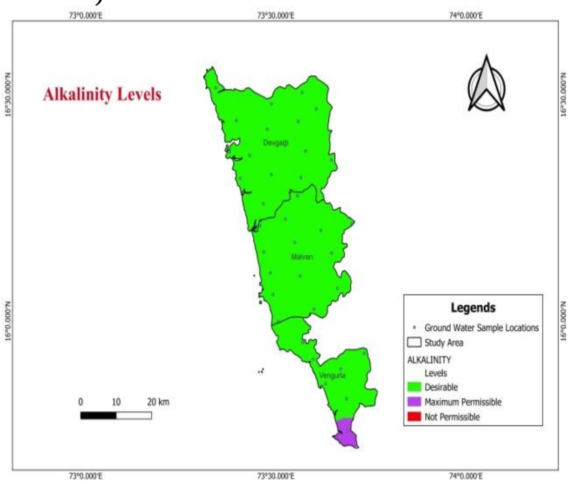
w) Chloride levels in Post Monsoon



x) Chloride levels in Pre Monsoon

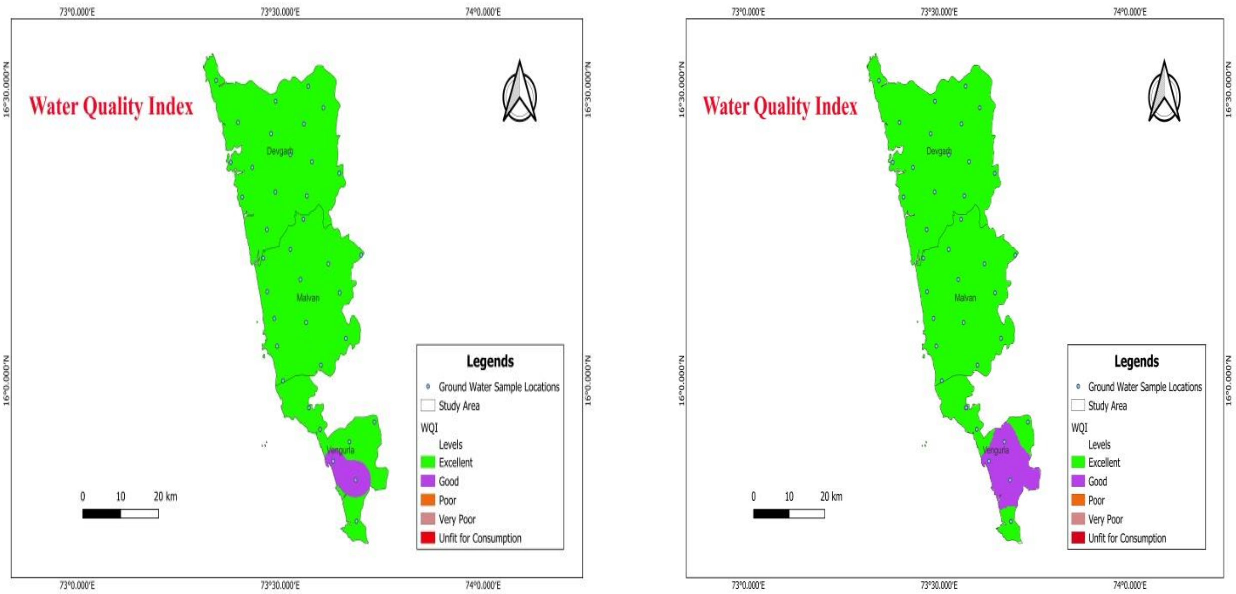


y) Alkalinity levels in Post Monsoon



z) Alkalinity levels in Pre Monsoon

Figure 4 (a to z) : Spatial Distribution maps of all Parameters in Pre & post monsoon season



a) Water Quality Index map in Post Monsoon b) Water Quality Index map Pre Monsoon

Figure 5 (a & b): Water Quality Index maps for pre & post monsoon

Conclusions

This work has demonstrated that groundwater quality in the study region can be mapped and evaluated throughout the pre-monsoon and post-monsoon seasons using GIS and laboratory analysis together. The research area's permitted limit for sodium, zinc, potassium, iron, calcium, chloride, nitrates, pH & alkalinity is demonstrated by the geographical distribution of these parameters in both seasons. However, a TDS examination of the water quality reveals that, in both seasons, over 10% of the study area's ground water is unsuitable for human consumption. With the exception of one sampling site, which is 2.44 Km from the coast in Vengurla Taluka, most of the samples fall inside the permitted range of values, according to spatiotemporal distribution map of hardness concentrations. With exception of 1 sample in each season, calcium levels are also within the uppermost allowable bounds. The alkalinity concentrations' geographical distribution map shows that every sample was within the desired range. There is just one location in the research region where the concentrations of TDS and Chloride in the groundwater are higher than maximum permitted limit.

The WQI score for study area was less than 20 in the pre-monsoon season, with the exception of a few samples 31, 33, 34, and 36 but only samples 33 and 36 had WQI values more than 20 in the post-monsoon season. It indicates that, overall, the groundwater is safe to drink and use for household needs, with exception of pre-monsoon season areas near Huda & Vadakhol compared to post-monsoon season. The elevated levels of hardness, chloride, calcium & TDS at these sites are probably the cause of the high water quality index result. This suggests that there may be seawater contamination in certain areas' groundwater.

The outcomes of the work at different stages were analyzed, and it was found that GIS is a useful tool for creating digital thematic layers and maps that display the geographical distribution of different water quality criteria. The investigation also discovered that sea water intrusion is gradually affecting the observation wells close to the coast. An essential method for assessing and measuring the effects of groundwater quality on seawater intrusion is the GIS research. This is concerning because it may eventually cause more groundwater supplies to become contaminated. The authors of the research advise local residents to be made aware of the overuse of groundwater and the ensuing incursion of seawater.

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