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Predictive Analysis of Groundwater Trends in Five Blocks of Sundarban Area in North 24 Parganas District, West Bengal, Through GIS Application

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Abstract: - Geoinformatics (GIS) is a special type of Information and Communications Technology ICT that integrates hardware, software and data for capturing, managing, analyzing and displaying all forms of geographically referenced information for comprehending geography and making intelligent decisions. Open source GIS is an easily available, free of cost user friendly software that integrates geographically referenced maps and data. Groundwater related data generated by State Water Investigation Directorate (SWID) and other agencies along with Minor Irrigation Census data have been integrated and analyzed in MapWindow 4.0 GIS platform for 5 saline blocks of North 24 Parganas district in West Bengal, India. Groundwater level, groundwater quality and Minor Irrigation (MI) census data of 2001 and 2007 have been analyzed along with trend of groundwater levels in each block. These blocks show high level of groundwater development against the backdrop of high salinity of groundwater. This GIS based analysis gives a transparent visualization of the groundwater scenario for the policy maker as well as for administrators even in an open source platform.

Keyword: *Chloride, GIS, pH, TDS, Trend of ground water level*

I. INTRODUCTION

Hydrogeological data and data related to groundwater development are essential for appropriate development planning in an area. In West Bengal, groundwater data is collected by State Water Investigation Directorate (SWID) and Central Groundwater Board (CGWB). These two organizations are also responsible for analyzing the Minor Irrigation (MI) Census data which is a reflection of groundwater development. The MI Census data is published at regular intervals. Since all this data is spatially related, a good GIS can make the data visible in georeferenced maps so that planners can visualize and compare the changes in parameters. In this paper an attempt has been made to translate the data of five blocks of Sundarban part of North 24 Parganas in a GIS platform.

II. METHODOLOGY

The processing steps followed in this paper are given below:-

1. Data has been collected from SWID pertaining to block wise groundwater level from the permanent hydrograph stations (PHS) and chemical quality of groundwater of those blocks. The data has been analyzed in Excel to delineate the trend of changes in the water level as well as certain chemical parameters.
2. MI census data has been computed for the years 2001 and 2007 and the changes in number of structures (Deep Tube Wells-DTW and Shallow Tube Wells-STW) as well as the Cultural Command Area (CCA) of the five blocks have been analyzed.
3. A georeferenced map of the North 24 Parganas district has been used as base map and the relevant blocks have been digitized as a shape file in an open source GIS, i.e. Quantum GIS.
4. The analyzed information for each block, e.g. Trend of groundwater level, Trend of water quality, number of STW, DTW, CCA etc. have been entered as shape files.

For the current project the following data sets and maps have been used:-

- Report on third minor irrigation census in West Bengal (2000-2001).
- Report on fourth minor irrigation census in West Bengal (2006-2007).
- Depth to Water level data from Permanent Hydrograph Stations of SWID.
- Water Quality Data of the area that had been analyzed in the Hydrological Laboratory of SWID.
- SRTM Digital Elevation Data.

III. RESULTS AND DISCUSSION

1. Study Area

The study area consists of 5 blocks viz. Haroa, Minakhan, Hasnabad, Sandeshkhali-I and Sandeshkhali-II of the district of North 24 Parganas in West Bengal, India. The district extends from latitude 22º 11' 06" north to 23º 15' 02" north and from longitude 88º 20' east to 89º 05' east. The district lies within the Ganges-Brahmaputra delta. The river Ganges flows along the entire west border of the district. There are many other rivers that flow through the district, chief among which are the Ichhamati, the Jamuna and the Bidyadhari. The district is bordered by the districts of Nadia in the north, South 24 Parganas and Kolkata in the south, Kolkata, Howrah and Hooghly in the west and Khulna Division of the neighboring country of Bangladesh in north and east.

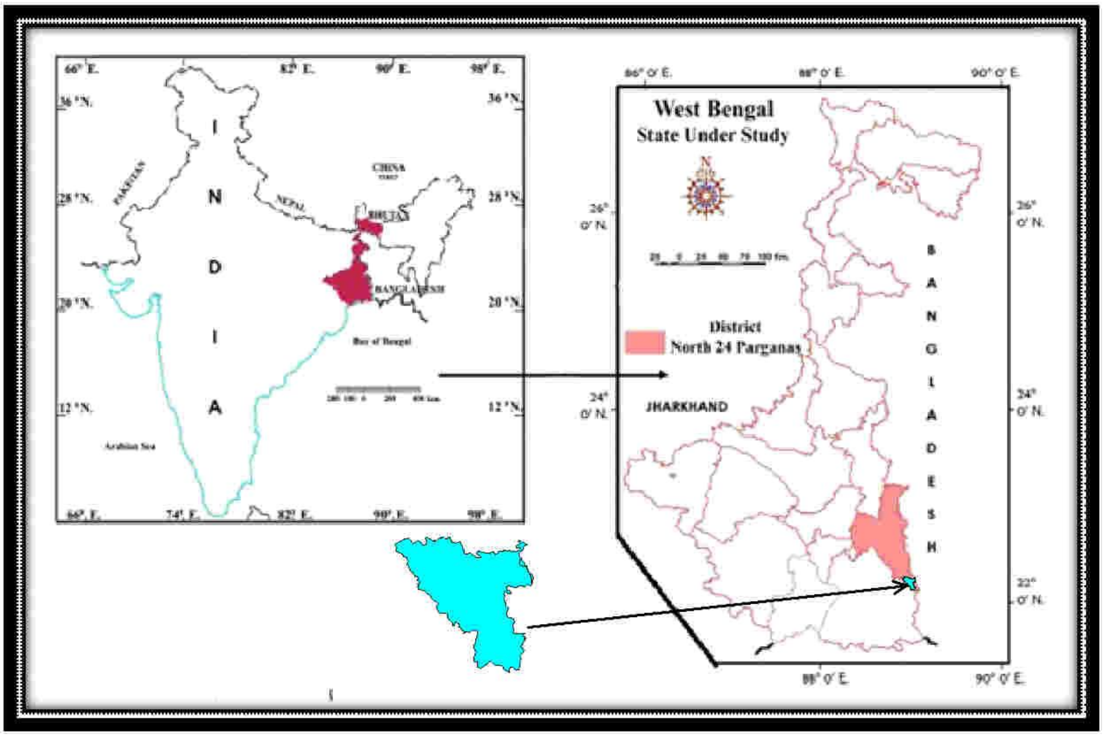

Figure 1: Map of Study Area (Five Blocks of North 24 Parganas)

2. Geology

The district of North 24 Parganas of West Bengal, India, lies in the southern part of the Bengal Basin. The basin is actually a peri-cratonic basin and comprises of Ganga-Brahmaputra delta in the southern part. It had broken from the Gondowanaland along the margin of the Indian plate and then moved northerly in the early Cretaceous (125Myr ago) period. The collision of the Indian plate and European plate began in the early Eocene (40 –41 Myrs ago) period and resulted in the formation of the Himalayas. Due to this, the two sediments from the Ganga and the Brahmaputra Basin got merged subsequently. Relatively recent folding and uplifting (Quaternary epoch) of the Brahmaputra sediments close to the intraplate boundary have redirected the course of the Brahmaputra to its present configuration.

The Ganga-Brahmaputra delta thickens towards the south and has three stratigraphic sequences – the proto-Ganges delta, the transitional delta and the modern delta (created11 Myrs ago) with a successive sequence of sand, sandy mud, silt and mud which were deposited under a major eustatic sea level about 11 Myrs ago. The modern delta has been formed primarily from alluvial sediments transported by the rivers originating from the Chotanagpur Uplands in the west e.g. the Mayurakshi, the Ajoy, the Damodar etc. and subsequently by the rivers flowing from the Himalayan foredeep basin from the north e.g. the Ganges, the Padma, the Bhagirathi, the Brahmaputra etc. when a gap named as the Garo-Rajmahal gap, was created due to tectonic movements. Arsenic contaminated groundwater occurs in the modern deltaic sediments.

In the present study area, the main water bearing formations are Quaternary formations which chiefly comprises of Recent and Pleistocene alluvial deposits and aquifer materials comprising of sand of varying grades and gravels. Thus ground water occurs within water table and in semi confined to confined conditions.

3. Geomorphology

In the district of North 24 Parganas of West Bengal certain geomorphological features are distinctively present. The region lies within the lower delta plain of the Bengal Basin. The delta can be divided into two regions:

(A) The upper delta plain of meander belts of the Padma- Bhagirathi rivers in the north; and

(B) The lower delta plain with several tidal creeks in the south.

The upper delta plain is characterized by a series of meander scars of various wavelengths and amplitudes, abandoned channels and oxbow lakes formed under varying hydrodynamic conditions in a fluvial regime. Abandoned meander scrolls are the most common form and could be related to flood-plain formation in the upper delta plain with a very gentle southerly slope. Report on the hydrogeology of the area suggests that there is shallow aquifer (12 - 15 m below ground level (bgl)) in the upper delta plain and is mostly under unconfined conditions except near its southern fringe where it occurs under semi-confined to confined conditions.

The lower deltaic plain consists of tidal mudflats, distributary levees and inter distributary marsh complexes formed under a fluvial-estuarine – marine environment under the influence of fluctuating sea level conditions in geologically recent times (Pleistocene-Holocene).

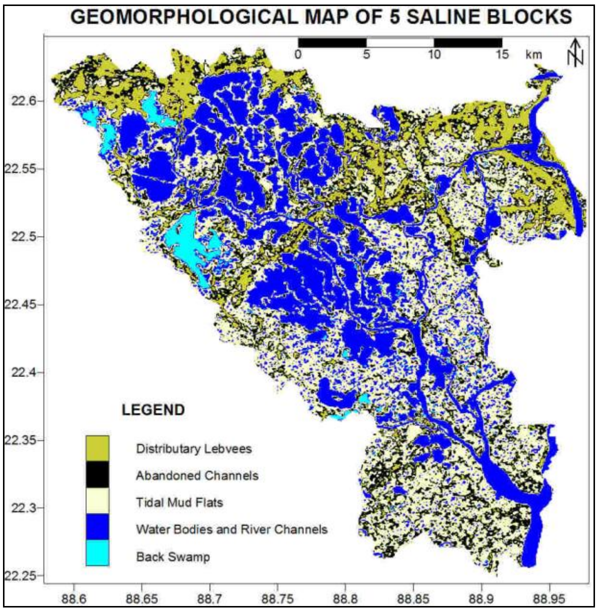

Figure 2: Geomorphological Map of Study Area

4. Hydrogeology

The lower deltaic plain is characterized by the presence of an extensive clay capping of varying thickness (15-76m) which is underlain by silt, sand and gravel in many places (Deshmukh and Goswami, 1973).

There are three aquifers with depths ranging from 2 to 26 mbgl, 35 to 46 mbgl and 120 to 160 mbgl in the Haroa and Basirhat blocks. In Minakhan, Sandeshkhali I & II blocks there is another aquifer at 230 to 290 mbgl. There is generally a southeasterly gradient of the water surface sub-parallel to the general slope of the area. All the aquifers are interconnected due to spatial variations in grain size.

The initial values of aquifer parameters were taken from the literature. CGWB (1994) and SWID (1998) estimated that transmissivity (T) values (in m^2/d) vary from 500 to 3000 in this region, with an average storativity (S) of 0.03.

5. Depth to water level

Pre and post monsoon depth to water level data collected from SWID for the years 2001 to 2008 show that groundwater level is very shallow (less than 5 meters bgl). However, the trend of groundwater level shows that in Haroa Block, post monsoon trend is rising and in other blocks the trend is falling in both pre and post monsoon period. (Table 1) and Figure. 3.

Table 1: Block wise Depth to Water Level and Trend

SL No.	BLOCK	Year								Trend
		2001	2002	2003	2004	2005	2006	2007	2008	
		Depth to Water Level in meter bgl								
1	Haroa pre monsoon	6.18	3.95	4.01	4.14	3.79	5	4.51	3.55	Rising
	Haroa post monsoon	1.95	1.89	1.6	2.18	2	2.26	2.06	2.1	Falling
2	Hasnabad pre monsoon	2.45	2.89	3.1	3.15	4.86	3.43	3.22	2.89	Falling
	Hasnabad post monsoon	1.74	1.96	1.82	2.89	3.29	2.64	2.33	2.45	Falling
3	Minakhan pre monsoon	2	1.78	1.63	2.63	2.15	2.92	3.63	3.58	Falling
	Minakhan post Monsoon	0.33	0.28	0.67	0.83	0.48	0.86	0.85	0.51	Falling
4	Sandeshkahli I pre monsoon	3.25	4.07	3.43	3.1	3.7	4.57	4.4	4.37	Falling
	Sandeshkahli I post monsoon	1.65	1.48	1.38	1.86	1.49	1.55	1.79	1.92	Falling
5	Sandeshkhali II pre monsoon	2.78	3.67	2.71	2.85	3.88	4.3	3.76	4.04	Falling
	Sandeshkhali II post monsoon	0.86	1.23	1.05	2.02	1.67	1.55	1.69	1.86	Falling

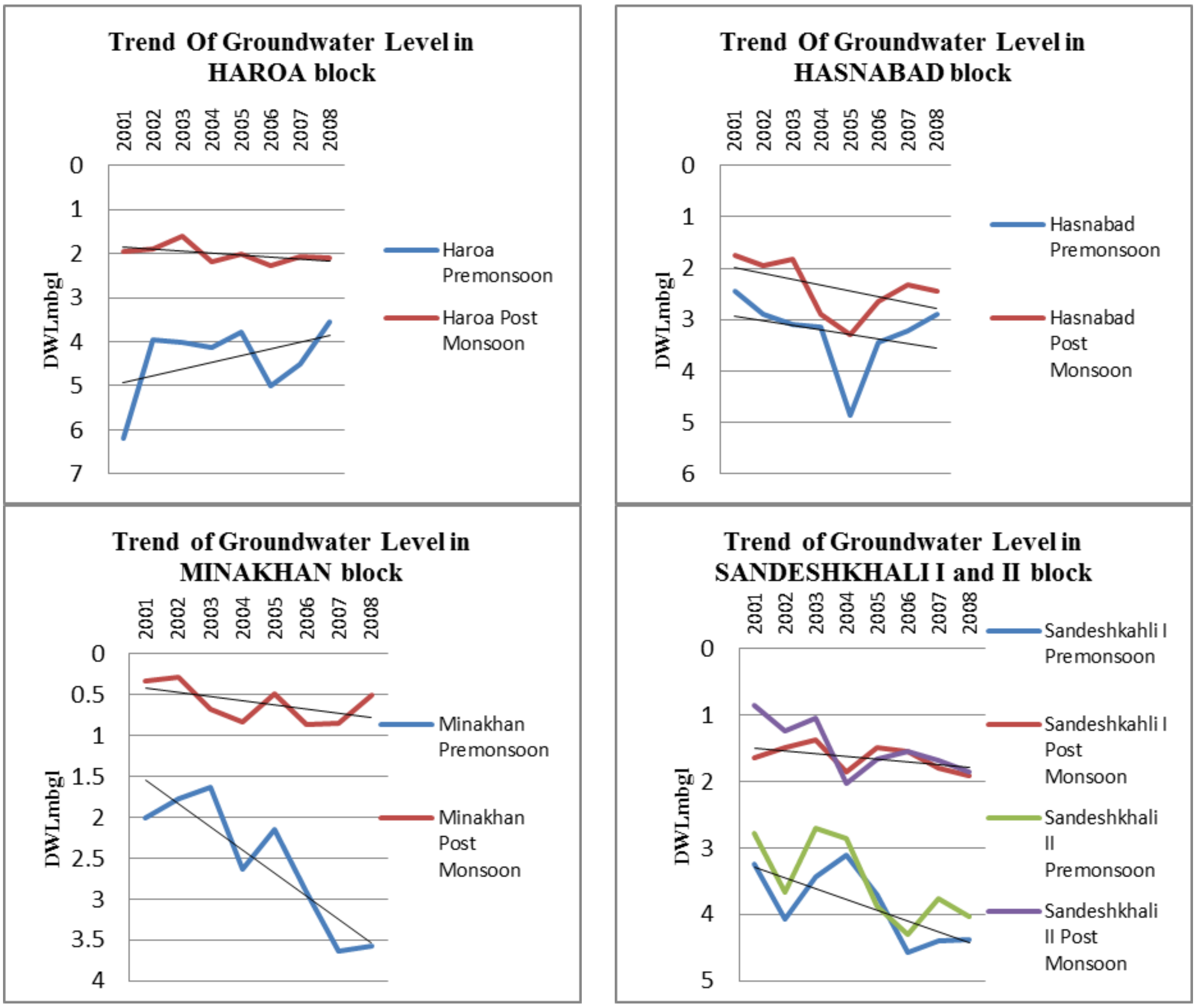

Figure. 3: Graphs showing trends of groundwater levels in 5 blocks

It can be interpreted from the above trend analysis that four of the five blocks under study depict a trend of decreasing groundwater level both in pre monsoon and post monsoon phases due to high population pressure. Only Haroa block depicts an increasing trend.

6. Chemical Quality

Groundwater quality data has been collected from SWID for the period 2004 to 2008. The data exhibits that in the blocks under study, the aquifers are brackish to saline in nature. Freshwater aquifer is available at a greater depth. Since there were some data gaps in the pre monsoon period, only post monsoon data has been analyzed. Here also there is both rising and falling trends in some chemical parameters like pH, TDS and Chloride. The results of the analysis have been summarized below in Table 2 to Table 4.

Table 2: Trend of Groundwater quality – Chloride in ppm

GROUND WATER QUALITY : CHLORIDE IN PPM(POST MONSOON)							
		YEAR					
SL No.	**BLOCKS**	**2004**	**2005**	**2006**	**2007**	**2008**	**TREND**
1	Haroa	50	20	20	90	180	Rising
2	Hasnabad	610	640	770	830	770	Rising
3	Minakhan	190	260	190	80	90	Falling
4	Sandeshkahli I	70	70	50	60	80	No Change
5	Sandeshkhali II	140	30	90	90	200	Rising

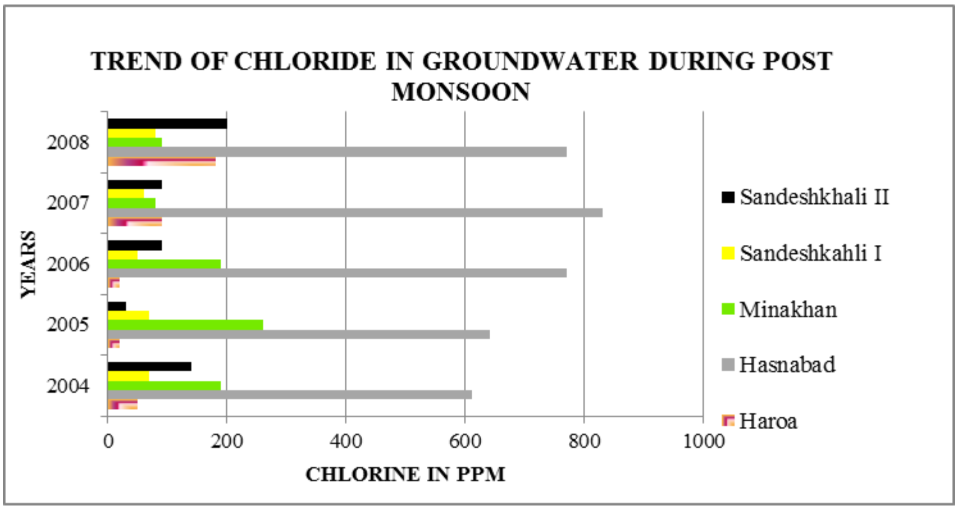

Figure 4: Trend of chloride in groundwater during post monsoon

Trend analysis of the available data exhibits that the concentration of chlorine in ground water for post monsoon period depicts a mixed trend from 2004 to 2008 in the five blocks under study with majority (3 blocks) showing an increasing trend in the year 2007.

Table 3: Trend of Groundwater quality – pH

GROUND WATER QUALITY : pH (POST MONSOON)							
		YEAR					
SL No.	BLOCKS	2004	2005	2006	2007	2008	TREND
1	Haroa	7.49	7.36	7.95	7.93	8.13	Rising
2	Hasnabad	7.9	7.39	7.87	7.27	7.5	Falling
3	Minakhan	8.21	8.04	8.45	7.85	7.06	Falling
4	Sandeshkahli I	8.19	7.87	8.16	7.85	8.09	No change
5	Sandeshkhali II	7.57	7.86	8	7.38	7.38	Falling

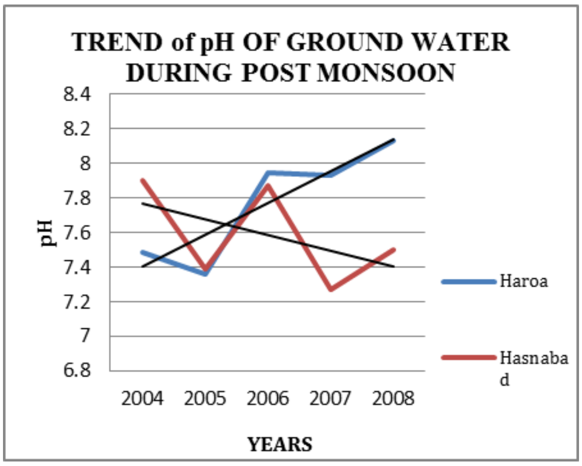

Figure 5(a)

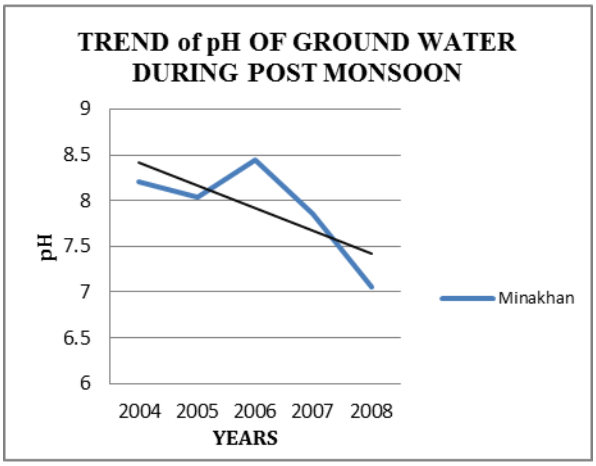

Figure 5(b)

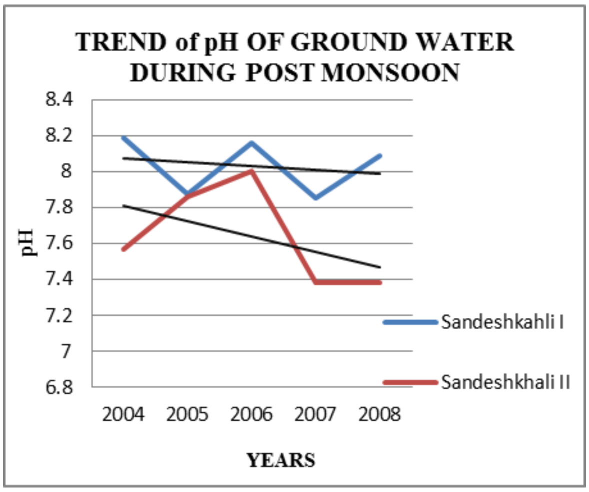

Figure 5(c)

Figure 5: Trends of pH of groundwater during post monsoon

Trend analysis of the available data show that pH of ground water during post monsoon period depicts a decreasing trend from 2004 to 2008 in majority (3) of the five blocks under study.

Table 4: Trend of Groundwater quality – TDS in ppm

GROUND WATER QUALITY : TOTAL DISSOLVED SOLIDS (TDS) IN PPM(POST MONSOON)							
		YEAR					
SL No.	**BLOCKS**	**2004**	**2005**	**2006**	**2007**	**2008**	**TREND**
1	Haroa	333	416	294	717	499	Rising
2	Hasnabad	1408	1600	1280	2112	1280	No Change
3	Minakhan	858	928	698	557	403	Falling
4	Sandeshkahli I	512	538	518	550	403	Falling
5	Sandeshkhali II	570	525	365	570	518	No Change

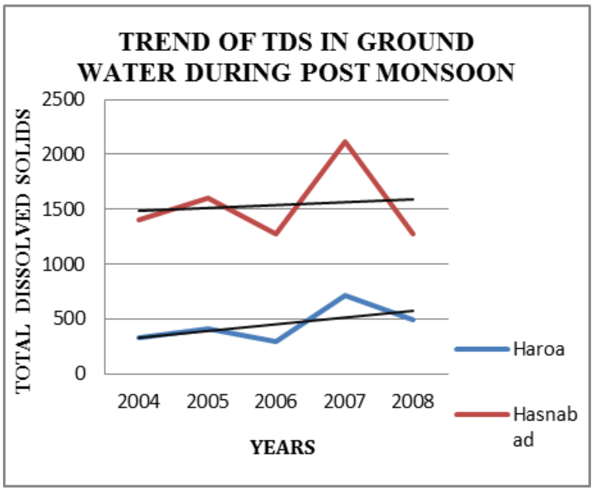

Figure 6(a)

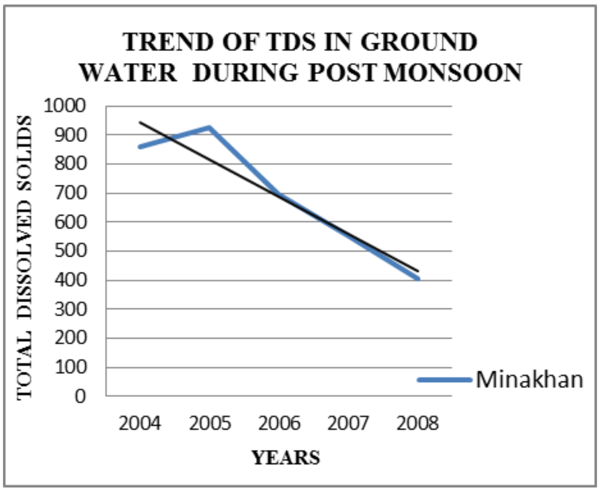

Figure 6(b)

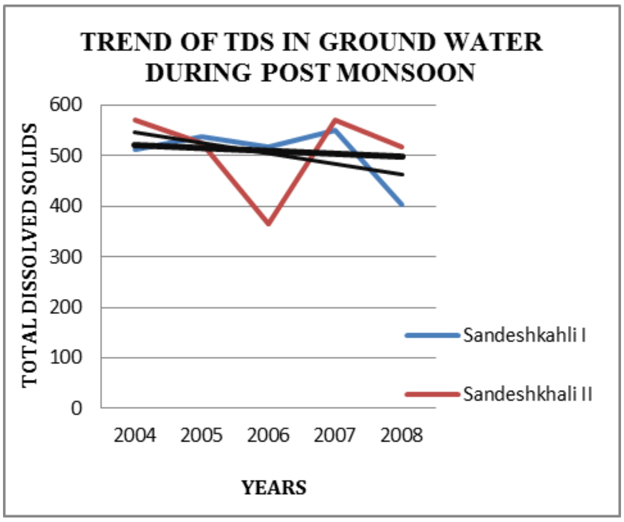

Figure 6(c)

Figure 6: Trend of TDS in groundwater during post monsoon

As can be seen from the trend analysis above, the TDS of ground water quality during post monsoon period depicts mixed results with 2 blocks showing no change at all.

7. Groundwater Structure and CCA

Minor Irrigation Census of West Bengal during 2001 and 2007 shows certain developmental activities have been undertaken for improvement of groundwater quality and availability in these blocks. Table 5 shows the number of groundwater structures and corresponding cultural command area per block. The data shows that though there is a decrease in the number of STW in Haroa, Minakhan, Sandeshkhali I and Hasnabad blocks, the corresponding CCA has increased. Whereas in Sandeshkhali I block 2 no. of new DTW increased in 2007.

Table 5: Groundwater Structures in 2001 and 2007

Sl No	BLOCK NAME	No.STW in 2001	No.STW in 2007	CCA from STW2001	CCA from STW2007	No. of DTW 2001	No. of DTW in 2007	CCA from DTW in 2001	CCA from DTW in 2007
1	HAROA	1709	1591	2295	2891	4	6	120	240
2	MINAKHAN	1005	652	1615	1745	0	0	0	0
3	SANDESHKHALI-I	567	551	1126	2050	0	0	0	0
4	SANDESHKHALI-II	569	763	860	2199	0	2	0	80
5	HASNABAD	698	577	1122	786	0	0	0	0

8. GIS based visualisation

The data analyzed for water level, chemical quality and groundwater census has been provided as input for the attribute table of the shape file (blocks. shp) in MapWindow GIS. From that data three maps have been generated that depict the trend of groundwater level, ground water development through STW and the change in chemical quality of groundwater in terms of TDS. These color coded maps show the changes in groundwater quality, trends of groundwater level and groundwater development the blocks under study.

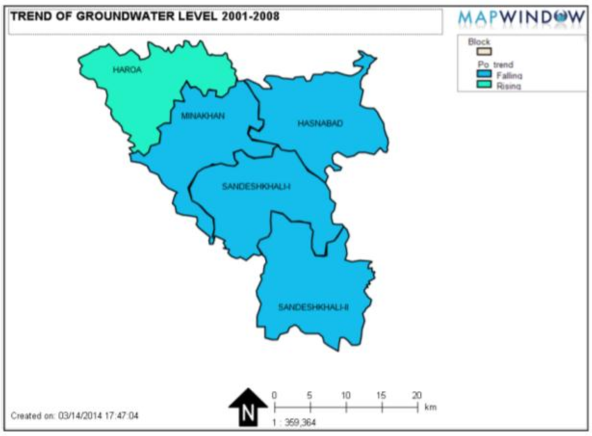

Figure7: Trend of Post Monsoon water Level

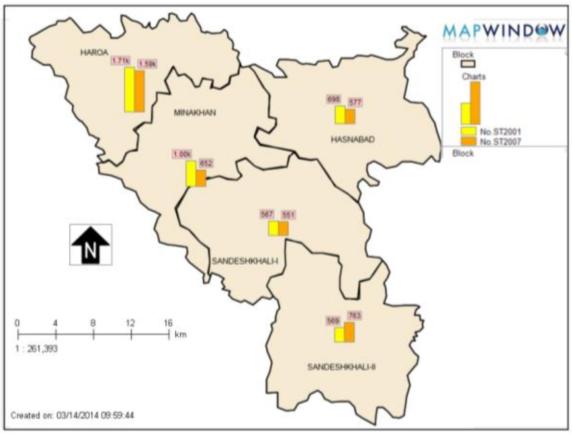

Figure 8: Number of STW in 2001 and 2007

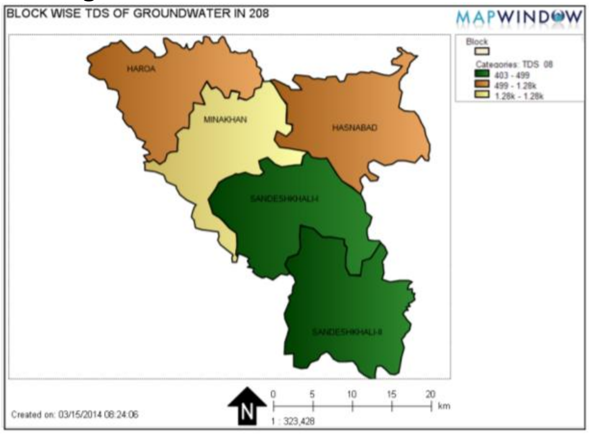

Figure 9: Blockwise TDS (ppm)

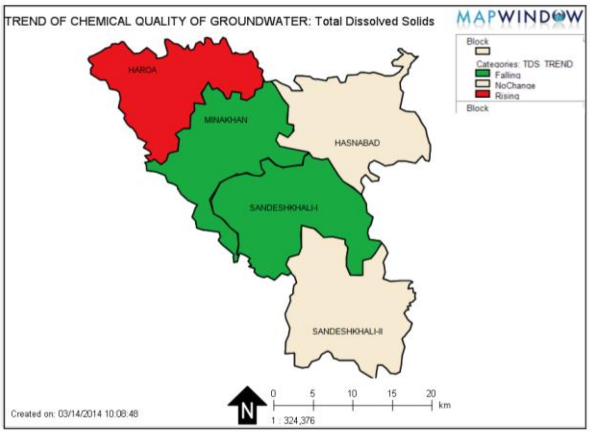

Figure 10: Trend of change of TDS (2004 – 2008)

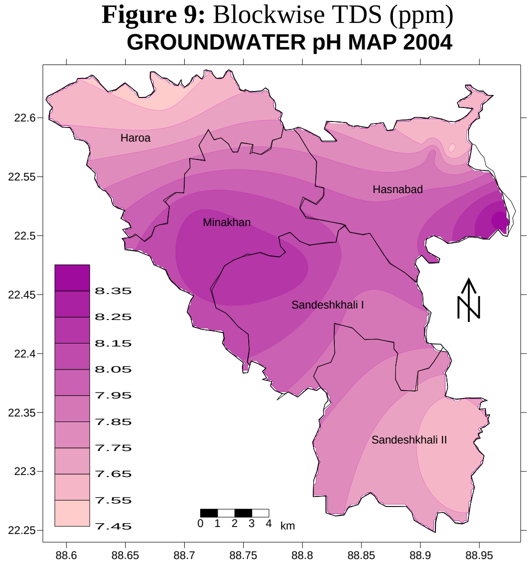

Figure11: Trend of pH in 2004

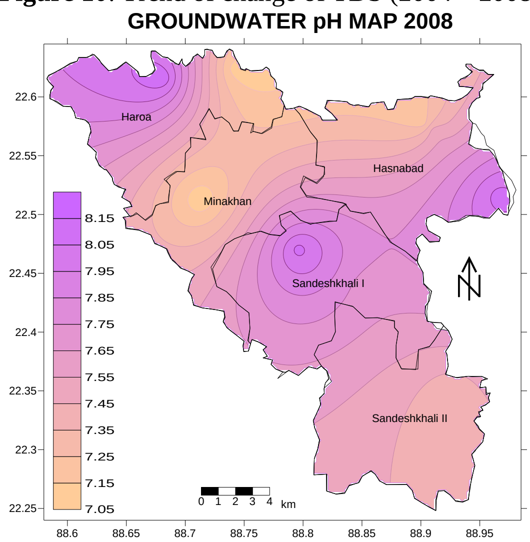

Figure 12: Trend of pH in 2008

The data when represented in the form of the maps can be used to propose the following interpretations:

- Post monsoon ground water shows a falling trend in four of the five blocks under study. This trend can be attributed to overutilization of groundwater in these blocks.
- Number of STW shows an increasing trend in only one block which can be attributed to the fact that the level of groundwater table is higher than at other locations.
- TDS shows a rising trend in one block and no deviation in two blocks. This trend can be attributed to the mode of utilization of groundwater which is chiefly used as drinking water in the study area with some insignificant usage for industrial, irrigation and other minor uses in the region.

- pH trend shows an improvement in the blocks over the years under study, which denotes that rainfall distribution during the post monsoon months has influenced this attribute.

IV. CONCLUSION

GIS plays an important role in decision support system. In this paper the groundwater resource and development scenario have been analyzed to show the trend in changes of different spatial parameters. After the analysis the data was visualized through GIS maps. It appears that in spite of reduction in the number of shallow tube wells from 2001 to 2007, the water level shows declining trend in most blocks. It also shows increase in cultural command areas. This leads to the following conclusions:

- There may be an increase in population and increased utilization of groundwater as drinking water.
- The other reason may be that due to increase in cultural command area, the actual groundwater withdrawal from individual tube wells has increased.

This paper argues that for proper interpretation of MI census data, water quality and water level data, GIS based analysis has been very helpful.

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