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Assessment of seasonal variation of ground water quality in the northern arcuate of Mizoram, India using geo-spatial technology

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Abstract: Water is one of the most important natural resources, which is extremely vital for our daily life. Ground water is the main source of water for irrigation, industrial and also for domestic purposes in India. Therefore, the quality of ground water is as important as its availability. Inconsistent ground water quality during different seasons may hamper agricultural and industrial products and also the wellbeing of the people. The northern part of Mizoram has become an important commercial hub resulting in rapid urbanization and growth of human and livestock population. The present study utilizes geo-spatial technology to map the spatial variability of ground water quality in various seasons. Ground water samples were collected from 50 point sources in season-wise i.e. pre-monsoon, monsoon and post monsoon seasons for three consecutive years i.e., 2016, 2017 and 2018 from the northern arcuate of Mizoram. All the samples were analyzed in the laboratory based on important ground water quality parameters. The major water quality parameters namely pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Iron, Total hardness, Alkalinity and Nitrate have been estimated and the averaged seasonal values of three years were taken for all the sampling locations. Interpolation technique called Inverse Distance Weighted (IWD) method was utilized for generating spatial variation maps of ground water quality parameters for different seasons. These seasonal and spatial variation maps of ground water quality within the study area can be utilized to give a guideline for the suitability of ground water uses and database for further developmental activities in water sector.

Keywords: GIS, Ground water, Water quality, Mizoram.

1. Introduction

Rapid urbanization, growth of population and extensive uses in domestic and agricultural sectors increase the demand for good quality of water supply (Choudhary et al., 1996; Majumder and Sivaramakrishnan, 2014; Goyal, 2013). Ground water is one of the most important natural resources and the major accessible source of fresh water (Neelakantan and Yuvaraj, 2012; Kumar, 2013; Nag and Das, 2014). However, urbanization and the unregulated growth of the population have altered the local topography and drainage system which affect both quality and quantity of the ground water (Vasanthavigar et al., 2010). Therefore, finding the potential areas, monitoring and conserving ground water have become highly crucial at the present moment (Rokade et al., 2004; Kumar and Kumar, 2011).

The geology of Mizoram comprises N-S trending ridges with high degree of slopes and narrow intervening synclinal valleys. Faulting in many locations has produced steep fault scarps (GSI, 2011). Therefore, majority of the rain water is lost as surface runoff even though the state received high amount of rainfall. Springs are the major sources of water in the area. Hence, the quality of water from such sources needs to be carefully analyzed and represented in a GIS environment (CGWB, 2007). Few efforts were made in studying the water quality within the state of Mizoram. These include seasonal variation in water quality of Tuirial river in vicinity of the hydel project (Lalparmawii and Mishra, 2012), Physico-chemical characteristics of Tamdil lake (Mishra and Chenkual, 2014) and Ground water quality mapping of Aizawl district (Lalbiakmawia and Vanthangliana, 2015).

The arrival of geospatial technology allows fast and cost effective survey and management for natural resources (Ramakrishna et al., 2013). Geographical Information System (GIS), Global Positioning System (GPS) and remote sensing are the main tools in this recently introduced technology. Hence, this technique has wide-range applications in geo-scientific researches including ground water quality mapping (Ganesh Babu and Sashi kumar, 2013). Therefore, many researchers have utilized these techniques successfully in ground water studies, both for prospecting and quality mapping (Krishnamurthy and Srinivas, 1995; Krishnamurthy et al., 2000, Dey, 2014). These techniques have proved to be of immense value not only in the field of hydrogeology but also for the development of surface water resource as well (Sharma and Kujur, 2012; Saraf and Choudhury, 1998).

2. Study area

2.1 Location and extent

The study area (Figure 1) lies in the northern arcuate of the state between 92° 31’ 39.80”E to 92° 53’ 45”E and the 24° 08’ 38.00”N to 24° 31’ 16.00” N, which is situated in northern part of Kolasib district and falls under Survey of India topographical map No. 83D/11, 83D/12, 83D/14 and 83D/15 covering 395 sq km. The area is bounded in the west by Mamit district, in the north by Hailakandi district and Cachar district of Assam and in the eastern side, it is bounded by Aizawl district of Mizoram. It falls under N. Thingdawl rural development block and there is one notified town i.e. Vairengte and about 20 other habitation.

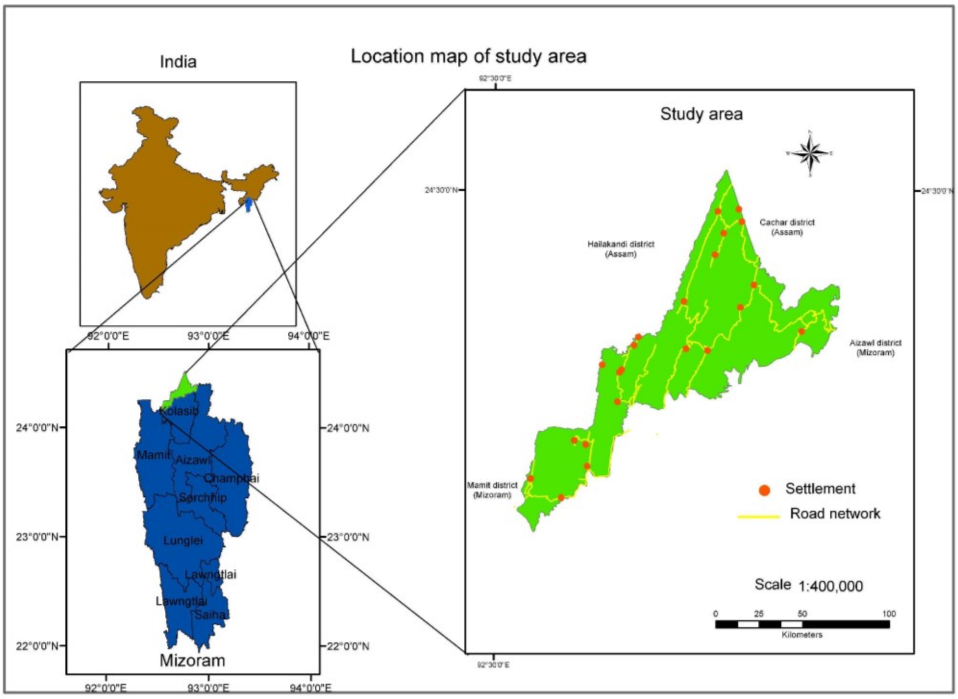

Figure 1: Location map of the study area

The area is bounded in the west by Mamit district, in the north by Hailakandi district and Cachar district of Assam and in the eastern side, it is bounded by Aizawl district of Mizoram. It falls under N. Thingdawl rural development block and there is one notified town i.e. Vairengte and about 20 other habitations.

2.2 Climatic condition

The climate of the study area ranges from moist tropical to moist sub-tropical. The entire area is under the direct influence of south west monsoon, with average annual rainfall of 2287.10 mm (Lalzarliana, 2018). Figure 2 shows the average annual rainfall and table 1 provides annual rainfall of the study area during 2008-2017.

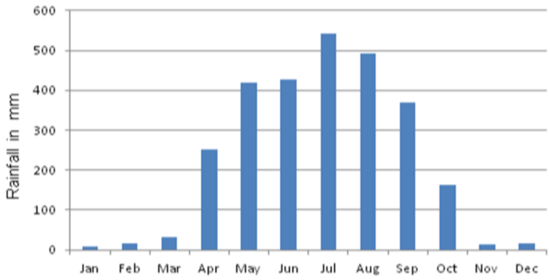

Figure 2: Average annual rainfall of the study area

Table 1: Annual rainfall of the study area during 2008-2017

Bilkhawthlir, Kolasib district Rainfall (in mm) 2008-2017												
Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2008	19	12	0	32	87	294	297	500	122	194	0	0
2009	0	18	52	142	200.8	325	313	383	196	0	14	0
2010	0	0	104	459	624	730	1111	1033	783	162	0	142
2011	0	0	78	83	657	726	1139	742	379	317	0	0
2012	50	18	0	867	369	558	282	480.4	373	315	8.2	0
2013	0	0	7	107	1085	330.6	698.8	319.9	292.3	119.9	0	0
2014	0	6.4	21.9	55.5	161.6	210	380.5	165.4	289.6	165.4	3.1	0
2015	10.6	19.2	11	397.7	390.3	356.8	468.4	361.2	242.4	361.2	22.5	11.4
2016	0	48	55.8	181	318	304.1	221.5	262.8	320.5	87.9	66.4	0
2017	0	1.9	166.6	358.9	263.5	411.4	385.6	525.5	256.7	243.2	0	103.1
Average	7.96	12.4	49.6	268	416	425	530	477	325	197	11.4	25.7

2.3 Geology

The earliest recorded work on geology of Mizoram reported that the area comprises great flysch facies of rocks made up of monotonous sequences of shale and sandstone (La Touche THD, 1891). The study area lies over rocks of Middle Bhuban, Upper Bhuban and Bokabil formations of Surma Group of Tertiary age. Middle Bhuban and Bokabil formations consist mainly of argillaceous rocks while Upper Bhuban formation comprises mainly of arenaceous rocks (GSI, 2011). It was also observed that the rocks exposed within the study area were traversed by several faults and fractures of varying magnitude and length (MIRSAC, 2007).

2.4 Geomorphology

The study area is characterized mainly by ridgelines and intervening valleys and less prominent ridges. Structural hills are the main geomorphic units which are classified as High, Moderate and Low Structural Hills based on their elevation. As the name implies, structural hills are of structural origin, associated with folding, faulting and other tectonic processes. Other geomorphic units like Valley Fill and Flood Plain are characterized by unconsolidated sediments, and occur along streams and major rivers respectively (Lalbiakmawia, 2015).

Geology, geomorphology and demographic profile can be utilized for analyzing the spatial variability in the water quality constituents. Nutrients from domestic waste or from agricultural pesticides add to the complexity of the research.

3 Materials

3.1 Data

Base map of the study area comprising roads, settlement and boundary were extracted from Natural Resources

Atlas of Mizoram prepared by MIRSAC. Satellite data, SOI topographical maps and various ancillary data were also referred in the study. Records of ground water quality prepared by State Referral Institute (SRI), Aizawl were imported and plotted in a GIS environment.

3.2 Software

GIS software ArcInfo 10.1 version and handheld GPS device were used for analysis, mapping, locating sample points and for ground truth verification.

4 Methodology

The base map was geo-referenced and digitized using ArcInfo 10.1 GIS software for spatial analysis. The water samples were collected from fifty locations which area within or near the settlement and covered the entire area uniformly (Figure 3). Hence, all the samples were collected from Built-Up areas in terms of Land use/land cover. Majority of the samples were collected from dug wells and springs, few tube wells were also included. Water samples were collected in a wide mouth bottle (Tarsons bottle), washed with distilled water and again rinsed with representative water samples. These are then transported to the laboratory at least within 24 hours for analysis. Pre-monsoon, monsoon and Post monsoon data were collected each year from 2016-2018. Pre-monsoon samples were taken during the month of March and April, monsoon data during July and August and post monsoon samples during October and November. The samples were tested for their physico-chemical parameters in State Referral Institute (SRI), Aizawl. Digital instruments made by Eutech instruments were used to test pH, Electrical Total Dissolved Solids (TDS), Conductivity (EC), Iron, Alkalinity, Total hardness and Nitrate were measured using the water testing kit made by Transchem Agritech Limited (Blick, 2018). The characteristics of the water were subsequently evaluated using the Indian Drinking Water Standards as per BIS Guideline (RGNDWM, 2011).

Interpolation technique through Inverse Distance Weighted (IDW) approach has been used in the present study for generating element-wise seasonal and spatial distribution of the ground water quality. This technique is one of the most commonly used techniques for interpolation of scatter points and has been used extensively in ground water quality mapping. The method is based on the assumption that the interpolating surface should be influenced most by the nearby points and less by the more distant points. (Ambica et al., 2017; Khadri and Pande, 2015; Mahalingam et al, 2014; Boominathan et al., 2015; Shyamala and Jeyanthi, 2017; Lalbiakmawia, 2015). Variation maps were utilized for comparing the ground water quality parameters through space and time.

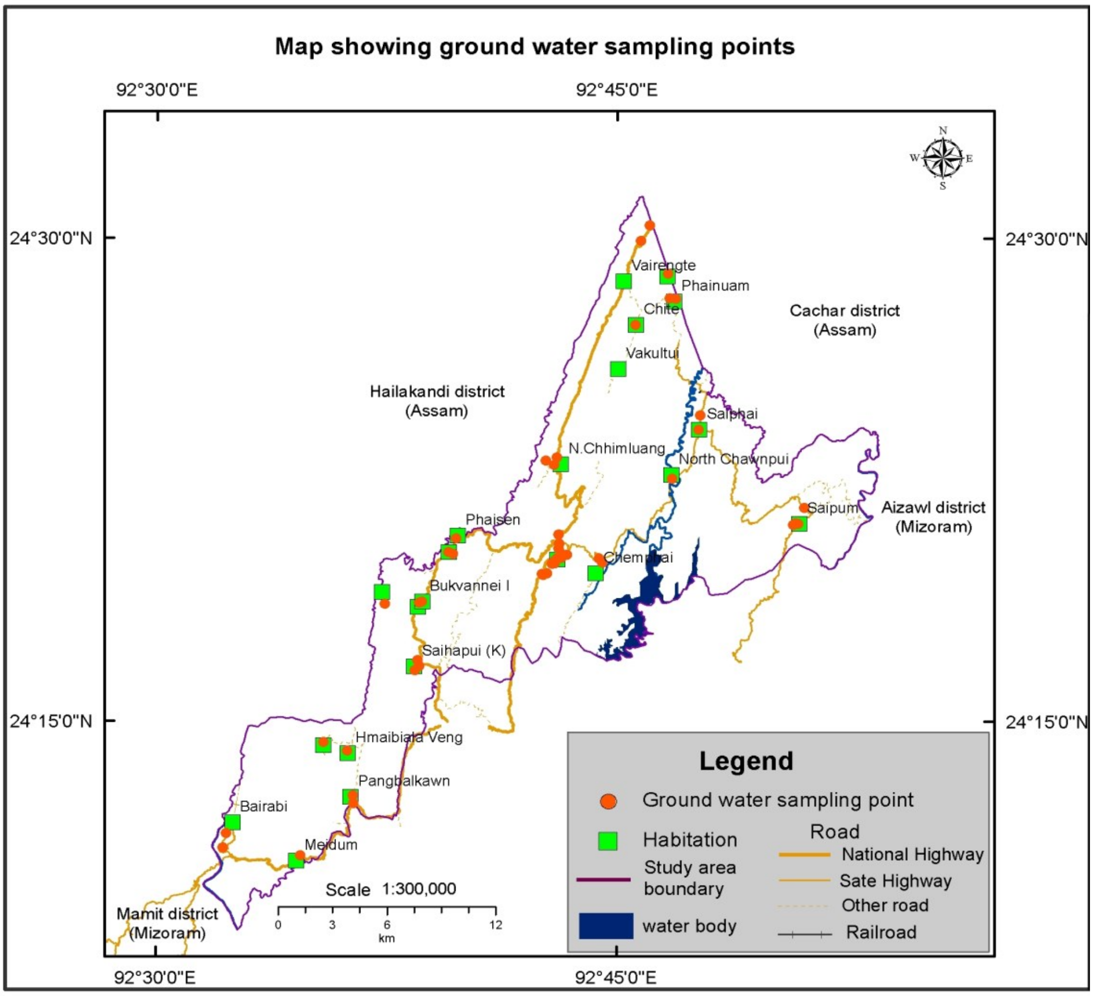

Figure 3: Map showing ground water sampling points

5 Results and Discussion

Seasonal and spatial ground water quality are integrated and presented in the form of maps. Results and discussion for the major parameters are as follows:

5.1 pH

pH is one of the important parameters of water which determines the acidic and alkaline nature of water. The pH value of water ranged between 6 and 8.5. The permissible range according to BIS is 6.5 to 8.5, hence, samples in some areas are acidic. Table 2 shows the average pH values and the spatial variation maps for pH are presented in the figure 4.

It was observed that the value of pH is lower during the monsoon period than the pre monsoon and post monsoon seasons especially in the eastern part of the study area. Since, jhum system of cultivation is still prevalent within and surroundings of the study area, burning of jhums right before the monsoon period may release huge volume of carbon dioxide into the atmosphere (Laldintluanga et al., 2016). When the monsoon starts, the carbon dioxide in the air may get dissolved within the rain and forms carbonic acid. When this precipitation reaches the ground surface, it act as a source of water to the spring.

Rainfall during the monsoon period also dissolve certain minerals in the sedimentary rocks like sandstone and shale which may cause lower pH value of water.

Table 2: Average pH value

Average pH Value			
Year	Pre-monsoon	Monsoon	Post monsoon
2016	6.90	6.87	7.27
2017	6.966	6.67	6.709
2018	7.14	6.66	7.46
Average	**7**	**6.74**	**7.15**

5.2 Total Dissolved Solids (TDS)

The Total Dissolved Solids (TDS) of water is classified in to three ranges (0-500 mg/l, 500-2000 mg/l and >2000 mg/l) by BIS guideline. Table 3 shows average TDS values and the spatial variation maps for TDS are presented in the figure 5. Total Dissolved Solids (TDS) usually refers to the mineral content of water. The most common source of dissolved solids in water is from the weathering of rocks which occurs more or less at the same rate within the study area. The concentration of TDS is controlled by the composition of the rocks and geomorphological condition of the area. It was also observed that the value of TDS is lower during the monsoon season than the pre monsoon and post that during monsoon periods. This may be due to increases of the solvent mainly rainwater during the monsoon. Accordingly, TDS value is much higher during pre-monsoon season due to decreasing amount of water during the dry period.

Table 3: Average TDS

Average TDS			
Year	Pre-monsoon	Monsoon	Post monsoon
2016	53.10	66.76	89.92
2017	61.74	74.20	59.20
2018	75.02	76.00	77.82
Average	**63**	**72.32**	**75.65**

5.3 Electrical Conductivity (EC)

The Electrical Conductivity (EC) of water was classified in to three ranges (0-2250 µmhos/cm, 2250-3000 µmhos/cm and >3000 µmhos/cm) by BIS guideline. Table 4 shows the average EC values and the spatial variation maps for Electrical Conductivity (EC) are presented in the figure 6. Electrical conductivity in ground water varies slightly in season-wise with the highest value during pre-monsoon especially in the eastern part and the lowest conductivity during monsoon period. Increase in the amount of aqueous solution during rainy season may have reduced the conductivity. The temperature of water while measuring the Electrical conductivity ranges from 25°-28°C.

Table 4: Average EC value

Average EC			
Year	Pre-monsoon	Monsoon	Post monsoon
2016	205.00	164.00	180.00
2017	220.00	170.00	185.00
2018	210.00	190.00	200.00
Average	212	174.67	188.33

5.4 Iron (Fe)

As per BIS guideline, in terms of Iron concentration, <0.3mg/l is Desirable limit, 0.3-1.0mg/l is Permissible limit and >1.0mg/l is in Non-potable class. Fe content in ground water depends on the chemical composition of the aquifers and may largely due to the hand pump components in a bore well. Table 5 shows average Fe concentration values and the spatial variation maps for Iron are presented in the figure 7. Season-wise, iron content is lowest during the monsoon period, while the pre-monsoon season has the highest iron concentration. Increasing amount of water during monsoon may have diluted the iron concentration while the amount of water is less during pre-monsoon causing higher concentration of iron.

Table 5: Average Fe concentration

Average Fe concentration			
Year	Pre-monsoon	Monsoon	Post monsoon
2016	0.41	0.34	0.28
2017	0.30	0.16	0.15
2018	0.23	0.13	0.18
Average	0.31	0.21	0.20

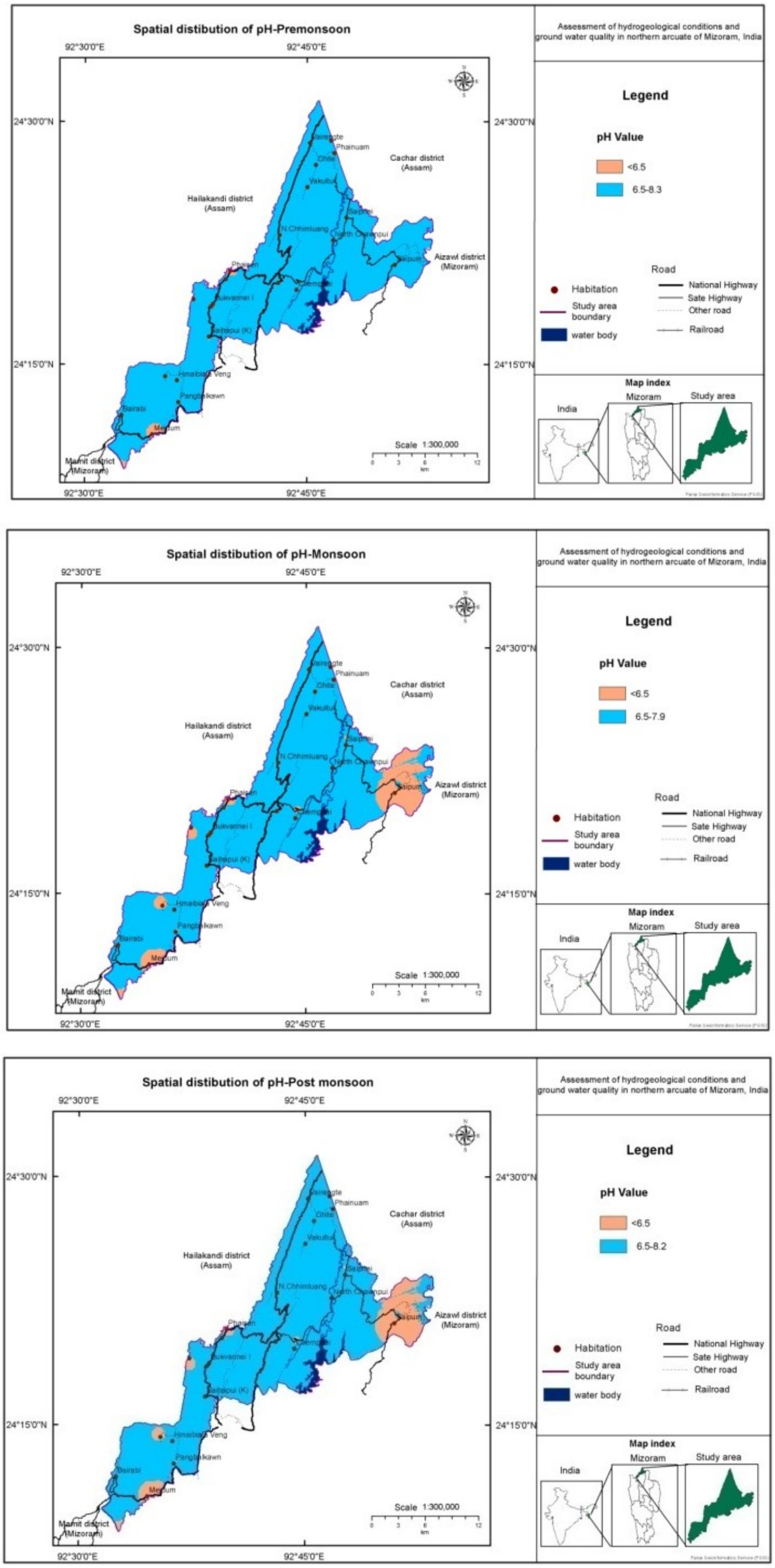

Figure 4: Spatial distribution of pH during pre-monsoon, monsoon and post monsoon season

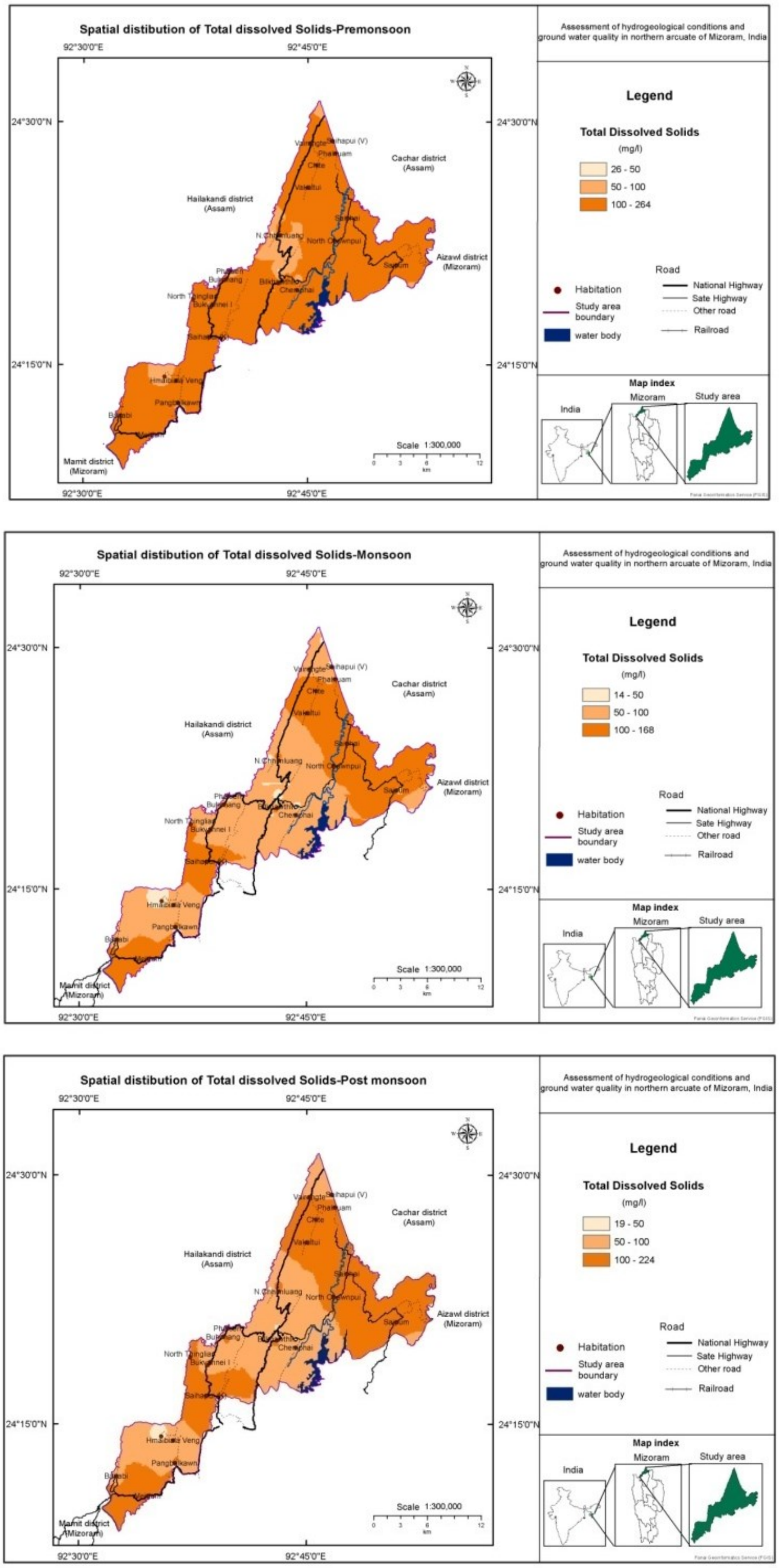

Figure 5: Spatial distribution of Total Dissolved Solids during pre-monsoon, monsoon and post monsoon season

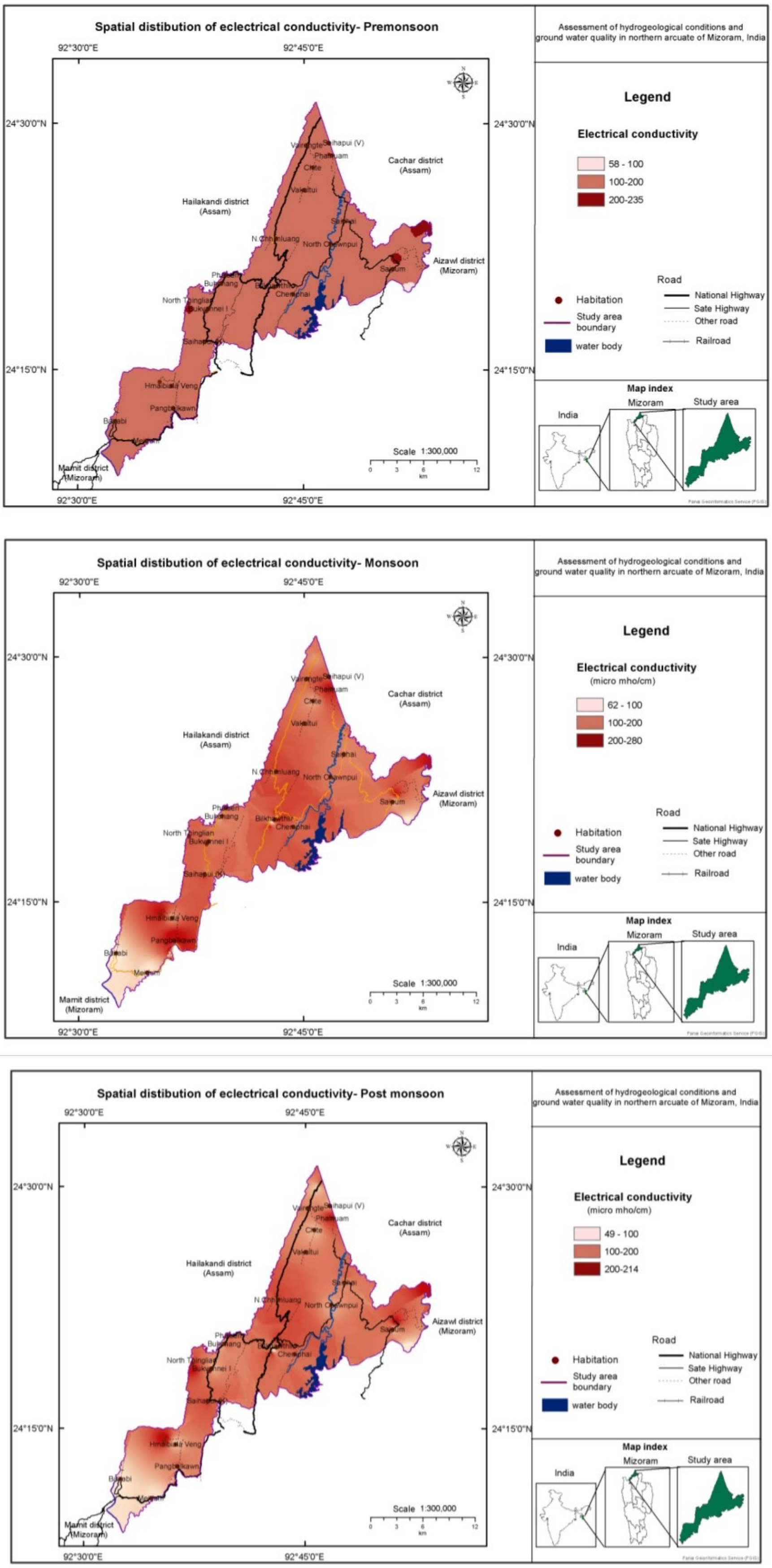

Figure 6: Spatial distribution of Electrical conductivity during pre-monsoon, monsoon and post monsoon season

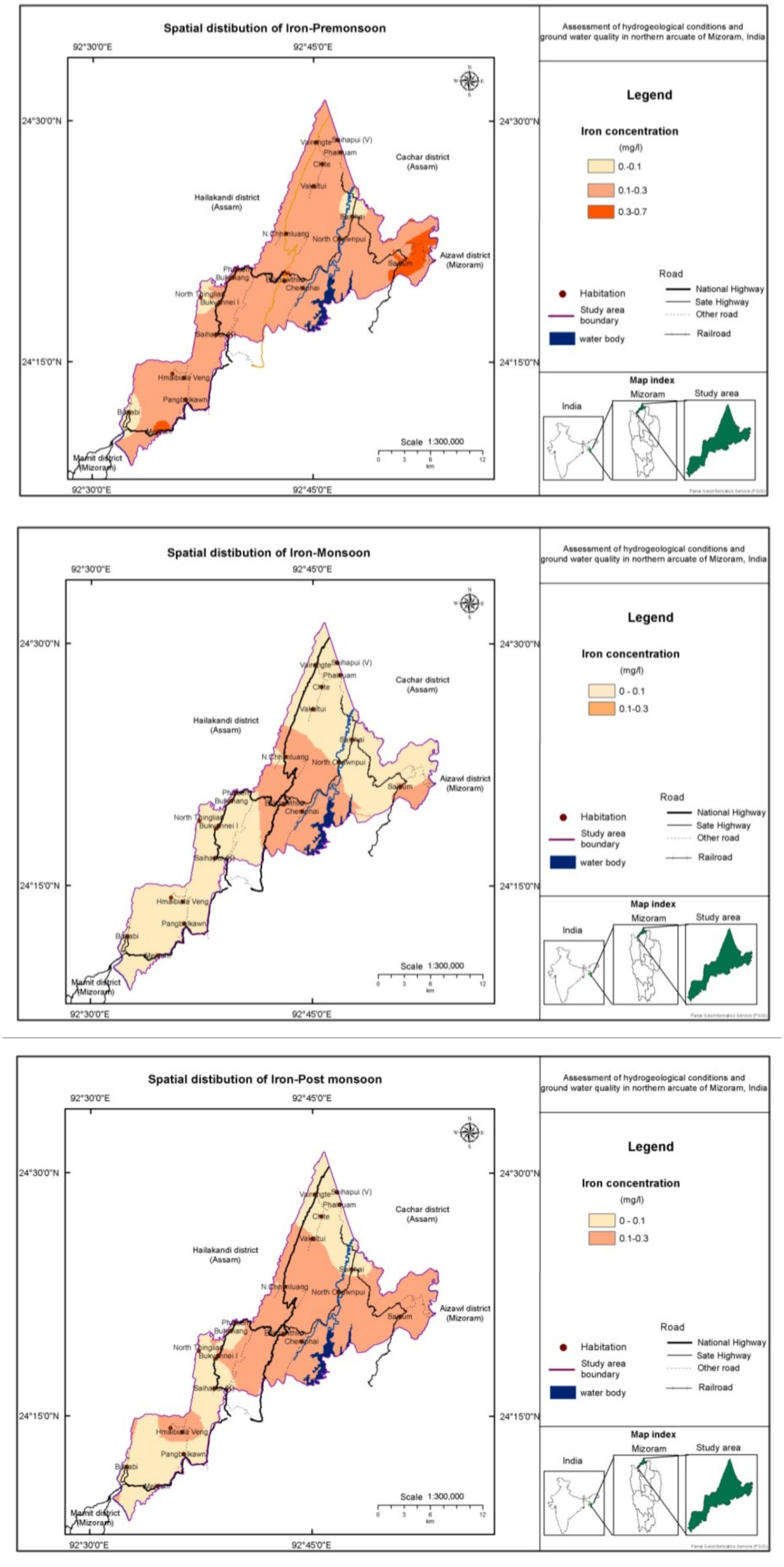

Figure 7: Spatial distribution of Iron during pre-monsoon, monsoon and post monsoon season

5.5 Total Alkalinity

The total alkalinity is categorized into three ranges (0-200 mg/l, 200-600 mg/l and >600 mg/l) by BIS guideline. Water with high alkalinity is said to be "hard." The most prevalent mineral compound causing alkalinity is calcium carbonate. Large amount of alkalinity imparts a bitter taste to water. However, in terms of Total alkalinity, all the samples from different sources within the study area are well within desirable limit. Table 6 shows average total alkalinity values and the spatial variation maps for Alkalinity are presented in the figure 8. The total alkalinity is lower during the monsoon season than the pre-monsoon and post monsoon periods. This may be due to the increase of amount of water and may also be due to slightly acidic nature of the rain water during the monsoon period.

Table 6: Average Alkalinity

Average Alkalinity			
Year	Pre-monsoon	Monsoon	Post monsoon
2016	68.30	64.85	70.70
2017	76.08	66.00	64.98
2018	78.00	68.00	72.00
Average	74.13	66.28	69.23

5.6 Total Hardness

The Total hardness is categorized in to three ranges (0-300 mg/l, 300-600 mg/l and >600 mg/l) as Desirable, Permissible and Non-potable classes by BIS guideline. The value of Total hardness in ground water may be controlled by the chemical composition of the aquifers. Hardness is the amount of dissolved calcium and magnesium in the water. Table 7 shows average total hardness values and the spatial variation maps for total hardness are presented in the figure 9. The highest total hardness value is 295mg/l. That means the quality of ground water in terms of total hardness within the study area is within Desirable class.

Total hardness is lower during the monsoon season than the pre-monsoon and post monsoon periods and slightly higher in Post monsoon and with the highest concentration during the Pre-monsoon period.

Table 7: Total Hardness

Average TH			
Year	Pre-monsoon	Monsoon	Post monsoon
2016	53.34	43.56	51.18
2017	70.66	60.58	61.42
2018	76.08	56.54	60.22
Average	66.69	53.56	57.61

5.7 Nitrates

Nitrates concentration was classified in to three ranges (<45 mg/l, 45-100 mg/l and >100 mg/l) by BIS guideline. Table 8 shows average nitrate concentration values and the spatial variation maps for nitrates are presented in the figure 10. Ground water from various locations of the study area is well within the Desirable class as per BIS classification.

The contamination of ground water by nitrates may also be due to anthropogenic activities like utilization of fertilizers, sewage from human habitations. Concentration of Nitrates in ground water may depend on the chemical composition of the rocks in which it occurs. Nitrate concentration is higher during the pre-monsoon season than the monsoon and post monsoon periods. This may be due to the increasing quantity of water during the rainy season where the element concentration got diluted. The monsoon period and post monsoon period have almost the same Nitrates concentration.

Table 8: Average Nitrate Concentration

Average Nitrates concentration			
Year	Pre-monsoon	Monsoon	Post monsoon
2016	53.34	43.56	51.18
2017	70.66	60.58	61.42
2018	76.08	56.54	60.22
Average	66.69	53.56	57.61

6. Conclusion

It can be concluded from the present study that the northern arcuate of Mizoram has no major problem in ground water quality in any of the seasons i.e. pre-monsoon, monsoon and post monsoon.

The eastern part of the area has lower pH value, higher concentration of Fe and higher EC as compared to the other parts. Value of Total Alkalinity is higher within the middle part of the area. Total Hardness and concentration of Nitrates are more or less equal within the study area. The difference in elements concentration may be due to geological variation within the study area.

There are seasonal variations in element-wise ground water quality of the area. The seasonal variation is mainly due to the amount of rainfall or absence of it. Undiluted rainwater seems to have a huge effect on the ground water quality.

The Ground water quality maps help us to know the existing ground water condition of the study area. Geo-spatial technology has been proven to be useful tools for mapping ground water quality. The ground water quality map prepared through this study will be useful for planning future ground water development and management.

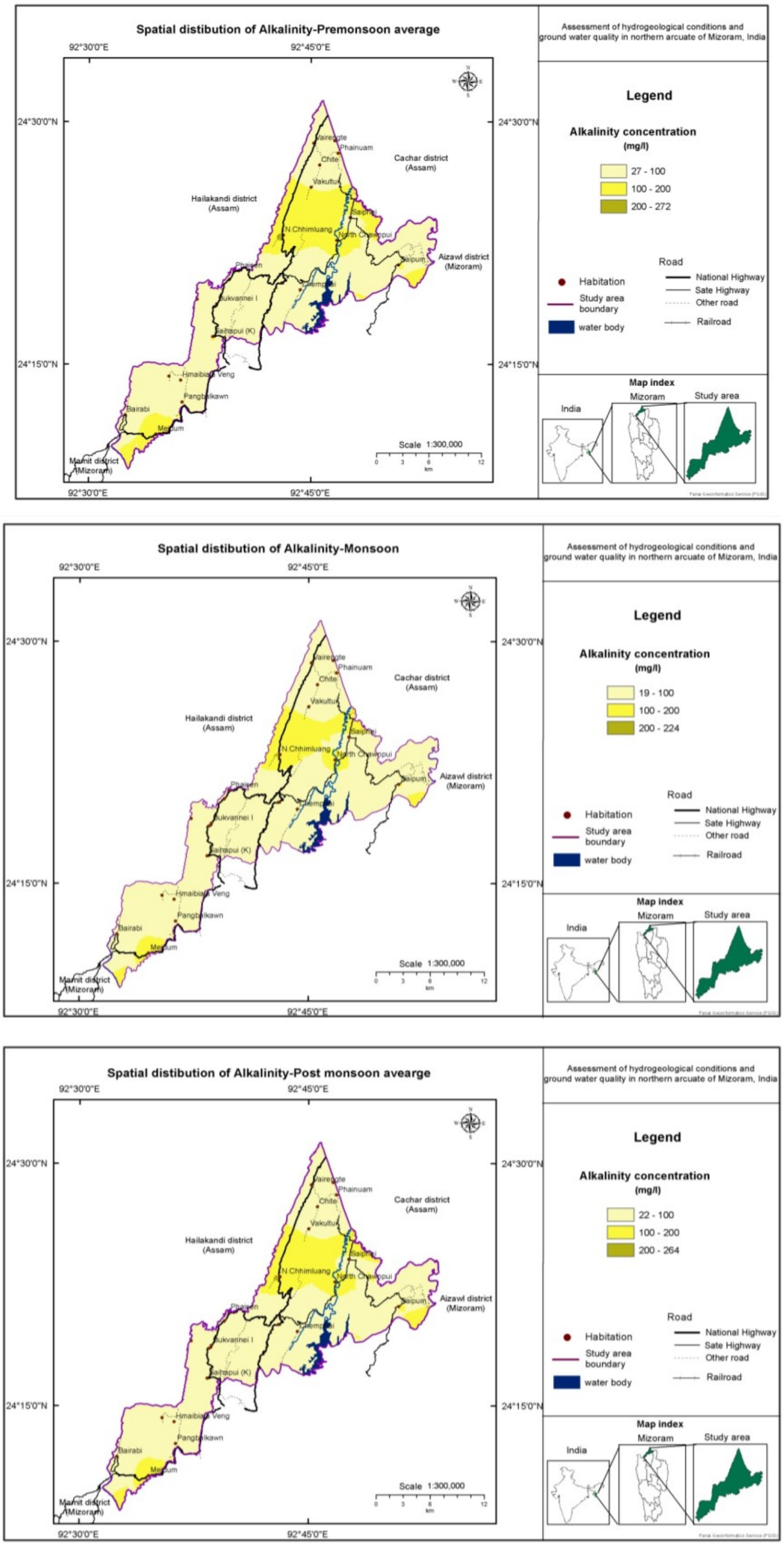

Figure 8: Spatial distribution of Alkalinity during pre-monsoon, monsoon and post monsoon season

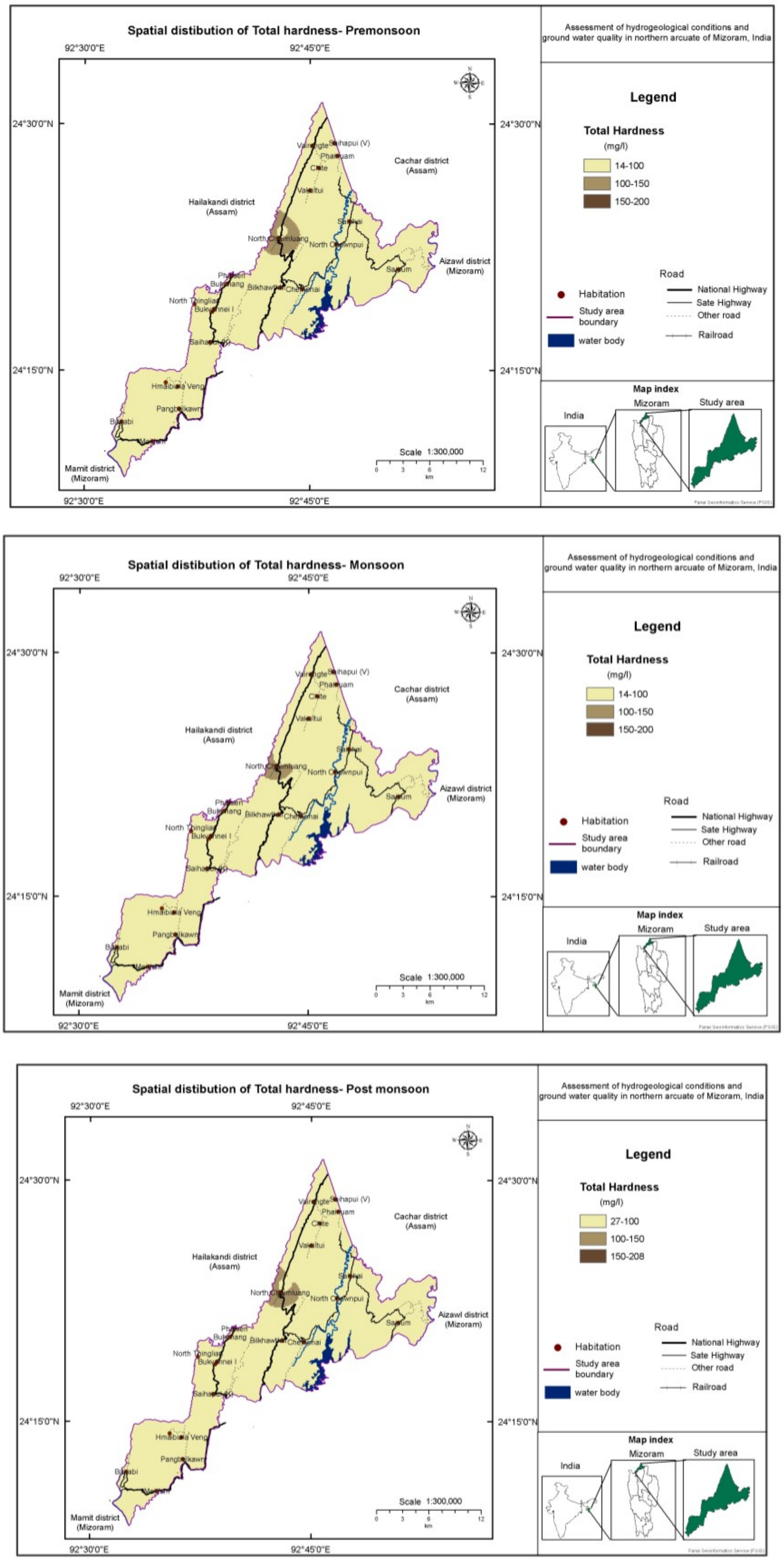

Figure 9: Spatial distribution of Total hardness during pre-monsoon, monsoon and post monsoon season

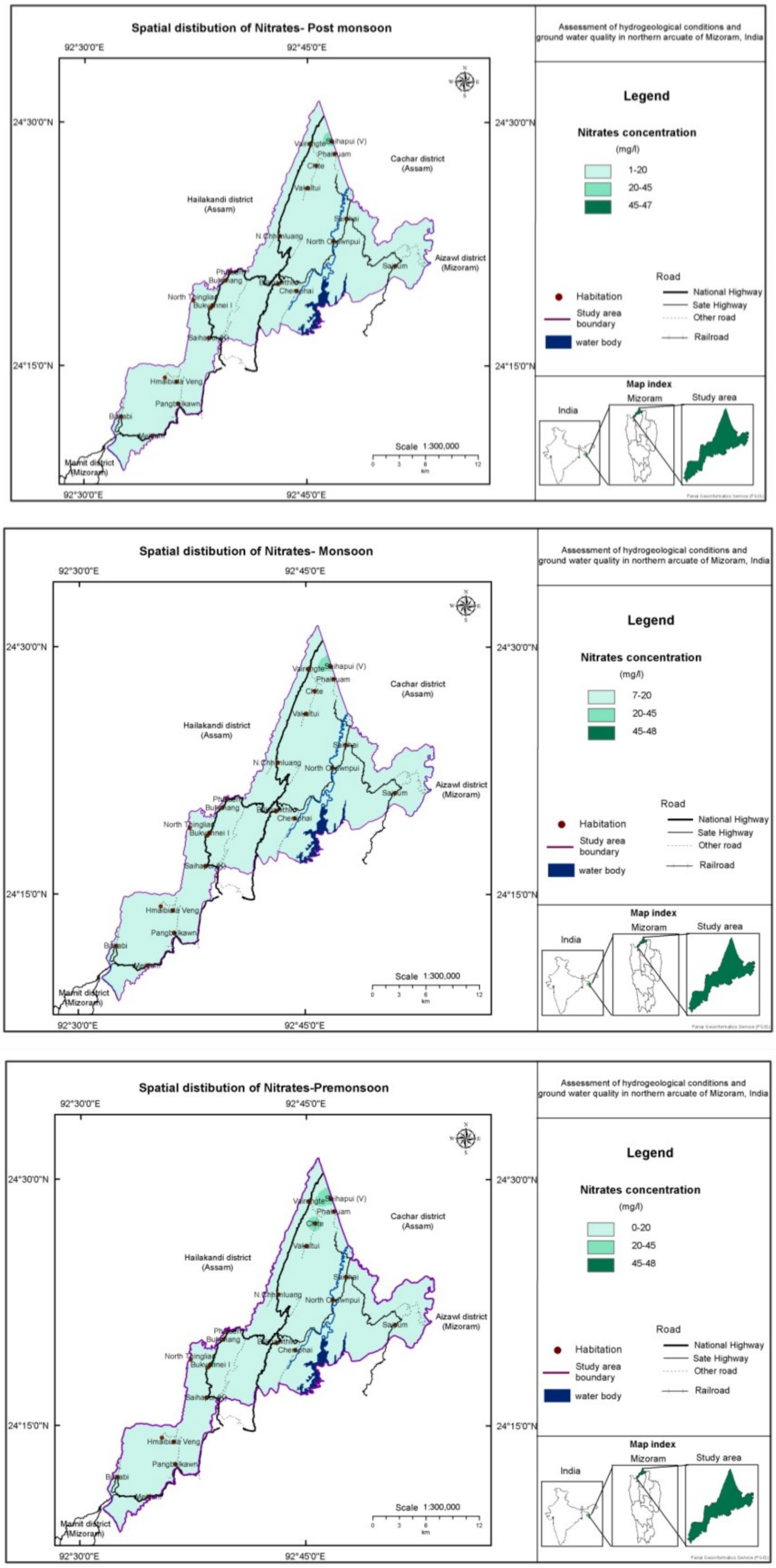

Figure 10: Spatial distribution of Nitrates during pre-monsoon, monsoon and post monsoon season

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