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Original Article

Spatial Variability of Major Ion Geochemistry in Groundwater from Uttar Mand Sub-Basin of Krishna River Basin, Maharashtra (India)

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ABSTRACT

This study was carried out to investigate the current status of groundwater quality and spatial hydrochemical changes in groundwater from Uttar Mand sub-basin of Krishna River Basin, Maharashtra (India). For this study, 100 groundwater samples were collected from wells and bore wells distributed in the study area and analyzed physicochemical parameters viz. pH, total dissolved solid (TDS), total hardness (TH), major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-} , Cl^{-}), and Boron. The data use for the present study is two post-monsoon seasons (November 2014 and November 2015) and two pre-monsoon seasons (May 2015 and May 2016). GIS approach was adopted to describe the physicochemical parameters and hydrochemistry of groundwater. The spatial attributes of the watershed were digitized and employed in overlay analyses. The data of routine parameters (EC, pH and TDS), cations and anions were processed in Arc-GIS software. The spatial distribution maps assist to determine suitable places for groundwater development and management. This work concluded that comprehensive assessment of groundwater quality would help for proper management and planning for future water need.

KEYWORDS: Groundwater, hydrogeochemistry, Arc-GIS, Spatial distribution maps

INTRODUCTION

Water is one the most precious natural resource existing on our planet and 71% of the Earth's surface comprises of it. Without this precious compound, life on the earth would not exist. However, due to rapid growth in the global population, the difference between supply and demand of water is widening and is reaching the alarming or dangerous levels in some part of the world (Duriaswami, 2005). However, due to increased anthropogenic activities i.e. domestic as well as economic, these valued resources are increasingly under threat, both qualitatively and quantitatively (Srinivasmoorthy, et.al. 2011).

Quality of water resources is directly affecting the quality of our food, health and environment. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources have been increased (Duriaswami, 2005). Thus, increasing stress on freshwater resources brought about by ever-rising demand and increasing pollution worldwide, is of serious concern.

At the beginning of the 21st century earth faces serious problems of environmental pollution occurs due to anthropogenic activities. The municipal waste generation and its disposal is the common problem being faced today (Srinivasmoorthy, et.al. 2011). The improper use and disposal of wastewater affects the human health and environment. Hence, the quality of the water and soil has been deteriorating day by day. The contamination and quality of water is main concern in the region where limited water resources. The industrial and municipal effluent is main source of water contamination.

The geographical information system (GIS) technique has emerged as a very effective and reliable tool in the identification of spatial variation of various geochemical parameters in the studied areas (Singh et. al., 1993, Akhouri, 1996, Reddy et al., 1996, Singh and Prakash, 2004; Sonar et al, 2018; Varade et al., 2018). In the present study researcher has select the Uttar Mand sub-basin of Krishna River Basin, Maharashtra State of India for the spatial distribution of various geochemical parameters in groundwater system. The Uttar Mand river basin bounded between latitude 17° 20' 12'' N to 17° 25' 24'' N and longitude 73° 55' 07'' E to 74° 5' 7'' E as per the Survey of India Toposheet numbers viz. 47 G/15, 47 K/3 and having area of about 109 km^2 (Fig. 1).

The Uttar Mand River is one of the tributary of the Krishna River. The soil cover in study area is fertile and this extremely helpful for agriculture purpose. The climate of the study area comes from across as an amusing blend of the coastal and inland climate of Maharashtra. The study area is famous for sugarcane cultivation. The temperature ranged from 10° C and 40° C. The average annual rainfall of the area is recorded about 4,800 mm. The present study area geologically covers a Deccan Volcanic Basalt of Upper Cretaceous to Lower Eocene age (Fig. 2). The laterite occurs in the upstream part of Uttar Mand river basin.

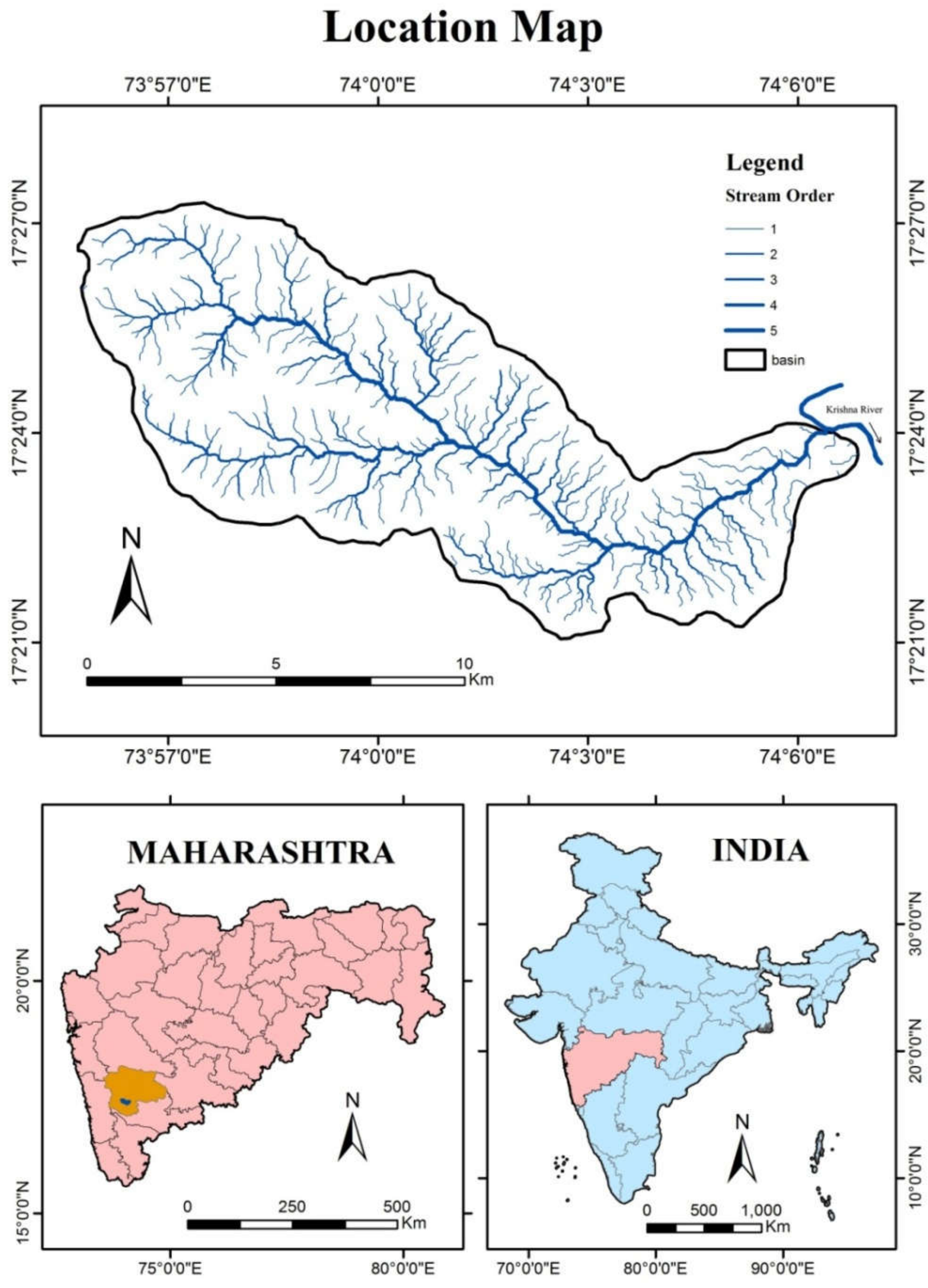


Figure 1: Location Map of the Study Area

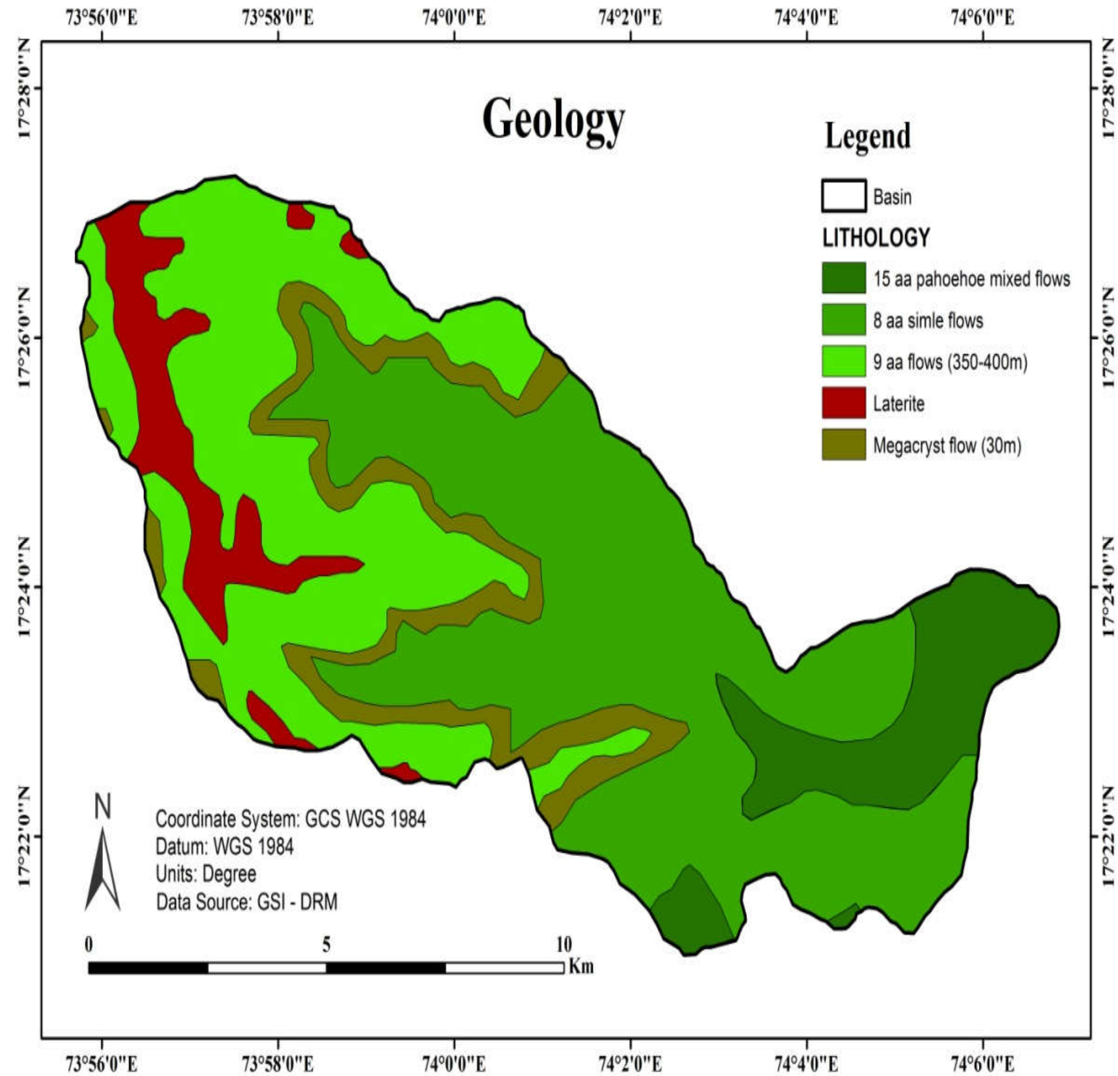


Figure 2: Geological map of the Uttar Mand sub-basin

METHODOLOGY

The actual methods of groundwater sample collection were based on the depth of individual wells. While collecting the samples precaution were taken. Plastic containers of one liter capacity were used for the collection and storage of water samples. The standard methods of collection and analysis of water samples were followed given by APHA (1998). The coordinates of each well were noted using GPS (GARMIN 12 channel) for geo-referencing. A total 100 groundwater samples were collected for pre-monsoon in May 2015 and 2016 and for post-monsoon in November 2014 and 2015 season. The location maps of water sampling station were depicted in Fig. 3.

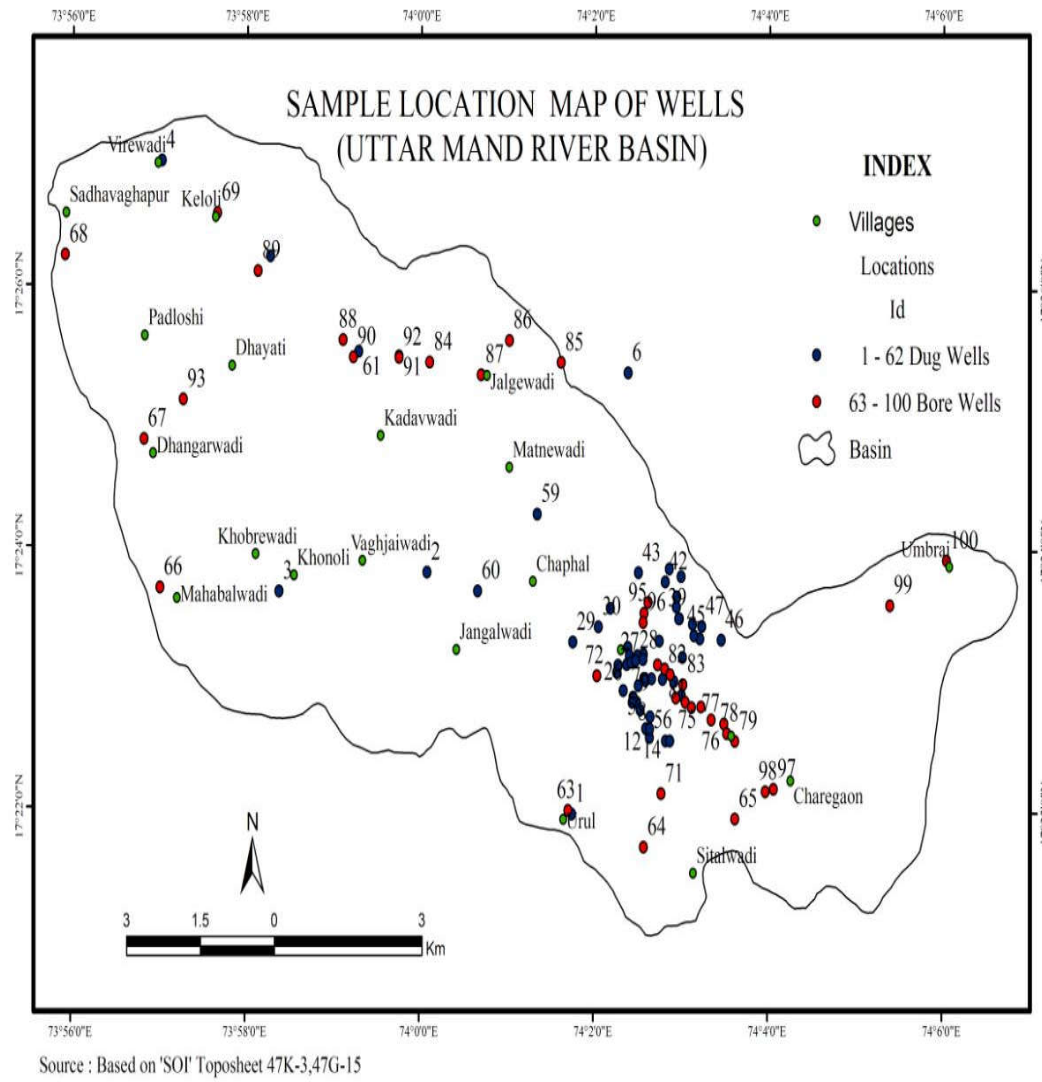


Figure 3: Location map of the water sampling stations

The chemical analysis of parameters like pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) was carried out using pH meter, conductivity meter and TDS meter, respectively. The cations, anions were analysed by standard methods. Na^+ and K^+ were analyzed by using flame photometer. Volumetric method use for the analysis of total alkalinity, calcium, total hardness and chloride in water samples from the area under study. Total hardness (TH) and Ca^{2+} determined by using standard EDTA titrimetric method, and magnesium determined by difference in total hardness and calcium titration by calculation method (APHA,1998). $AgNO_3$ method was used for estimation of Cl^-. Analysis of Sulphate concentration in water samples by using UVVIS Spectrophotometer.

In the study case, the assessment of groundwater suitability for irrigation was determined through three indexes: Sodium Adsorption Ratio (SAR), Residual Soluble Carbonate (RSC) and Permeability Index (PI).

The SAR ratio was determined using the equation suggested by Richards (1987).

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad (1)$$

The value of RSC is calculated as per Eaton (1950),

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad (2)$$

Where all ionic concentration expressed in meq/l
The permeability index (PI) was determined by the equation 1 created by Doneen et al. (1962) where all elements are in milli-equivalent per liter.

$$PI = \frac{(Na^{+} + \sqrt{HCO_3^{-}})}{(Ca^{2+}+Mg^{2+}+Na^{+})} \times 100 \quad (3)$$

To clear understanding, we have prepared a spatial variation map of various physicochemical parameters was carried out using an inverse distance weighed (IDW) algorithm in the Arc-GIS software. In IDW method, values for each grid note are calculated by considering surrounding points lying within the limits of user defined search radius. Spatial variation map of pH, EC, TDS, TH, HCO_3^-, B, Cl^-, Ca^{2+}, Na^+, Mg^{2+}, K^+ and SO_4^{2-} will help a suitable part for drinking purposes and SAR, RSC and PI will useful for irrigation purposes. This study will analyze the different zones of groundwater quality for drinking and irrigation purposes. It will help in change for cropping pattern to farming community and for drinking use.

RESULT AND DISCUSSION

The statistical summary of geochemical results of groundwater quality parameters collected from Uttar Mand sub basin has depicted in table 1 and 2. The spatial variation of geochemical parameters was analyzed by comparing the two year seasonal data. To evaluate the suitability of groundwater samples were compared with Indian Standards (BIS, 2003) prescribed for drinking water. The spatial variation maps of various geochemical parameter of groundwater from studied area were presented in Fig.4-15.

Table 1: Statistical summary of geochemical results of groundwater samples (Post-monsoon 2014 and Pre-monsoon 2015)

Water quality Parameters	BIS Standards (10500:2012)		Post-monsoon (November 2014)			Pre-monsoon (May 2015)		
	Max. Desirable Limit	Max. Permissible limit	Min.	Max.	Average	Min.	Max.	Average
pH	6.5 - 8.5	-	5.99	7.82	7.16	6.5	7.78	6.86
EC	-	-	191	1205	783.7	233	1251	814.4
TDS	500	2000	114.6	723	470.2	139.8	750.6	488.6
HCO_3^-	-	-	146.4	585.6	421.1	146.4	920.9	509.3
Hardness	200	600	79.1	498.9	324.5	92.3	495.4	323.2
B	0.5	1.0	0	4.9	3.1	0	10.5	2.6
Cl^-	250	1000	56.7	184.3	97	14.2	752.6	238.1

Ca^{2+}	75	200	42	211	147.3	48	228.5	126.5
Na^{+}	-	-	0.9	6.9	4.8	3.4	9.2	25.2
Mg^{2+}	30	100	3	131.8	65.4	48.8	299.5	136.1
K^{+}	-	-	16.6	48.4	42.5	20.9	49	30.6
SO_4^{2-}	200	400	110.4	240	202.5	100.3	219.7	146.7

Table 2: Statistical summary of geochemical results of groundwater samples (Post-monsoon 2015 and Pre-monsoon 2016)

Water quality Parameters	**BIS Standards (10500:2012)**		**Post-monsoon (November 2015)**			**Pre-monsoon (May 2016)**		
	Max Desirable Limit	**Max Permissible limit**	**Min**	**Max**	**Average**	**Min**	**Max**	**Average**
pH	6.5 - 8.5	-	5.75	7.51	6.87	6.76	8.09	7.14
EC	-	-	166.2	1048.4	681.8	249.3	1338.6	871.4
TDS	500	2000	105.4	665.2	432.6	795.6	148.2	518
HCO_3^-	-	-	156.6	626.6	450.6	130.3	819.6	453.3
Hardness	200	600	68	429.1	279	99.6	535	349.1
B	0.5	1.0	0	4.7	3	0	10.9	2.7
Cl^-	250	1000	59	191.7	100.9	16.2	858	271.4
Ca^{2+}	75	200	39.5	198.3	138.4	46.1	219.4	121.4
Na^{+}	-	-	0.8	6.1	4.3	3.6	26.2	9.6
Mg^{2+}	30	100	3.1	134.4	66.7	42	257.6	117
K^{+}	-	-	15.9	46.5	40.8	17.9	42.1	26.3
SO_4^{2-}	200	400	117	254.4	214.7	86.3	188.9	126.1

The pH concentration of Post monsoon 2014 ranges in between 5.99 – 7.81, the West side will comprise of 5.99-6.80 and middle part ranging in 6.80 – 7.18 and further part with light blue to dark blue ranges from 7.18 – 7.81 (Fig. 4. a). The pH concentration of Pre monsoon 2015 ranging from 6.51 – 7.57, the most of the part is comprised with 6.51 – 6.98 pH value (Fig. 4. b). pH concentration of Post Monsoon 2015 varies from 5.75-7.51 in which East part will comprised of a 5.75-6.83 and other part comprised of a 6.83-7.51 (Fig. 4. c). The pre-monsoon season 2016 will have ranges in between 6.77-7.87 (Fig. 4. d).

Electrical Conductivity of Post monsoon 2014 ranges from 191-1205 µs/cm, The East part is comprised of less EC in between 191-595 µs/cm while West part is composed of value 595-1200 µs/cm which is a large part is occupied (Fig. 5. a). In Post monsoon 2015 Eastern part is composed of a 233 – 631 µs/cm EC and other part comprised of 631 – 1228 µs/cm EC (Fig. 5. b). The Post monsoon 2015 showed that EC value ranged from 166 – 518 µs/cm were observed in west part while at other part is comprised of 518 – 1046 µs/cm (Fig. 5. c). In Pre-monsoon 2016, it is seen that 250 – 675 EC µs/cm were observed at East part while at West side there is a 675 – 1314 µs/cm EC were analyzed (Fig. 5. d)

TDS concentration were observed at Eastern part of study area which is ranging from 114.64-296.69 mg/l and highest value (660-721 mg/l) observed at West part in post-monsoon season of Nov 2014 (Fig. 6. a). In Pre monsoon 2015 Eastern part of the study area TDS concentration ranged from 140-379 mg/l and other part ranging in between 379-737 mg/l (Fig. 6. b). In post monsoon season of 2015 TDS ranges from 105-663 mg/l of which East part having a less value as compared with western part (Fig. 6. c). In pre-monsoon season of 2016, the Eastern part was comprised of 148-401 mg/l and other part comprised of a 401-781 mg/l (Fig. 6. d).

HCO_3^- variation of pre and post season demarcated in fig.7, In post monsoon season 2014, it is seen that the eastern part comprised of 146-321 mg/l and other part covered with a 321-583 mg/l of HCO_3^- (Fig. 7. a). Further in Pre-monsoon season of 2015, eastern part encompassed with 146-449 mg/l and other part comprised with 449-903 mg/l (Fig. 7. b). Post monsoon 2015 the HCO_3^- concentration showed that the eastern part comprised of 156-343 mg/l and other part with 343-624 mg/l (Fig. 7. c). In pre-monsoon season 2016, HCO_3^- varies from 130.6-807.07 mg/l (Fig. 7. d).

From fig. 8, It is seen that the Post monsoon 2014 hardness concentration were ranged from 79.13-497.85 mg/l and some patches it is observed between 79.13-204.74 especially in eastern part of the basin (Fig. 8. a). In Pre monsoon 2015 hardness concentration were ranged from 92.56-486.56 mg/l (Fig. 8. b). The spatial variation map of hardness concentration of Post monsoon season 2015 showed that elevated values were seen in central and western part of the basin (Fig. 8.c). The Hardness map of pre-monsoon season in 2016 suggested that western part comprised of a 99-270 mg/l and other part ranging in between 270-525mg/l (Fig. 8.d).

From fig 9, Post monsoon season of 2014 it is observed that western part comprised of a 0-1.96 B (mg/l) and some patches in central part with 3.4-4.4 B (mg/l) (Fig. 9. a). In pre-monsoon 2015, Boron ranges from 0-10.45 mg/l (Fig. 9.b). In post-monsoon season of 2015 the Boron ranges from 0-1.8 mg/l at western part and other part comprised of 1.8-4.67mg/l (Fig. 9. c). In Pre-monsoon season of 2016, some small patches were seen at eastern side ranges between 7.6-10.8 mg/l (Fig. 9.d).

From fig 10, In Post monsoon season of 2014, it can be observed that variation of chloride is in western part ranges in between 55-90 mg/l and central and eastern part comprised of a 90-142 mg/l (Fig. 10. a). In pre monsoon 2015 Cl^- ranges in between 40-664 mg/l (Fig. 10. b). The Post monsoon season of 2015 ranges in between 0-117 mg/l, most part of the area comprised of a 0-11 mg/l concentration of Cl^- (Fig. 10. c). In pre monsoon 2016 Cl^- ranges from 0-684 mg/l and most part of the area comprised of a 0-68 mg/l (Fig. 10.d).

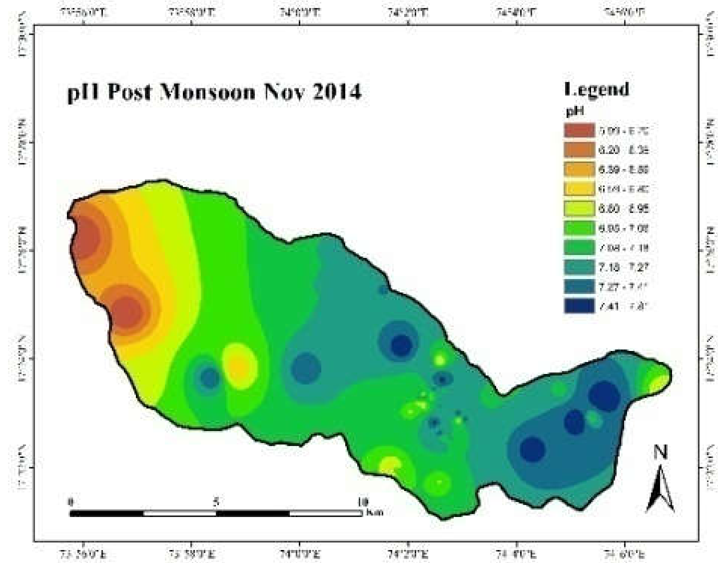
From fig. 11, it can be illustrating that calcium in Post-monsoon season 2014, western side ranges from 42-89 mg/l at some patches. Other part comprised of an 89-201 mg/l concentration (Fig. 11.a). In pre-monsoon season 2015, Ca^{2+} varies from 48-228 mg/l (Fig. 11. b). In post monsoon 2015 Ca^{2+} varies from 39-189 mg/l and it observed in some patches in ranging between 39-84 mg/l (Fig. 11. c). In pre-monsoon 2016, it is observed that most part of the area comprised of a 0-57 mg/l (Fig. 11.d).

From fig. 12, sodium concentration in post monsoon season of 2014 ranged from 0.9-2.6 mg/l which is seen at eastern and western side at some places and other part comprised of a 2.6-6.7 mg/l (Fig. 12.a). In pre monsoon 2015, Sodium varies from 3.7-19.14 mg/l and it is seen in some small patches at central part of the basin with ranging from 9.9-14.53 mg/l (Fig. 12.b). The post-monsoon season of 2015, Sodium concentration varies from 0.8-5.9 mg/l (Fig. 12.c). In pre monsoon 2016, Sodium concentration varies from 3.9-19.89 mg/l, there are some small patches of which ranged from 10-15 mg/l (Fig. 12.d).

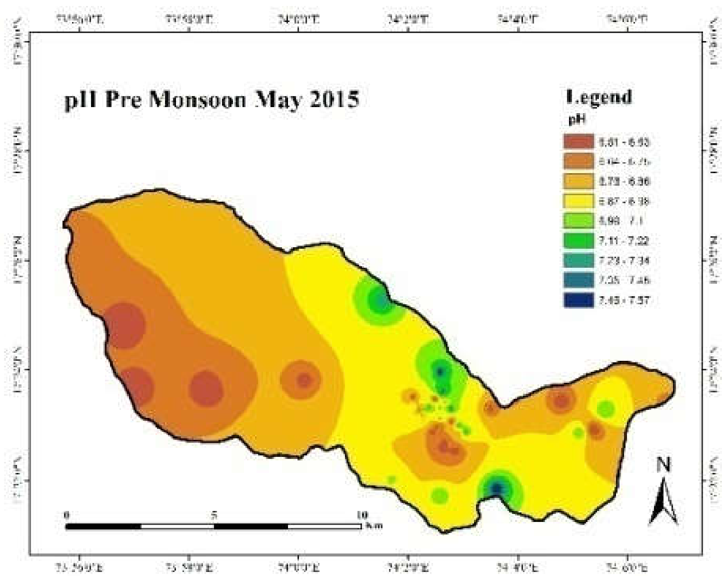
From fig.13, Post monsoon 2014 magnesium concentrations varies from 3-129 mg/l and western part comprised of a 3-41 mg/l concentration (Fig. 13. a). While pre-monsoon 2015 Mg^{2+} varies from 48-259 mg/l (Fig. 13.b). In post monsoon season of 2015, Mg^{2+} concentrations demonstrate that western part which comprises of 3-54 mg/l and other part covered with 54-132 mg/l (Fig. 13. c). While in pre-monsoon 2016 it is ranged from 42-222 mg/l (Fig. 13.d).

From fig.14, Post monsoon season of 2014, potassium varies from 16-46 mg/l of which most of the part covered by 37- 46 mg/l concentration (Fig. 14. a). The pre-monsoon season of 2015 varies from 20-48 mg/l (Fig. 14.b). In the monsoon of 2015 potassium varies from 15-44 mg/l (Fig. 14 c) and in pre-monsoon of 2016 ranging from 17-42 mg/l (Fig. 14.d).

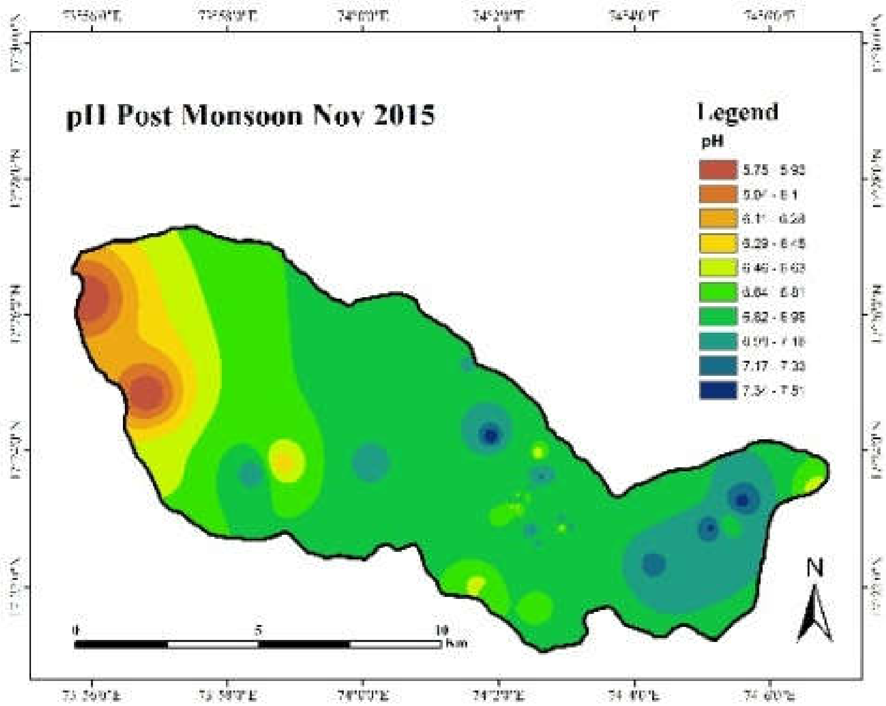
Fig. 15, Post monsoon season of 2014 of SO_4^{2-} ranges from 113 -239 mg/l of which eastern part comprised with a 113 -164 mg/l (Fig. 15. a). In pre-monsoon season of 2015 sulphate varies from 100-218 mg/l and at eastern part it is ranging from concentration 194-218 mg/l (Fig. 15. b). In post monsoon 2015, Sulphate ranges from 120-254 mg/l (Fig. 15. c) and pre-monsoon of 2016 ranges from 0-139 mg/l, the most part of the area covered by 0-27 mg/l concentration (Fig. 15.d).



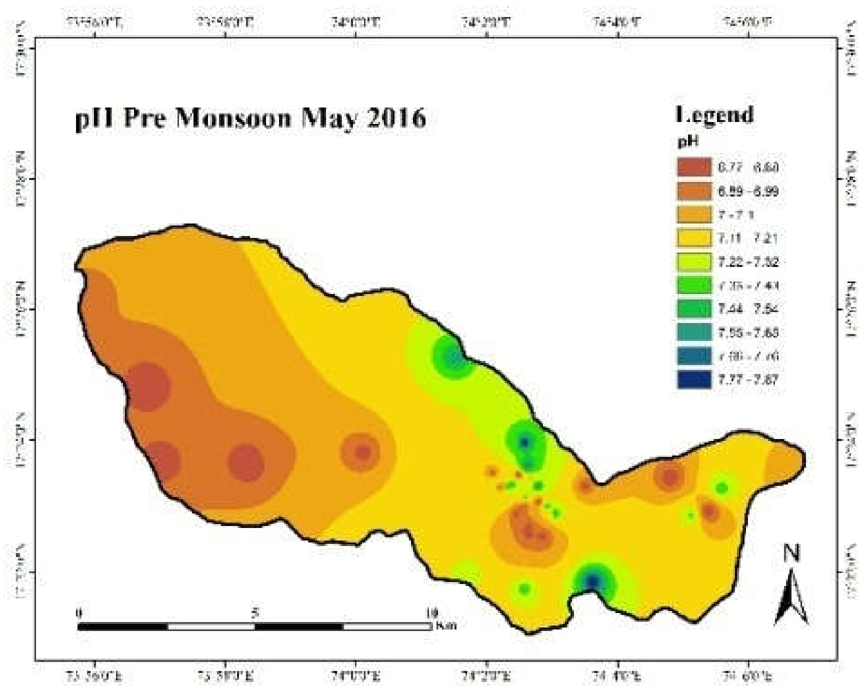
4. a



4. b

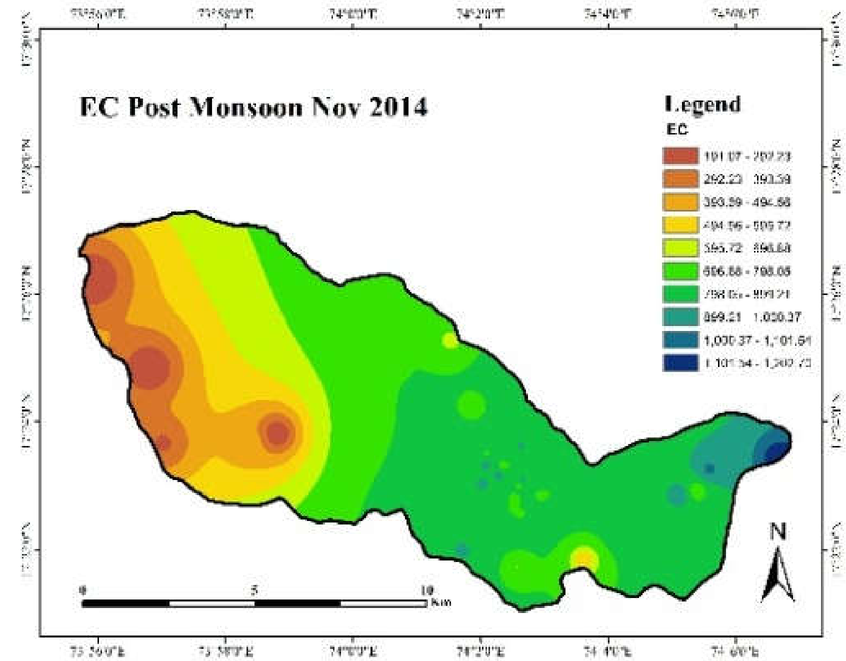


4. c

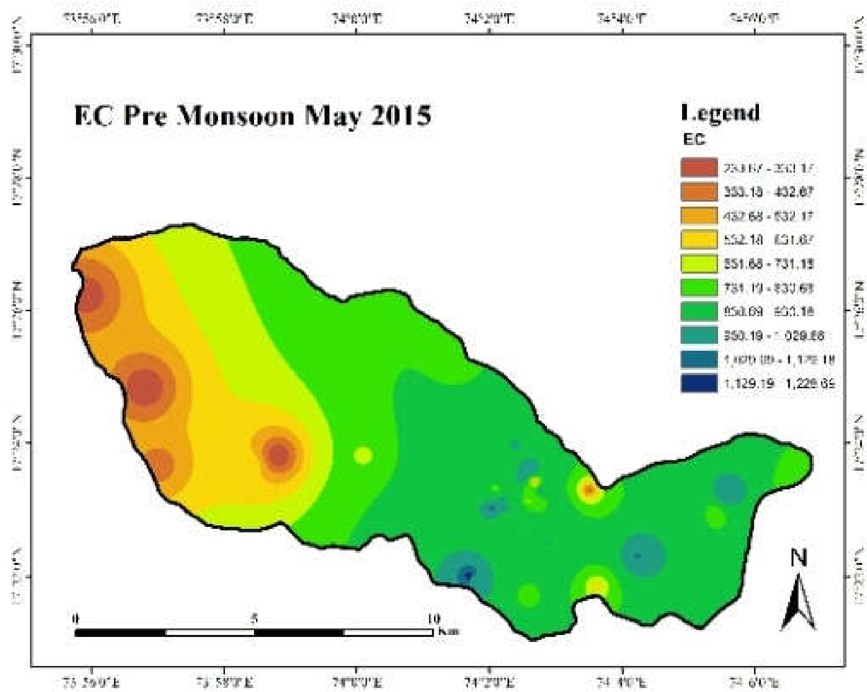


4. d

Figure 4: Spatial variation map of pH during study period


EC Post Monsoon Nov 2014
Legend
EC
N
0
5
10
Km

5. a


EC Pre Monsoon May 2015
Legend
EC
N
0
5
10
Km

5. b

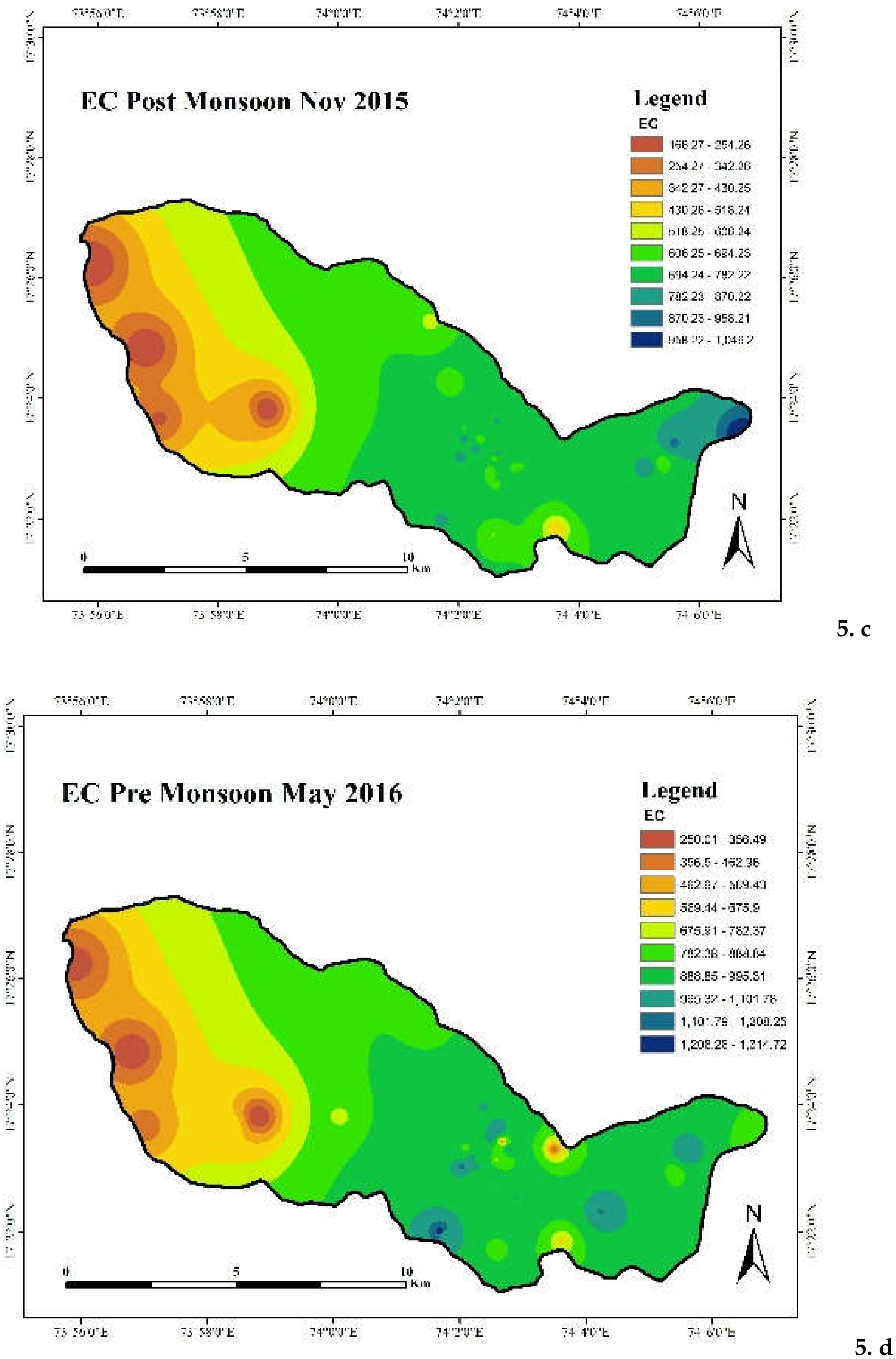
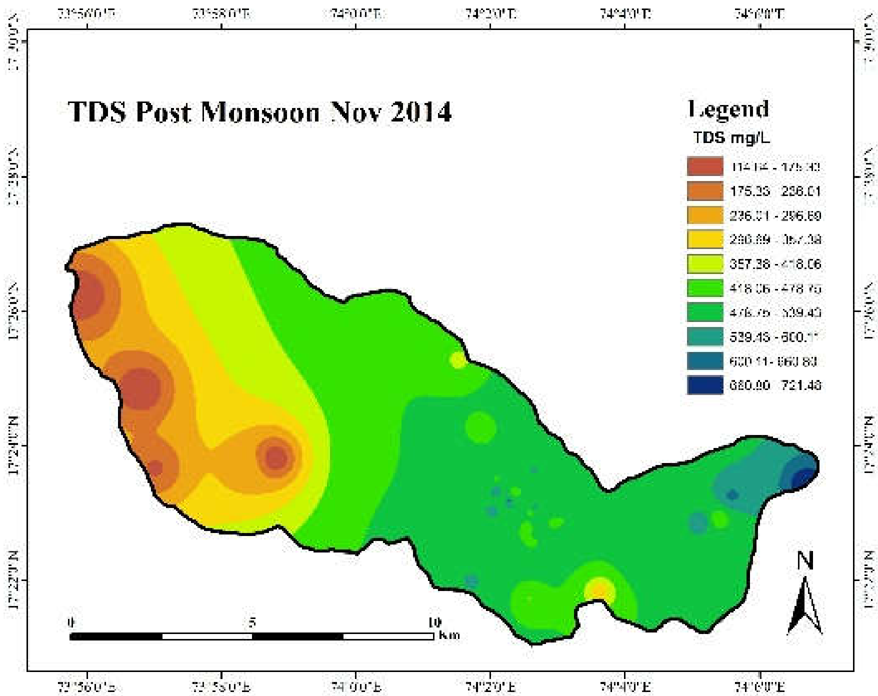
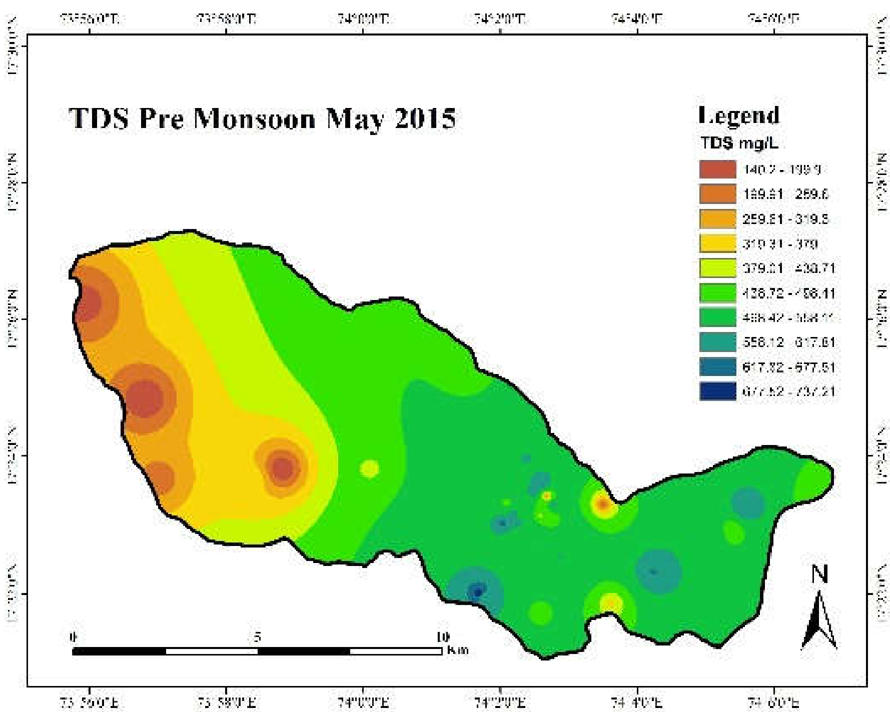


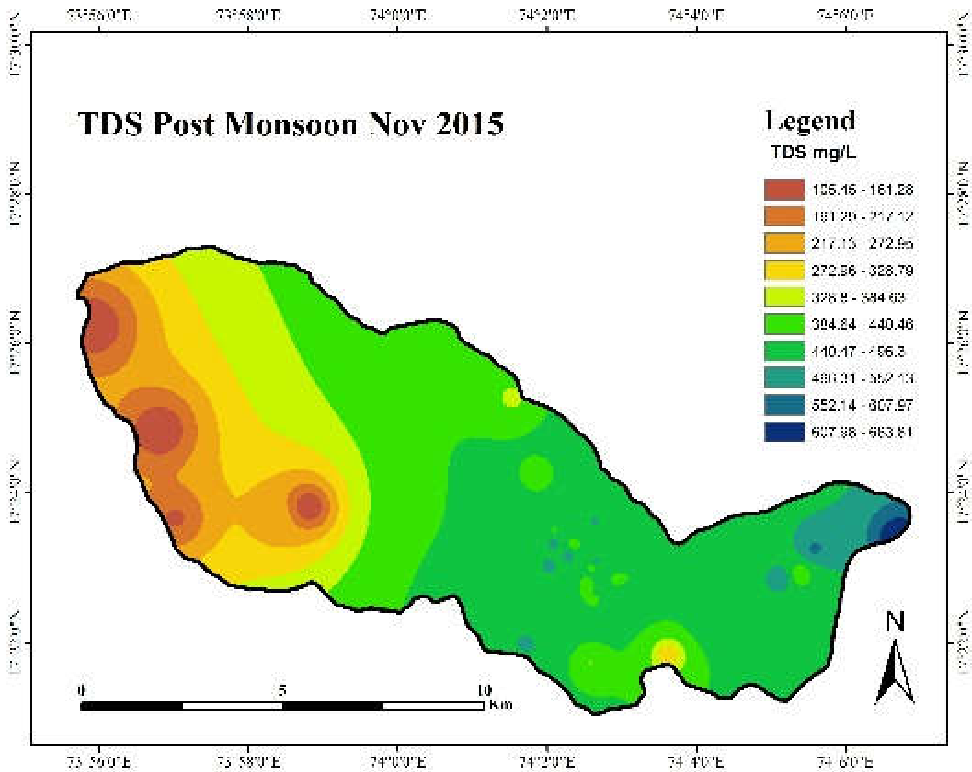
Figure 5: Spatial variation map of EC during study period


TDS Post Monsoon Nov 2014
Legend
TDS mg/L
175.33 - 236.01
357.38 - 418.06
418.06 - 478.75
N
0
5
10
Km

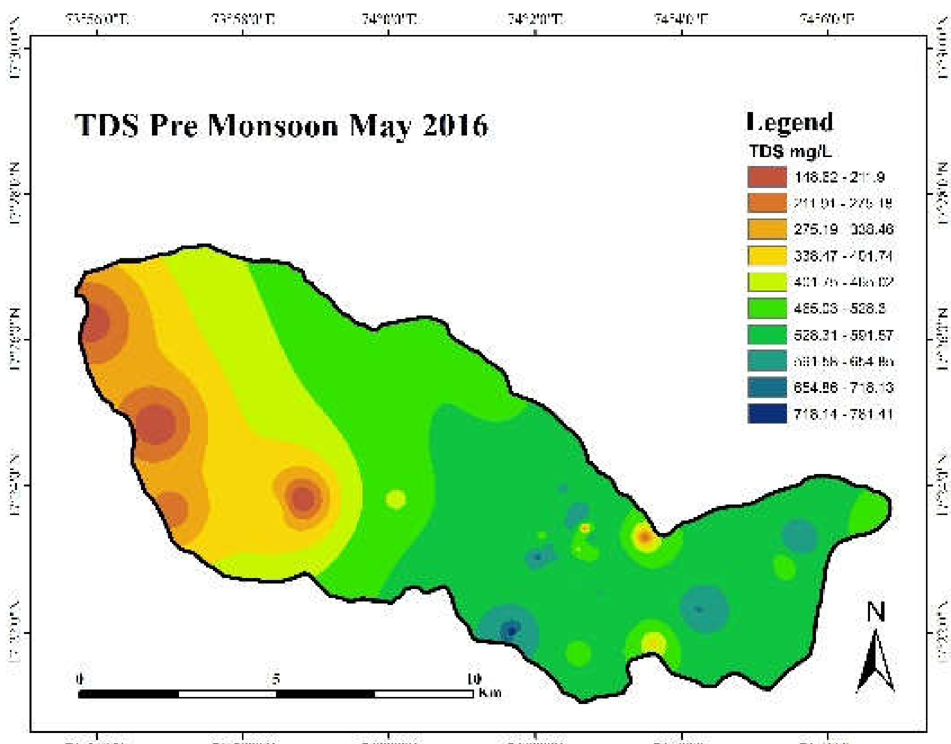
6. a


TDS Pre Monsoon May 2015
Legend
TDS mg/L
259.81 - 319.5
558.12 - 617.81
617.82 - 677.51
N
0
5
10
Km

6. b

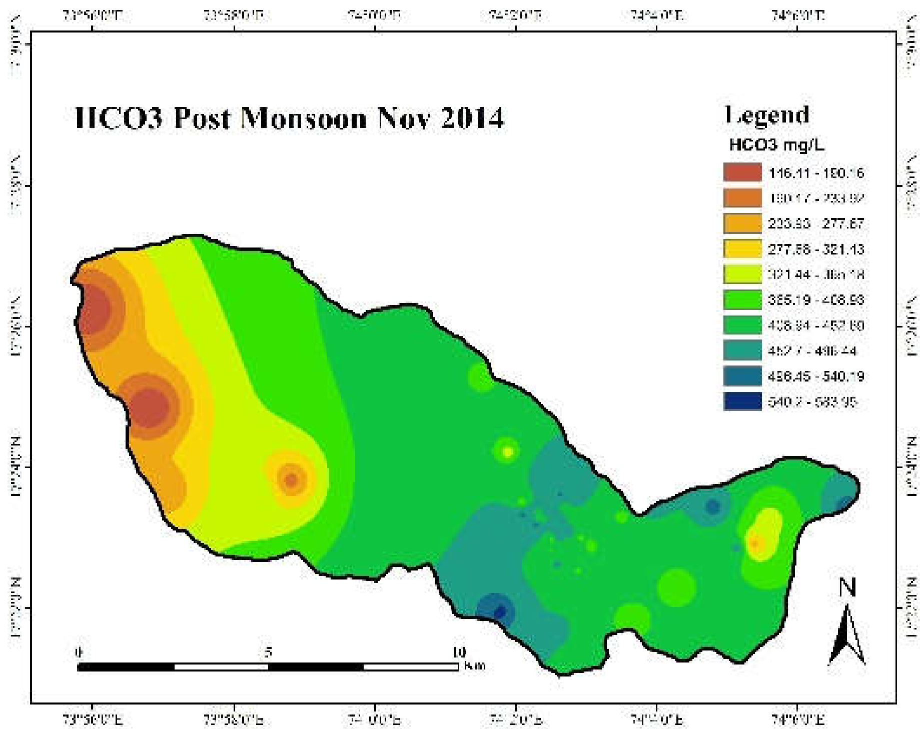


6.c

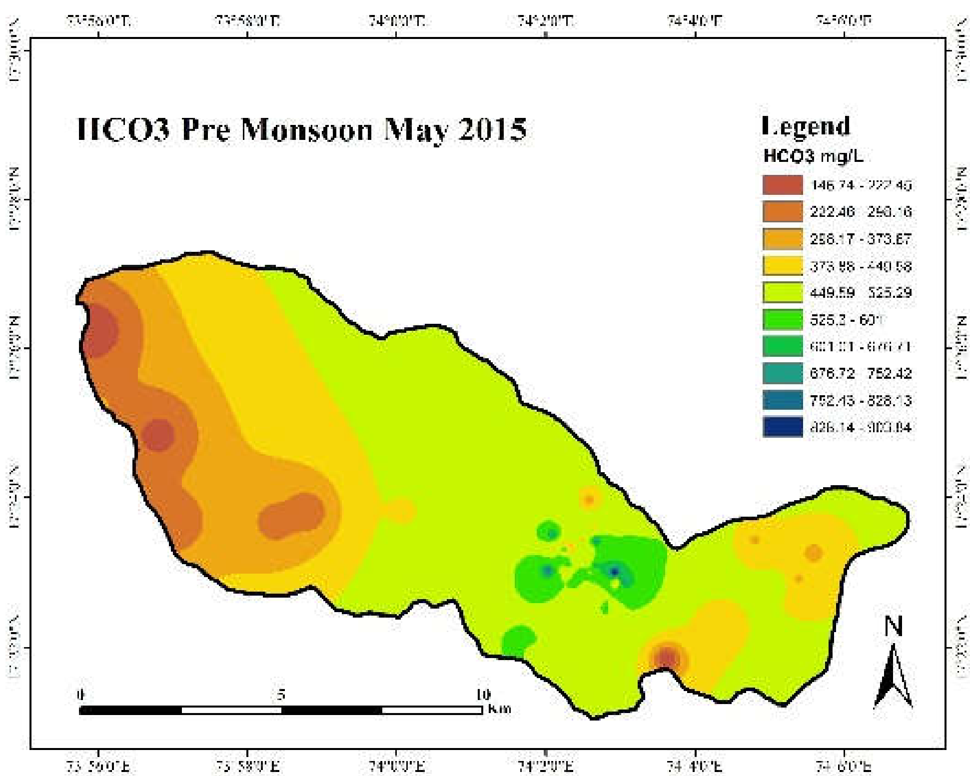


6. d

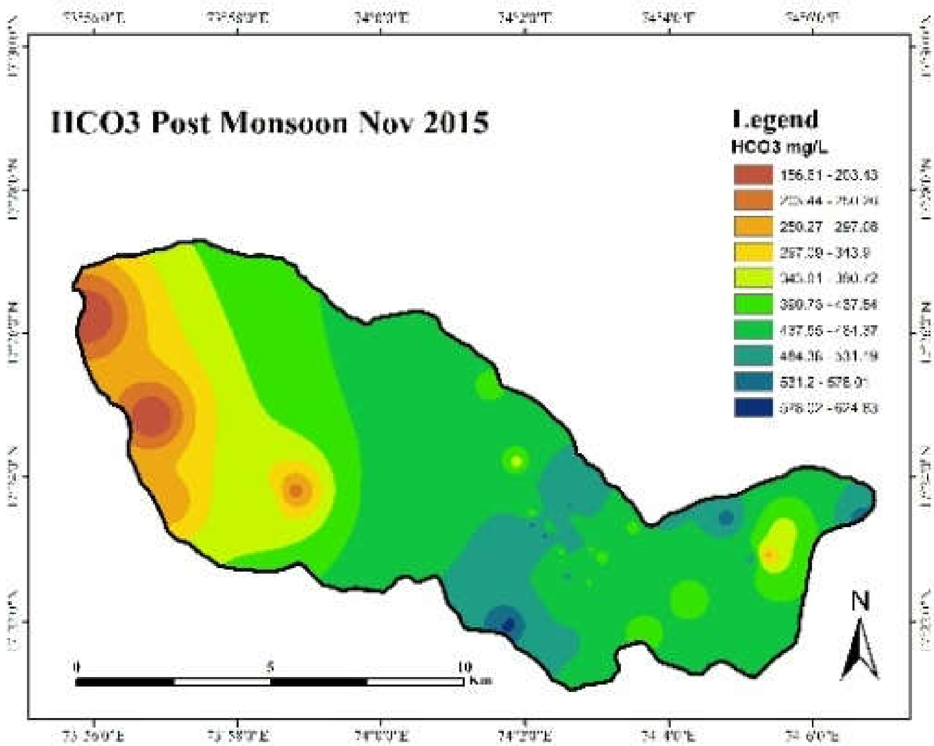
Figure 6: Spatial variation map of TDS during study period


HCO3 Post Monsoon Nov 2014
Legend
HCO3 mg/L
116.11 - 190.16
277.58 - 321.13
436.45 - 540.19
0
5
10
Km
N

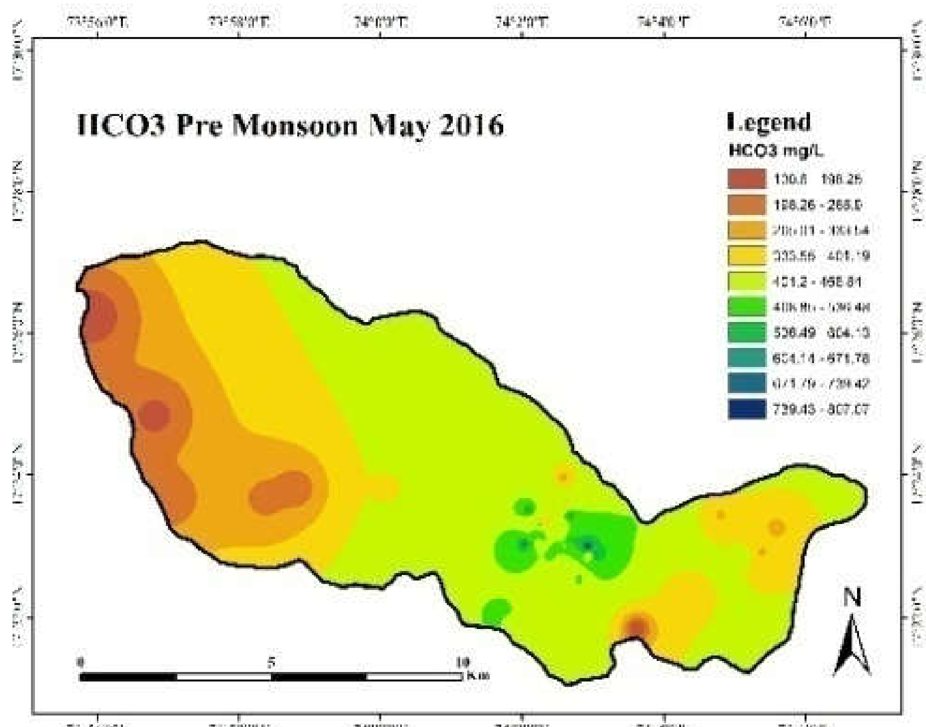
7.a


HCO3 Pre Monsoon May 2015
Legend
HCO3 mg/L
258.17 - 373.87
676.72 752.42
0
5
10
Km
N

7.b

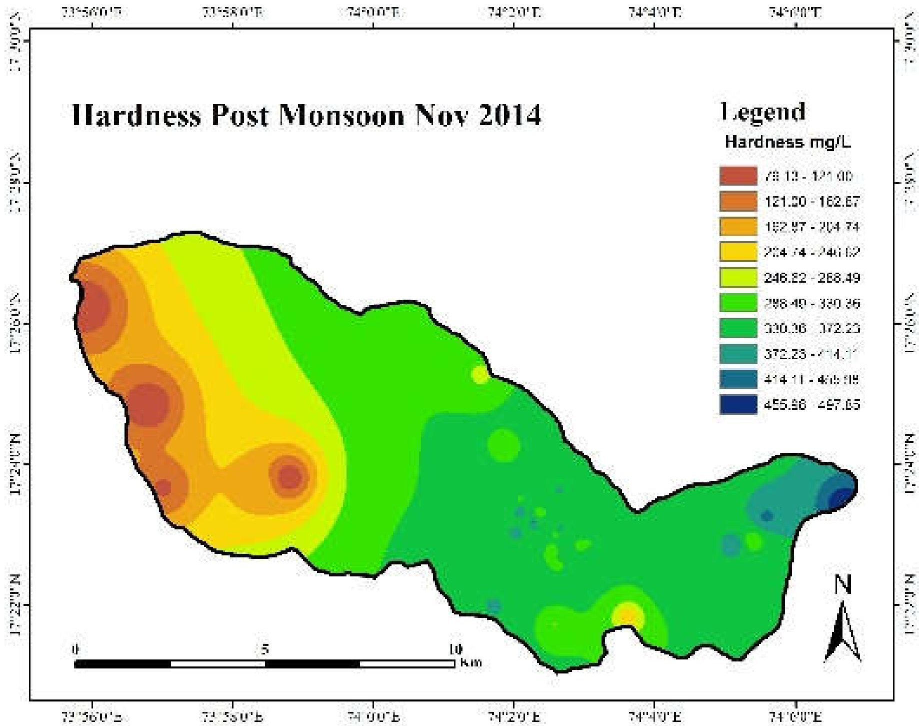


7.c

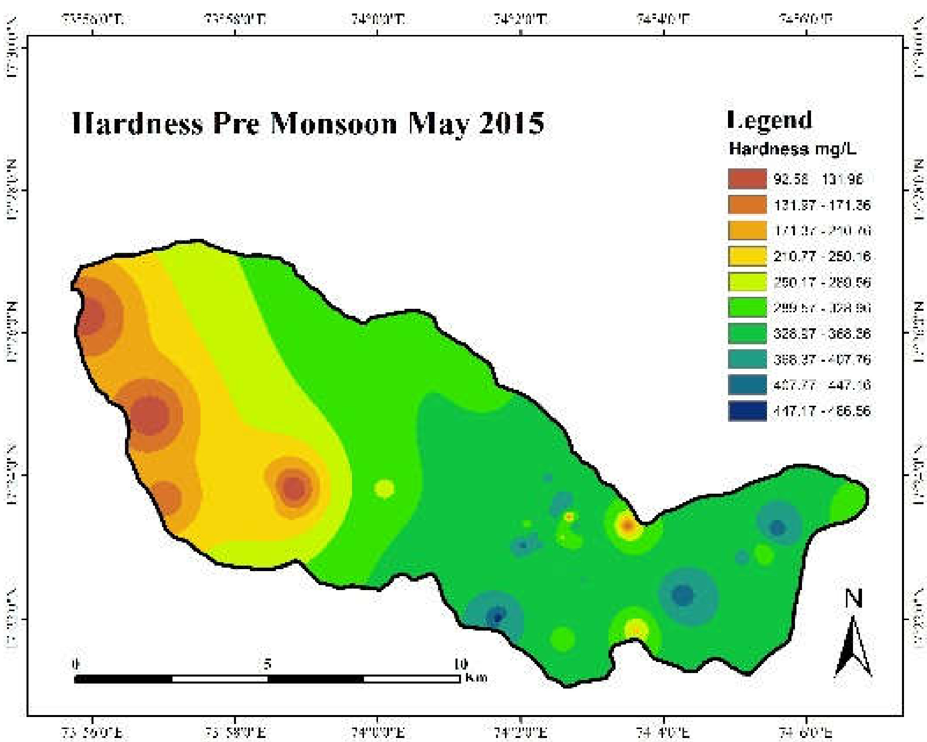


7.d

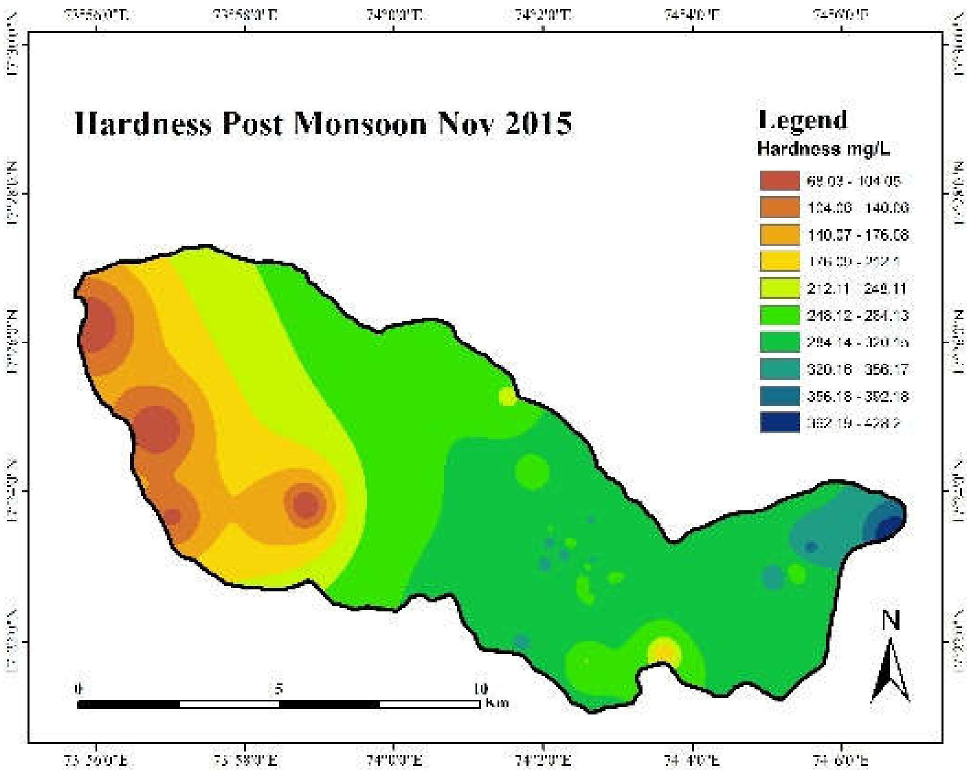
Figure 7: Spatial variation map of HCO_3^- during study period


Hardness Post Monsoon Nov 2014
Legend
Hardness mg/L
121.20 - 162.67
246.22 - 288.49
455.98 - 497.05
N
Km

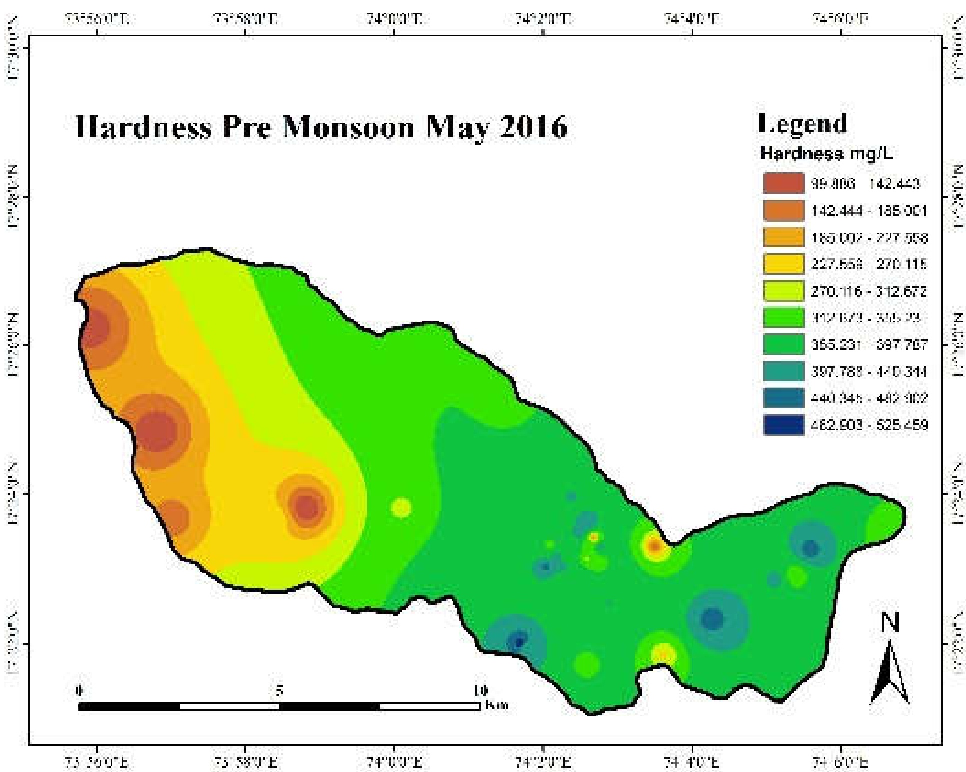
8. a


Hardness Pre Monsoon May 2015
Legend
Hardness mg/L
131.37 - 171.36
210.77 - 250.16
328.37 - 368.36
N
Km

8.b

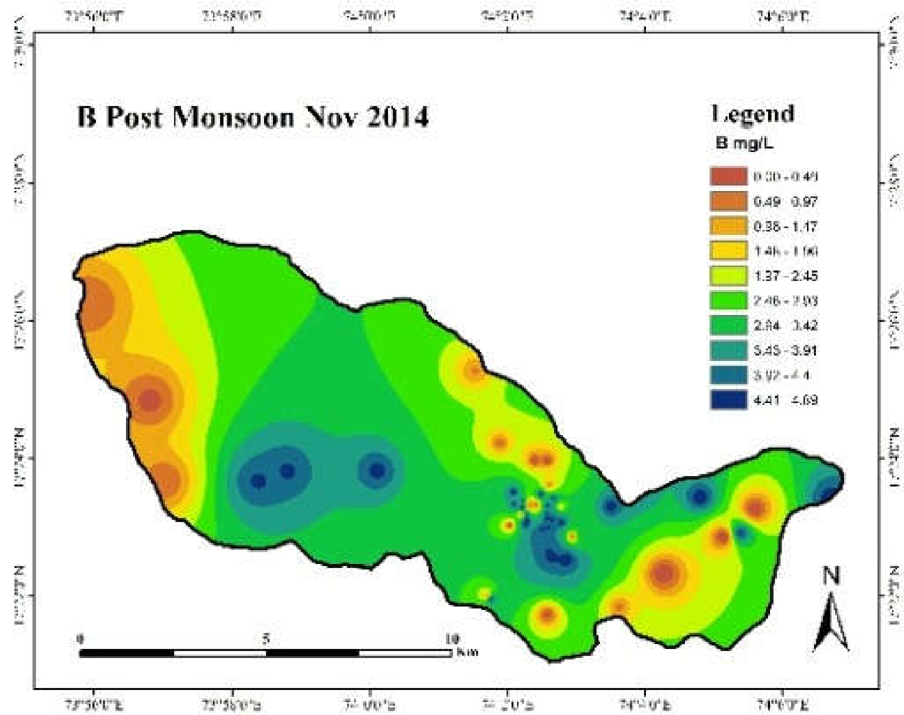


8. c

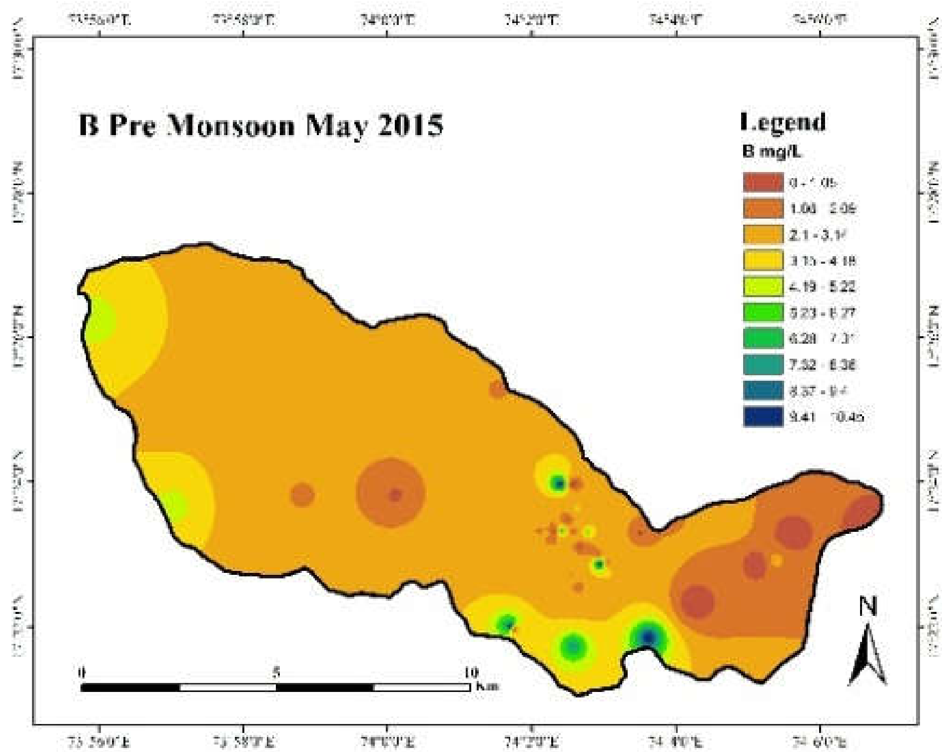


8.d

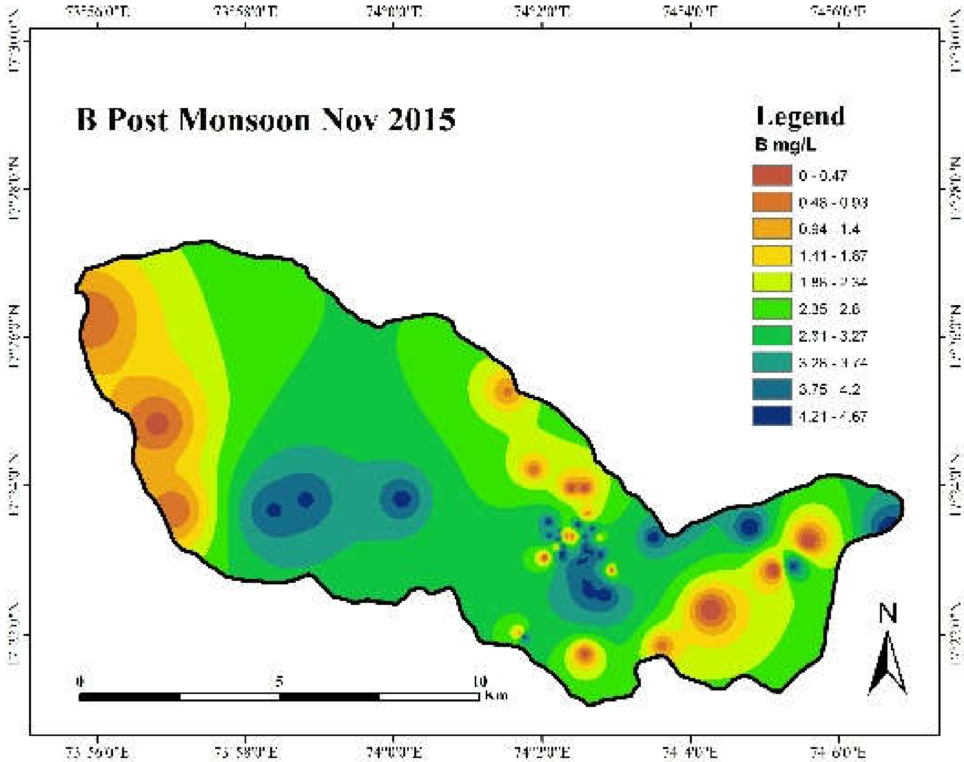
Figure 8: Spatial variation map of Hardness during study period


B Post Monsoon Nov 2014
Legend
B mg/L
0.49 0.97
0.38 - 1.17
1.37 - 2.45
2.84 3.42
3.43 - 3.91
N
0
5
10
Km

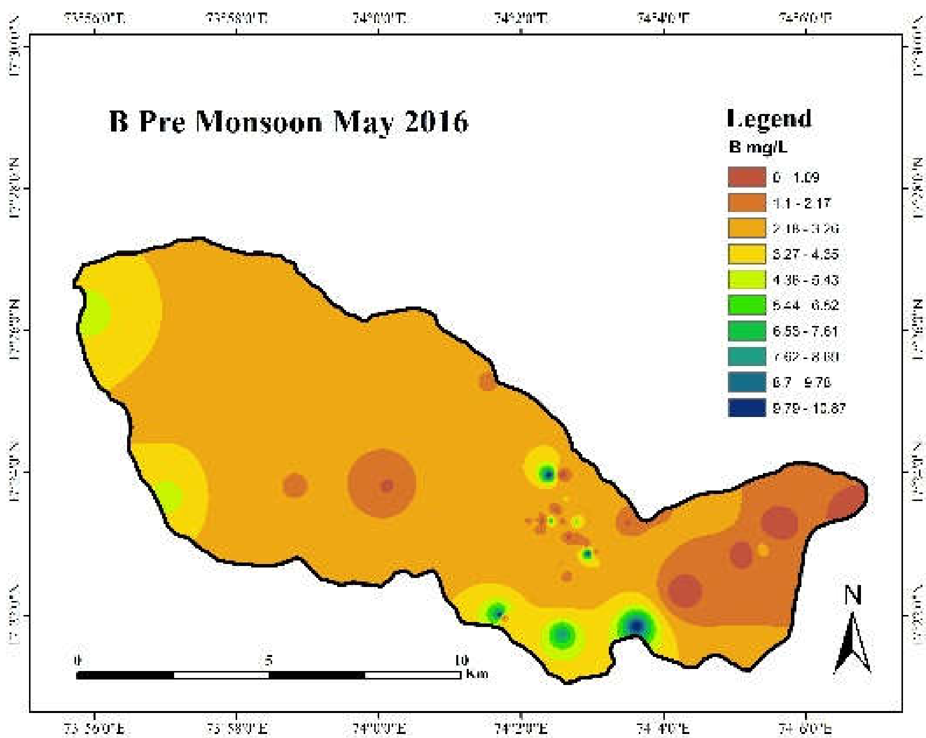
9. a


B Pre Monsoon May 2015
Legend
B mg/L
2.1 - 3.1
9.41 10.45
N
0
5
10
Km

9.b

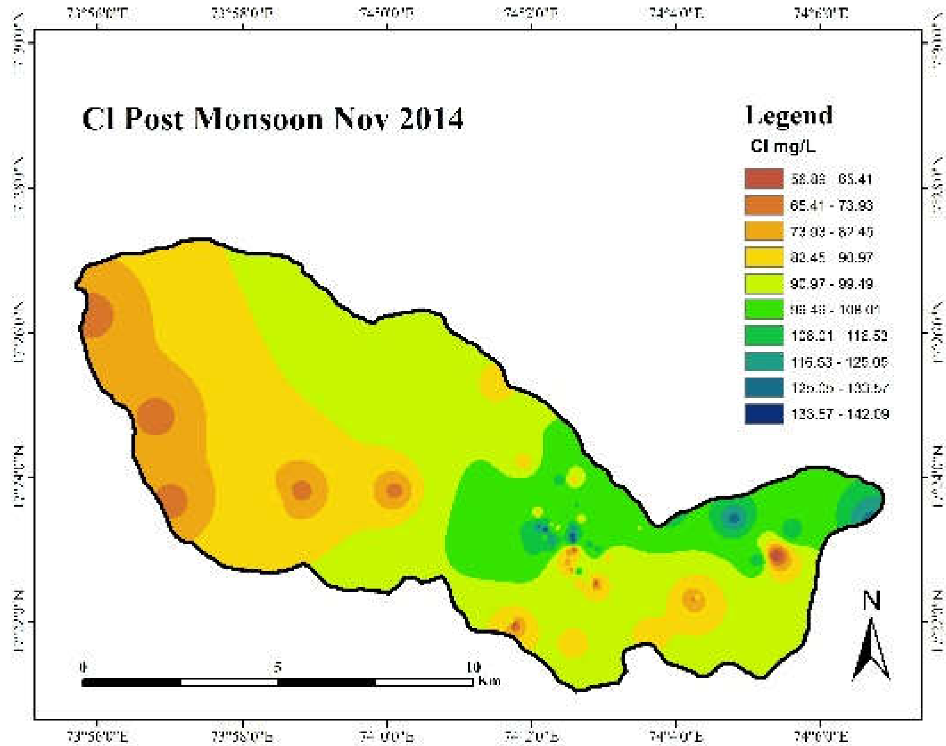


9. c

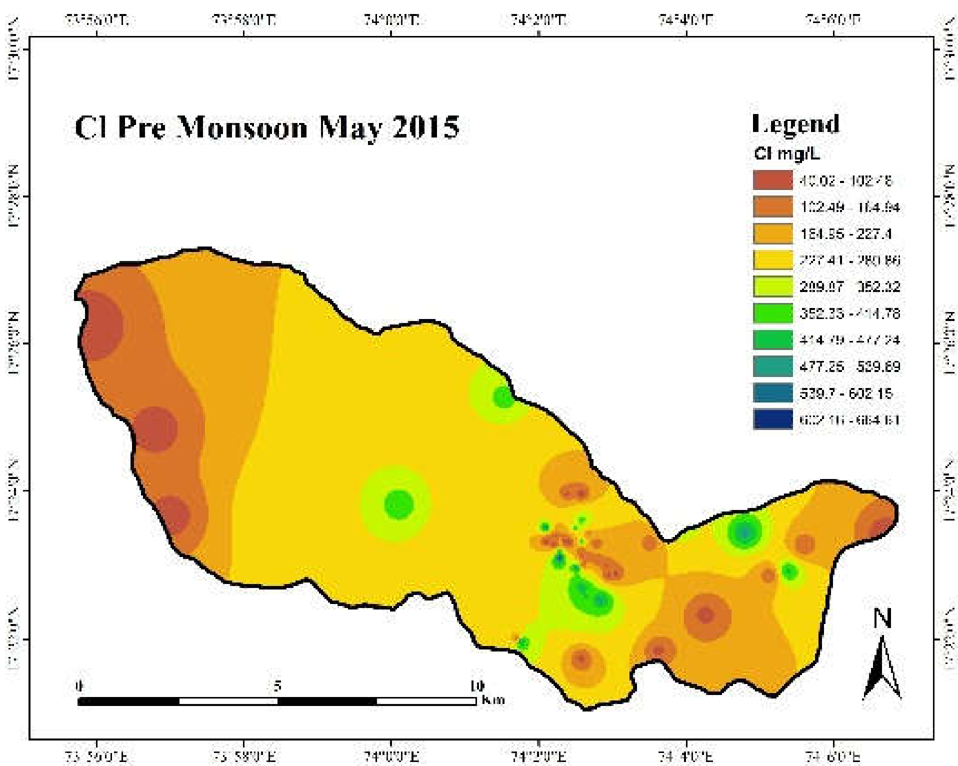


9.d

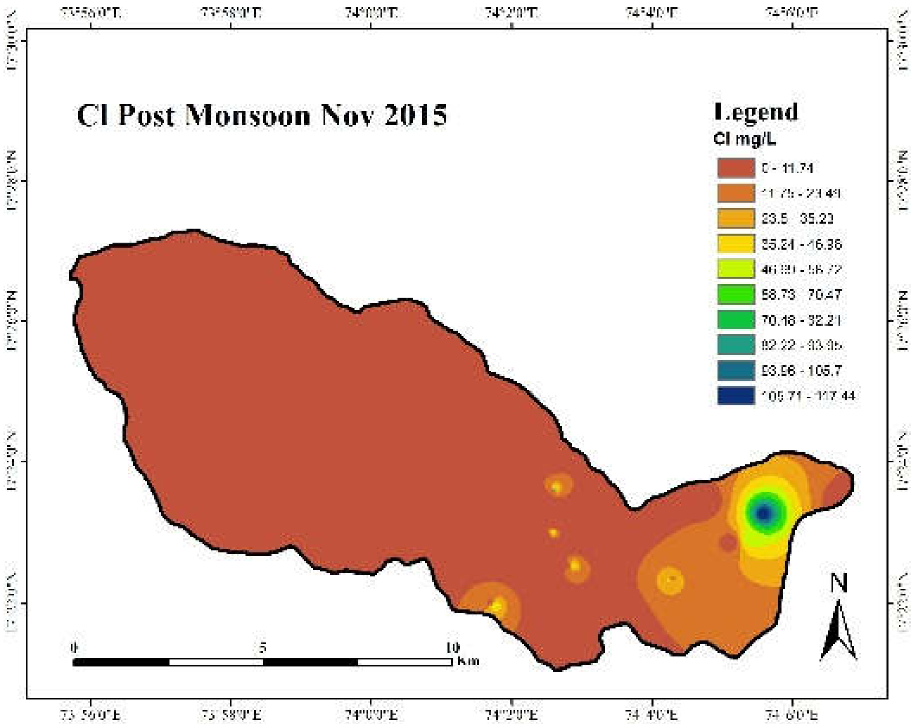
Figure 9: Spatial variation map of Boron during study period


Cl Post Monsoon Nov 2014
Legend
Cl mg/L
65.41 - 73.93
90.97 - 99.49
116.53 - 125.05
133.57 - 142.09
N
0
5
10
Km

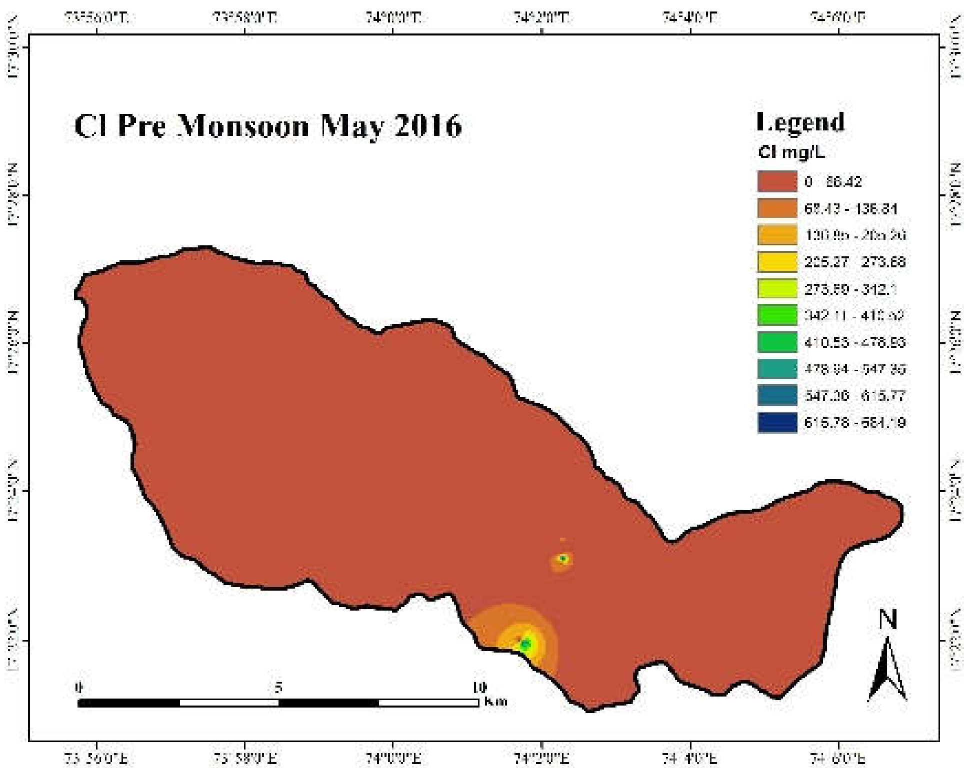
10. a


Cl Pre Monsoon May 2015
Legend
Cl mg/L
477.25 - 539.69
539.7 - 602.15
N
0
5
10
Km

10.b

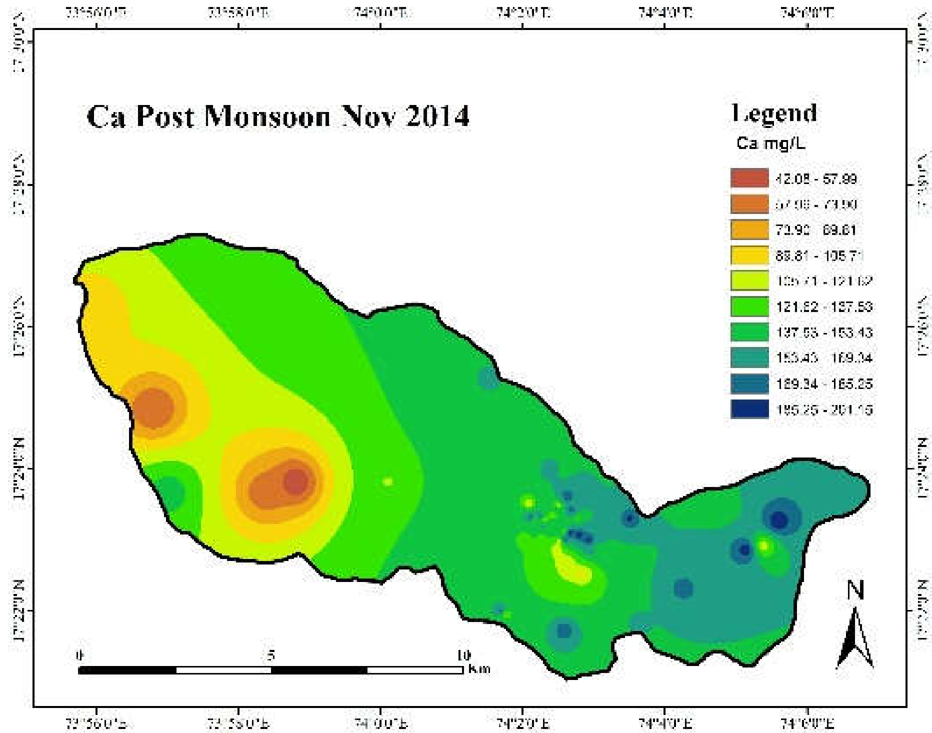


10. c

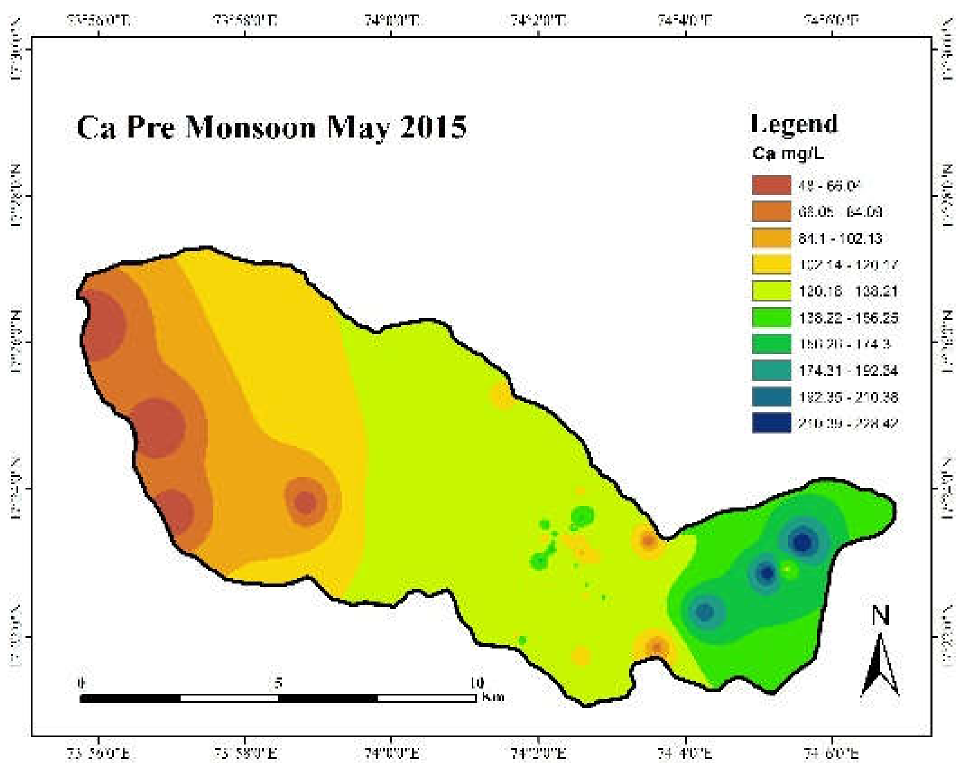


10.d

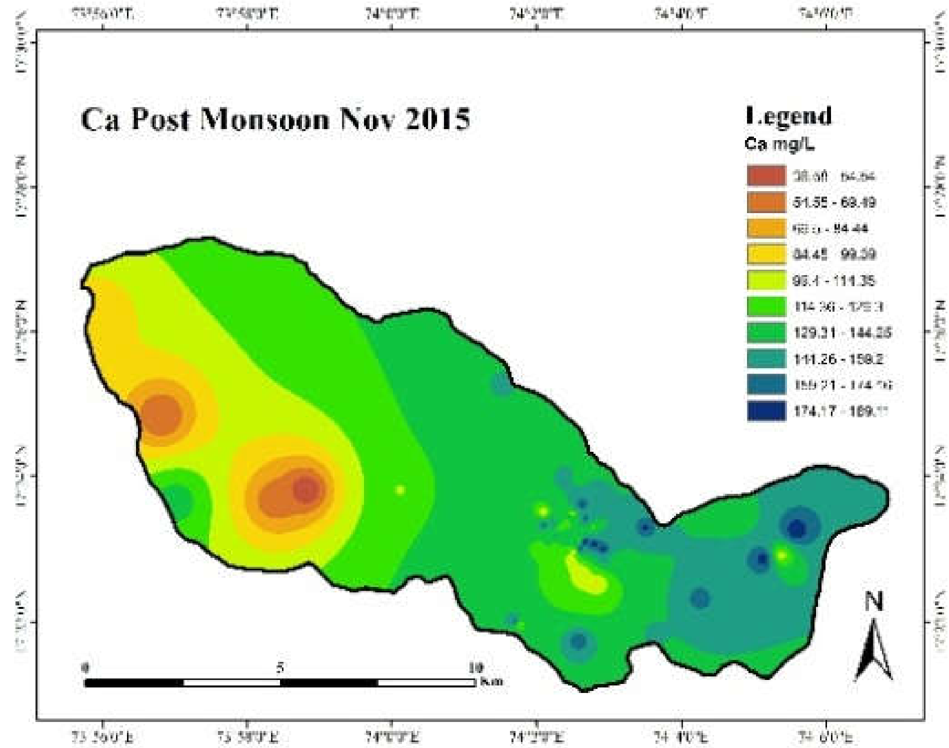
Figure 10: Spatial variation map of Cl^- during study period


Ca Post Monsoon Nov 2014
Legend
Ca mg/L
42.08 - 57.99
121.82 - 137.53
189.34 - 185.25
0
5
10
Km
N

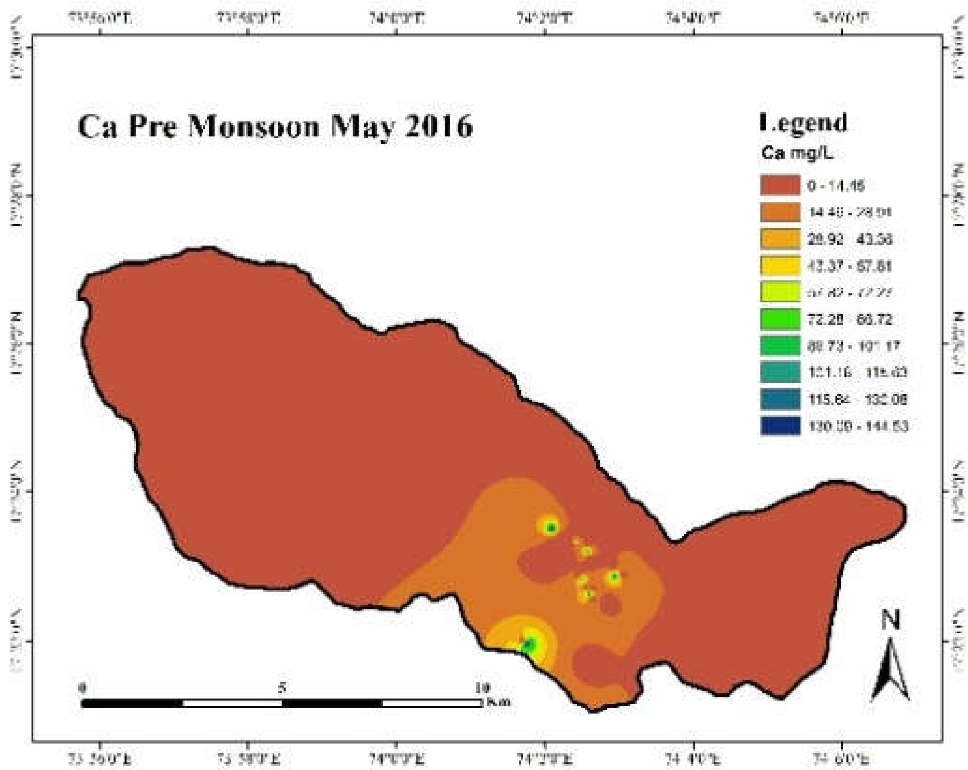
11. a


Ca Pre Monsoon May 2015
Legend
Ca mg/L
81.1 - 102.13
120.16 138.21
138.22 - 156.25
174.21 - 192.34
0
5
10
Km
N

11.b

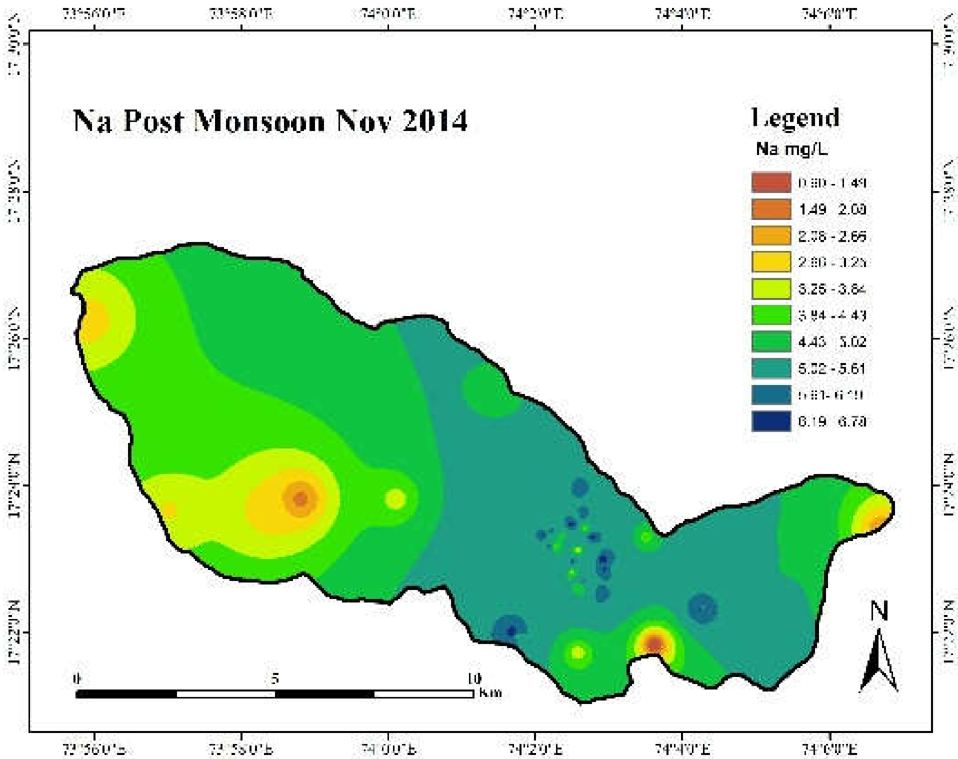


11. c

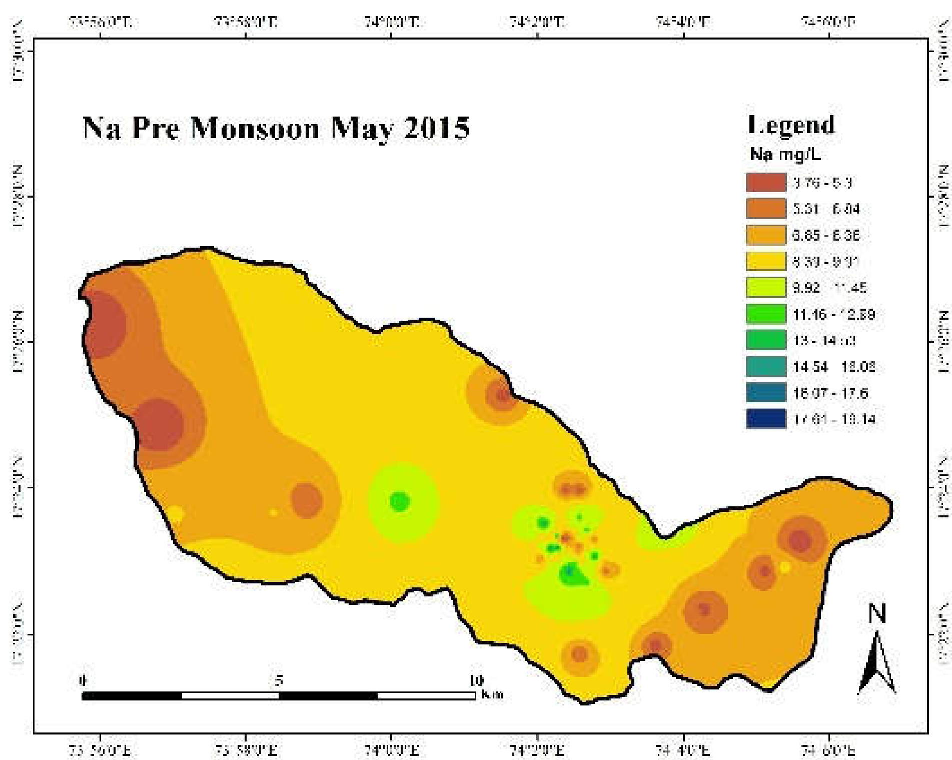


11.d

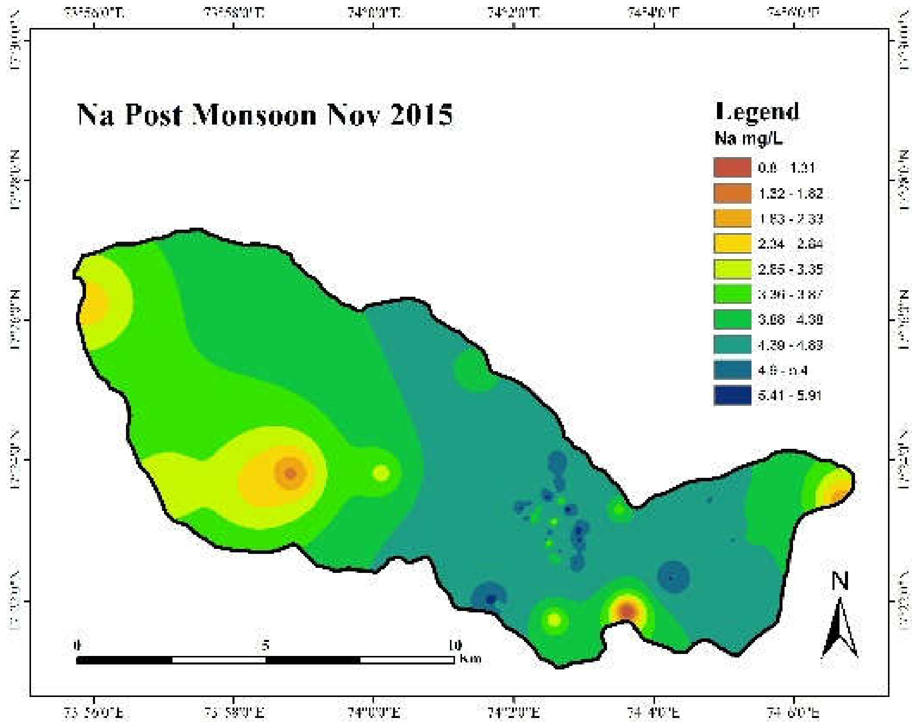
Figure 11: Spatial variation map of Ca^{2+} during study period


Na Post Monsoon Nov 2014
Legend
Na mg/L
1.49 2.08
3.25 - 3.84
5.32 - 5.61
N
0
5
10
Km

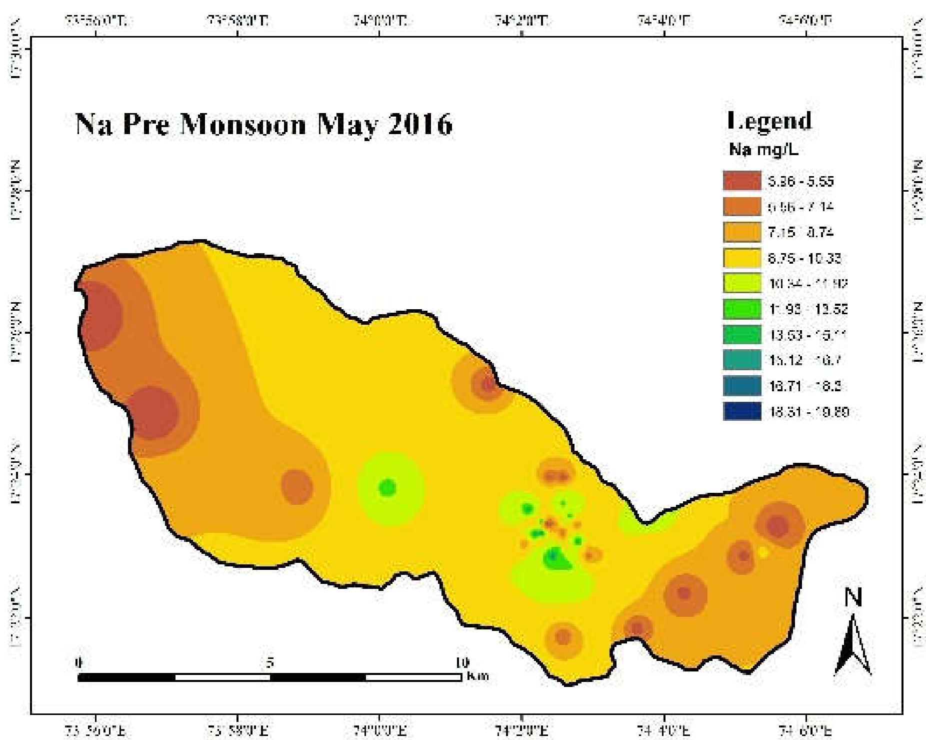
12. a


Na Pre Monsoon May 2015
Legend
Na mg/L
11.16 - 12.89
14.54 16.08
16.07 - 17.6
N
0
5
10
Km

12.b

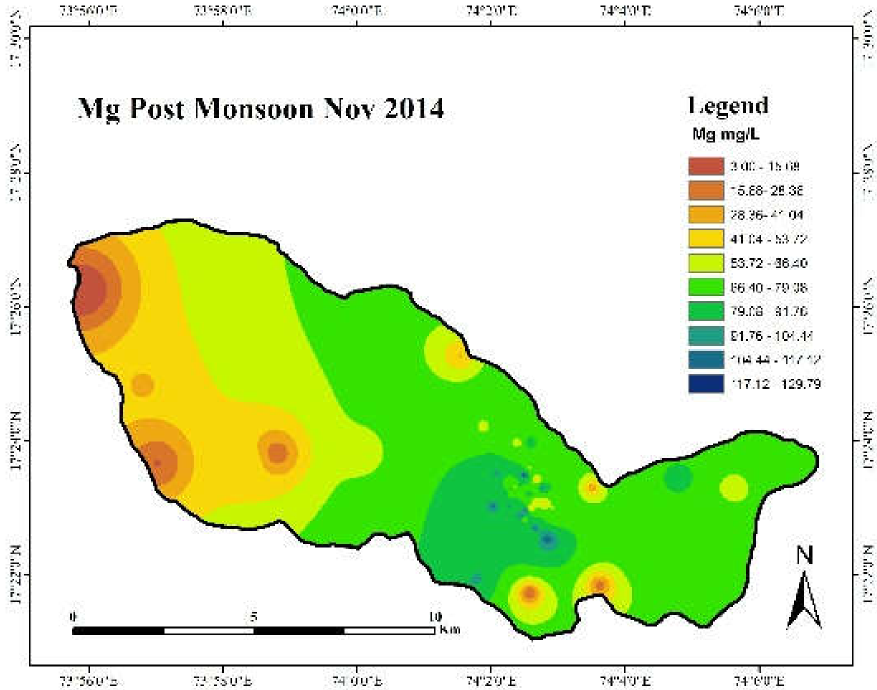


12. c



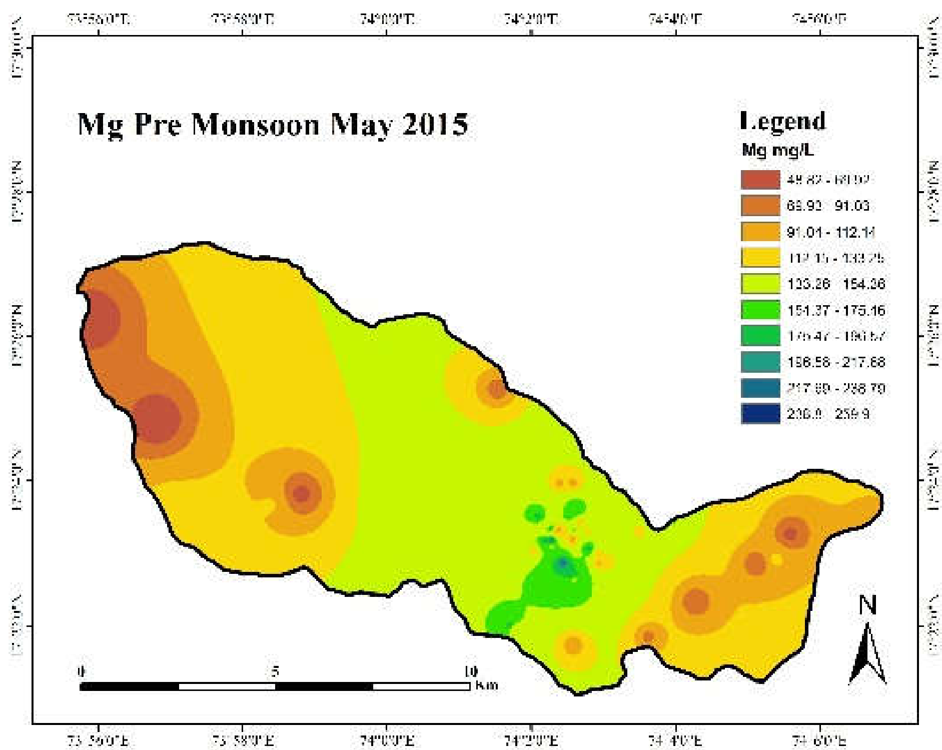
12.d

Figure 12: Spatial variation map of Na^+ during study period



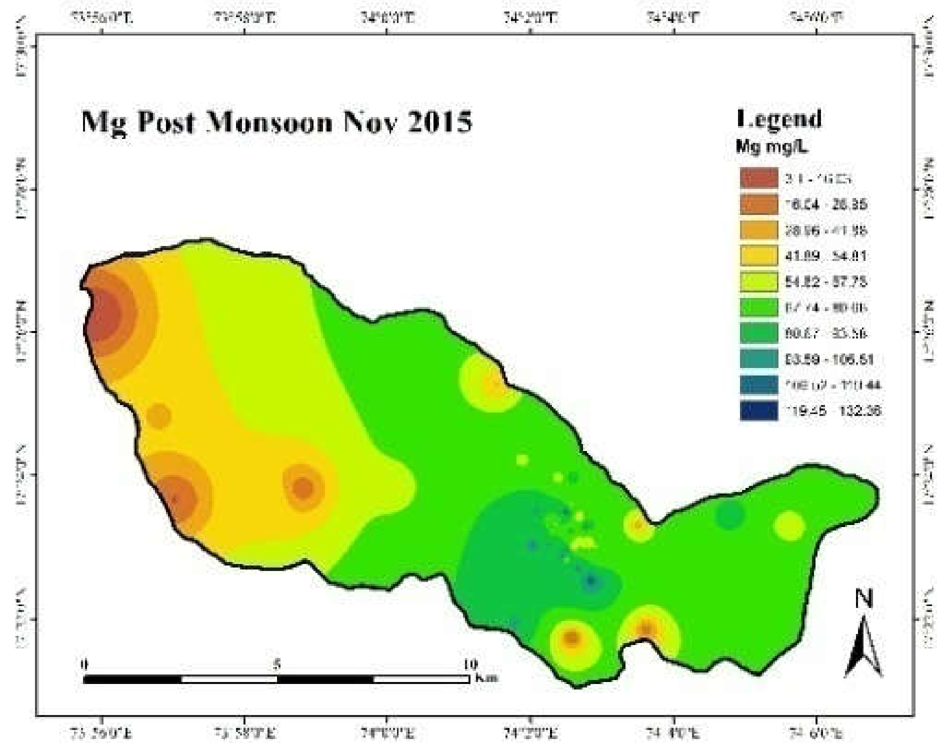
Mg Post Monsoon Nov 2014
Legend
Mg mg/L
117.12 129.79
N
0
5
10
Km

13. a

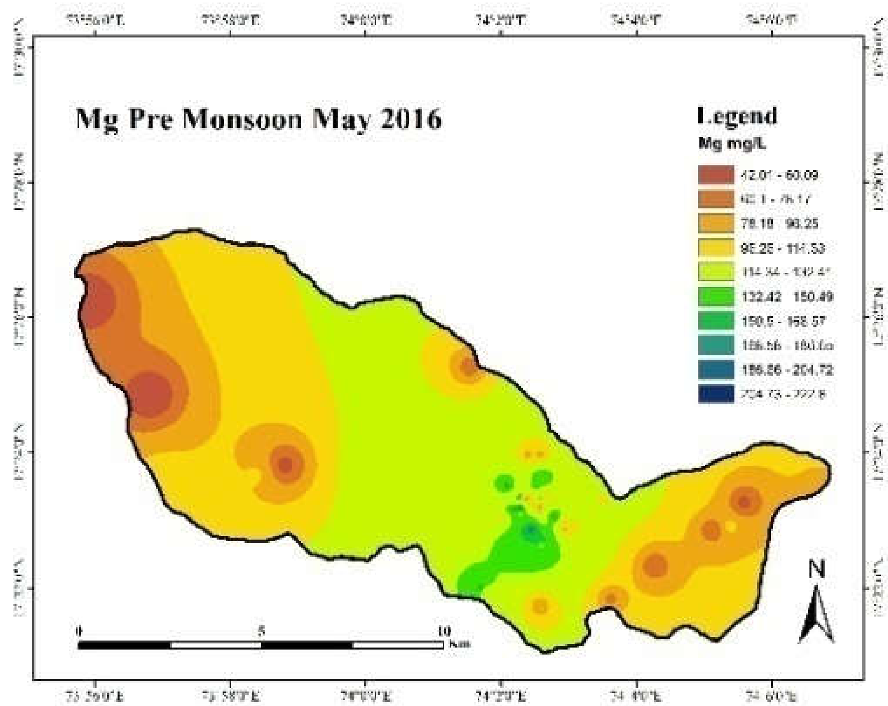


Mg Pre Monsoon May 2015
Legend
Mg mg/L
91.01 - 112.14
N
0
5
10
Km

13.b

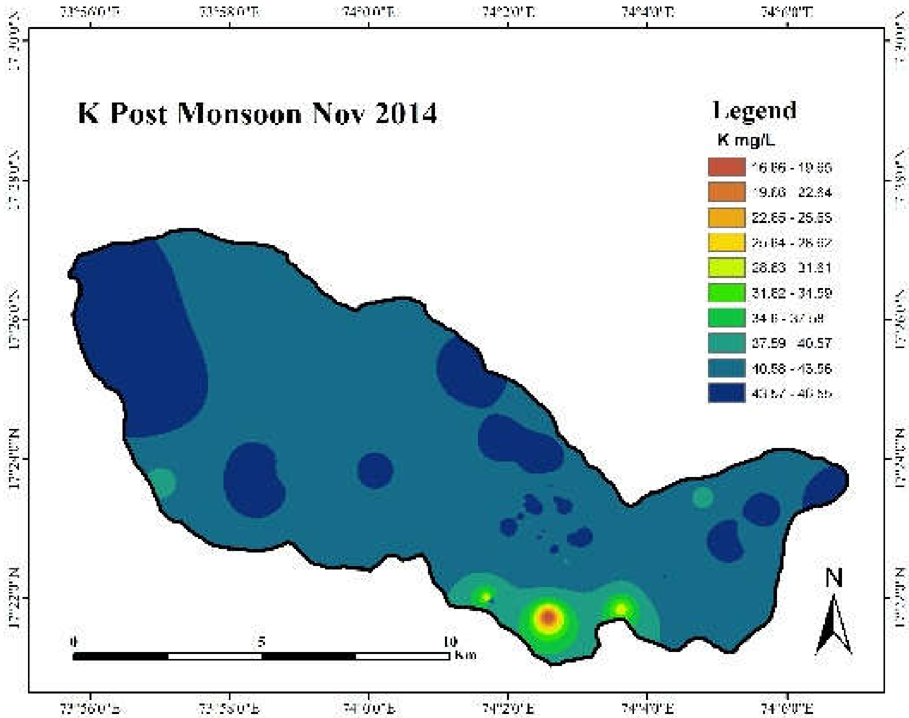


13. c

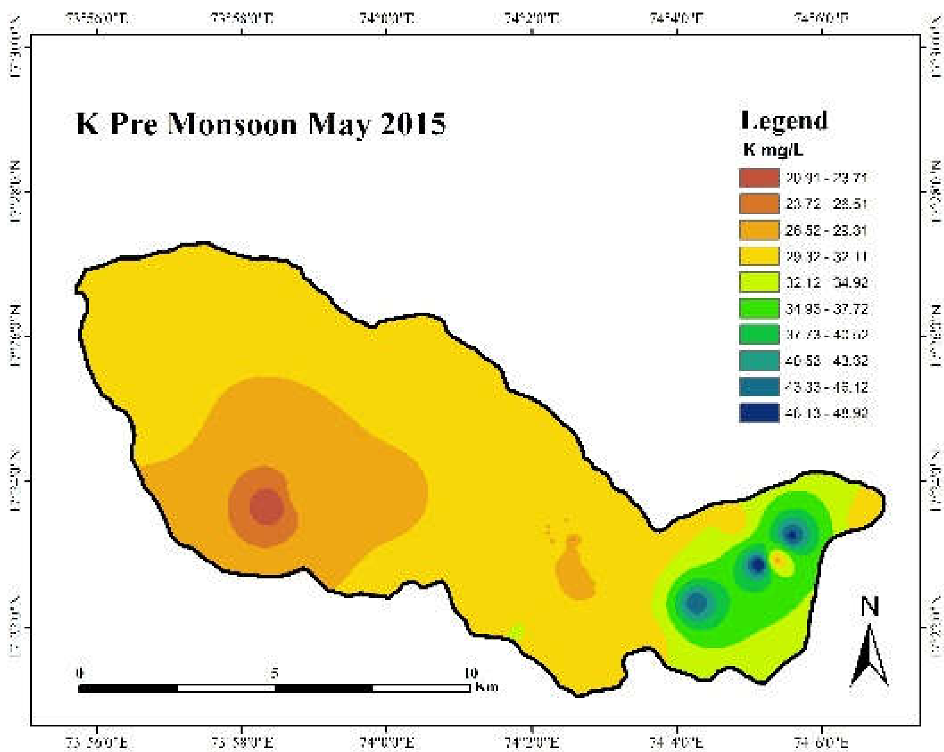


13.d

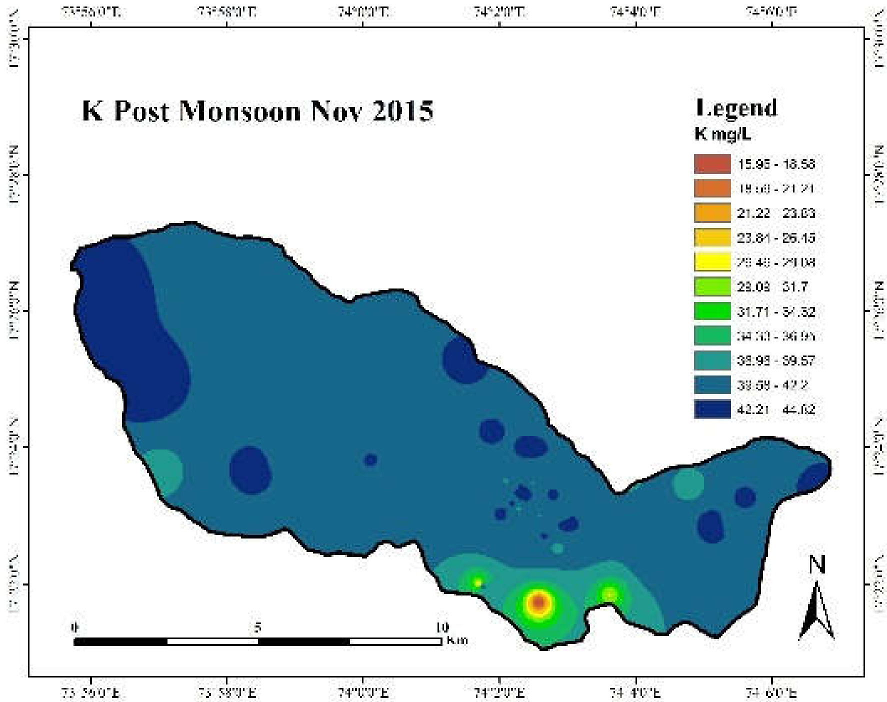
Figure 13: Spatial variation map of Mg^{2+} during study period


K Post Monsoon Nov 2014
Legend
K mg/L
22.65 - 25.65
37.59 40.57
N
0
5
10
Km

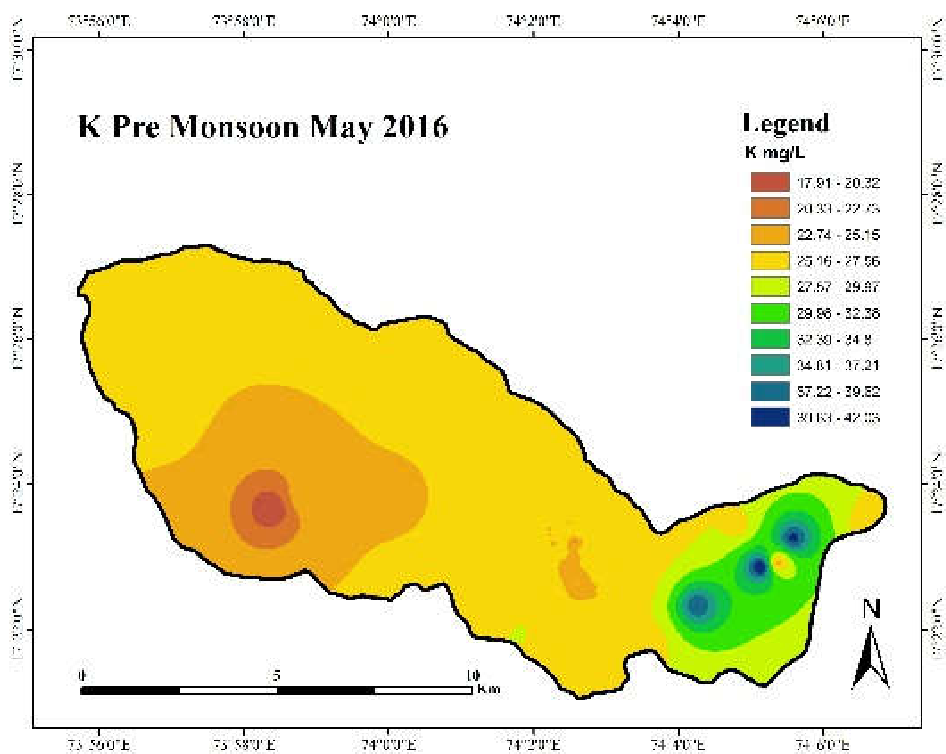
14. a


K Pre Monsoon May 2015
Legend
K mg/L
26.52 - 23.31
31.95 - 37.72
N
0
5
10
Km

14.b

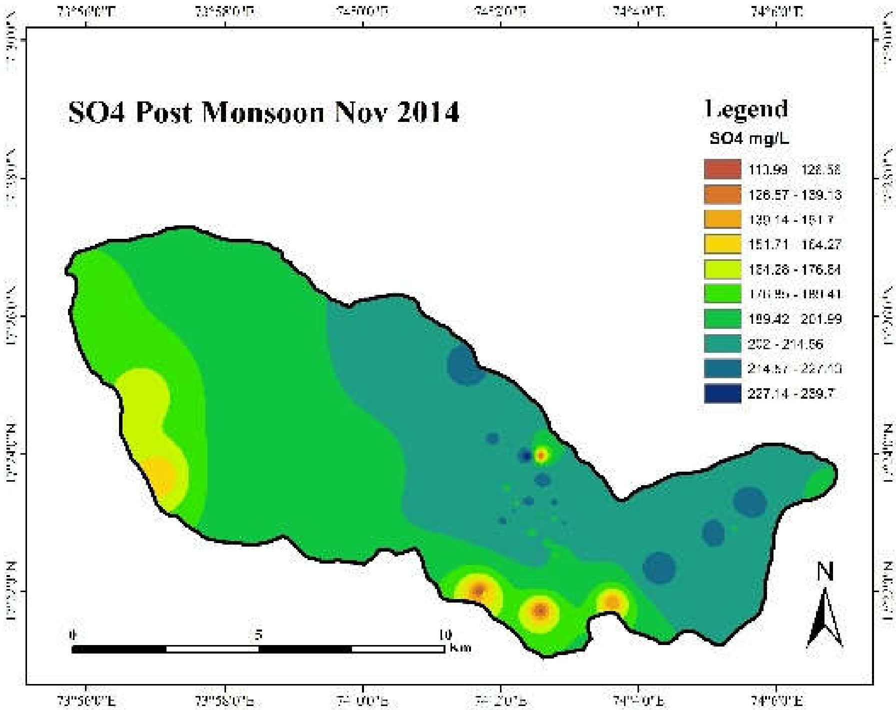


14. c

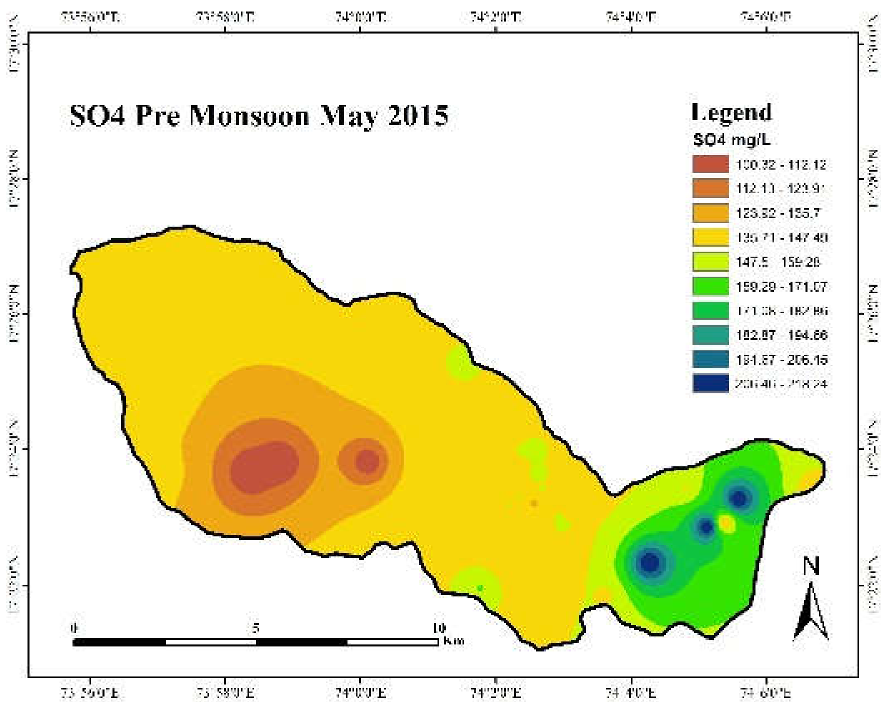


14. d

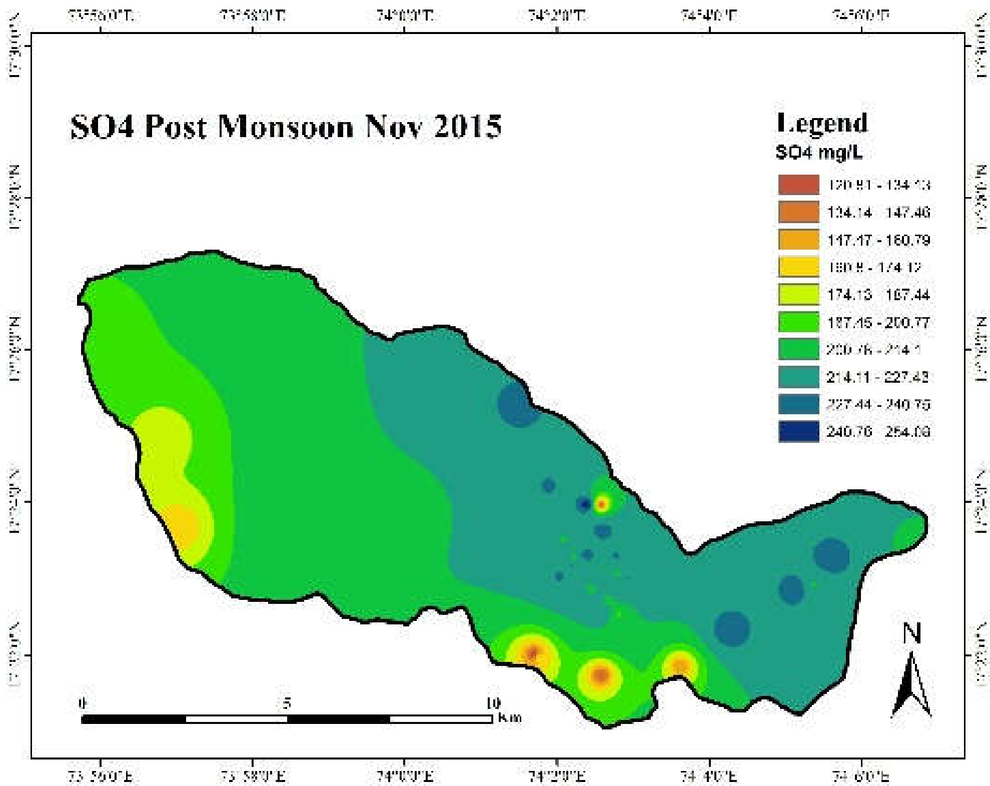
Figure 14: Spatial variation map of K^+ during study period


SO4 Post Monsoon Nov 2014
Legend
SO4 mg/L
126.57 - 139.13
164.28 - 176.84
202 - 214.56
227.14 - 239.7
0
5
10
Km
N

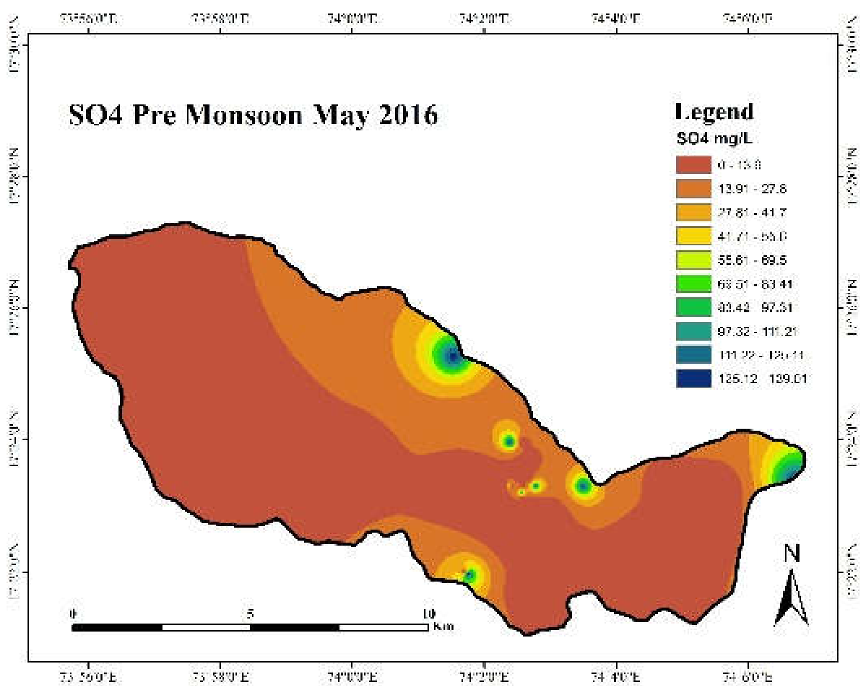
15. a


SO4 Pre Monsoon May 2015
Legend
SO4 mg/L
100.32 - 112.12
159.29 - 171.07
0
5
10
Km
N

15. b



15. c



15. d

Figure 15: Spatial variation map of SO_4^{2-} during study period

Irrigation water quality

SAR (Sodium Adsorption ratio)

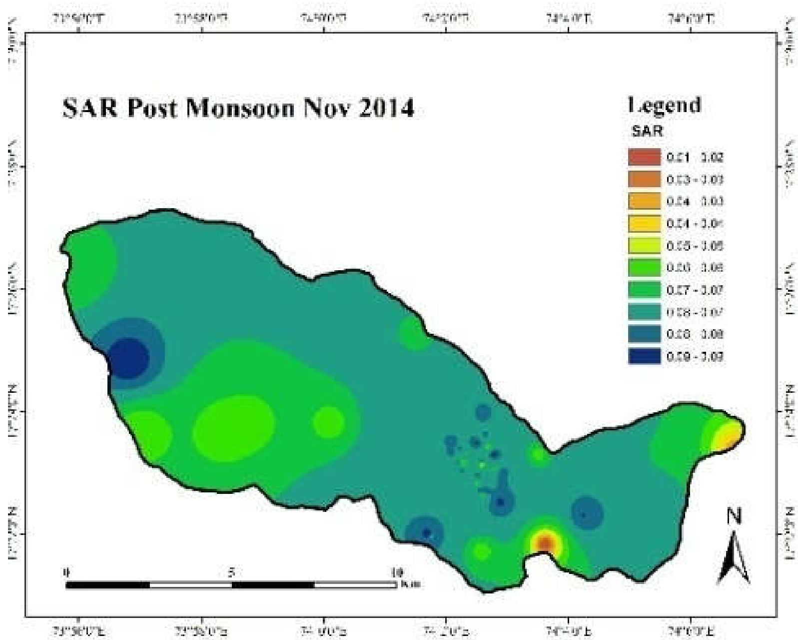
From fig. 16 it can be observed that SAR value of Post monsoon 2014, study area ranges from 0.01-0.09 and the less concentration was sees at eastern part (Fig. 16. a). The Pre-monsoon season of 2015 varies from 0.05-1.1 at western and central part of the area (Fig. 16. b). The SAR value of Post monsoon 2015 ranging from 1.68-3.52 and pre-monsoon season of 2016 varies from varies from 1.84 -9.47 (Fig. 16. c and d). According to SAR ratio, waters were grouped into three classes. Water with SAR ranging from 0 to 3 is considered as good, while SAR ranging from 3 to 9 is characterized by moderate type and greater than 9 is considered unsuitable for irrigation purpose. This suggests that SAR ratio of groundwater samples from studied area belongs to the good to moderate type.

RSC (Residual Soluble Carbonate)

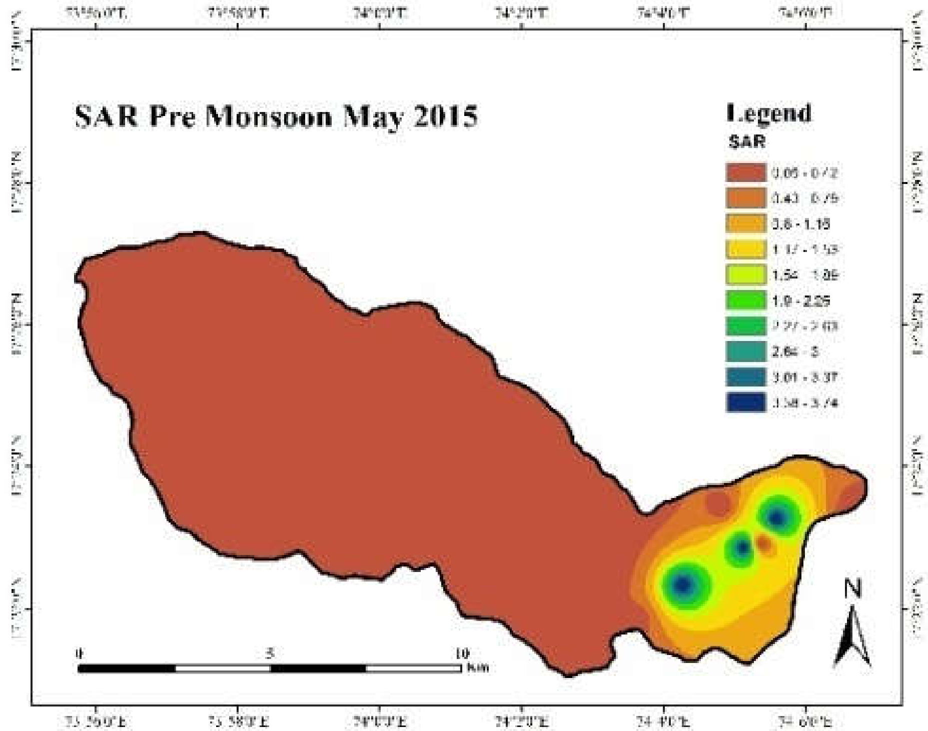
From fig, 17 It can be seen that RSC values are in negative. Lloyd and Heathcote (1985) have classified irrigation water based on RSC as suitable (< 1.25), marginal (1.25 to 2.5) and not suitable (> 2.5). Accordingly, all the water samples from the study area are excellent quality for irrigation because of its RSC concentration < 1.25.

Permeability Index

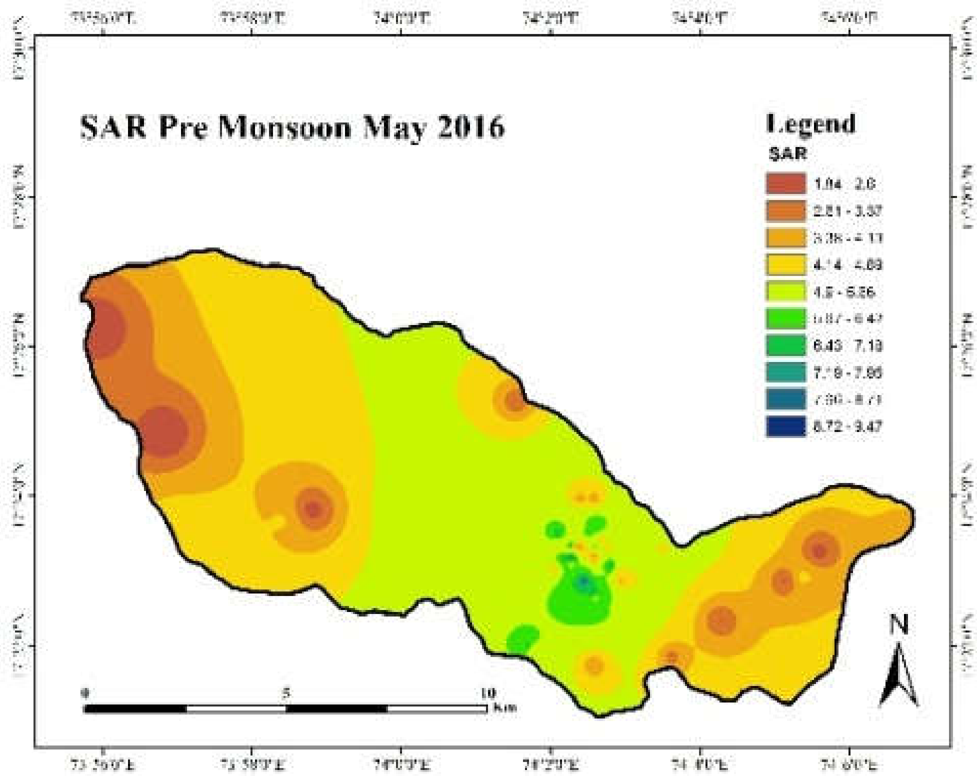
To assess the groundwater suitability for irrigation, Doneen et al. (1962) evolved a water classification based on the PI. Hence, three classes were identified: Class I which is characterized by PI <25%, and classify the water as unsuitable for irrigation, Class II is categorized as good and suitable water for irrigation with a 25 % < PI > 75% and the last class III where the PI >75%, is distinguished by excellent water for irrigation. From fig, 16 Post monsoon season of 2014 PI varies from a 29-50 at western side while at eastern side 17-22 at eastern side (Fig. 18. a). In pre monsoon 2015 PI varies from 12 -29 (Fig. 18. b). The Post monsoon season of PI in post monsoon 2015 varies from 30-53 at eastern side while at western side it ranges from 18-23 (Fig. 18. c) and in pre monsoon 2016 PI ranging from 21-31 at eastern side and other part ranging in between 15-21 (Fig. 18. d). This suggests water is unsuitable for irrigation especially in the eastern part of the basin.



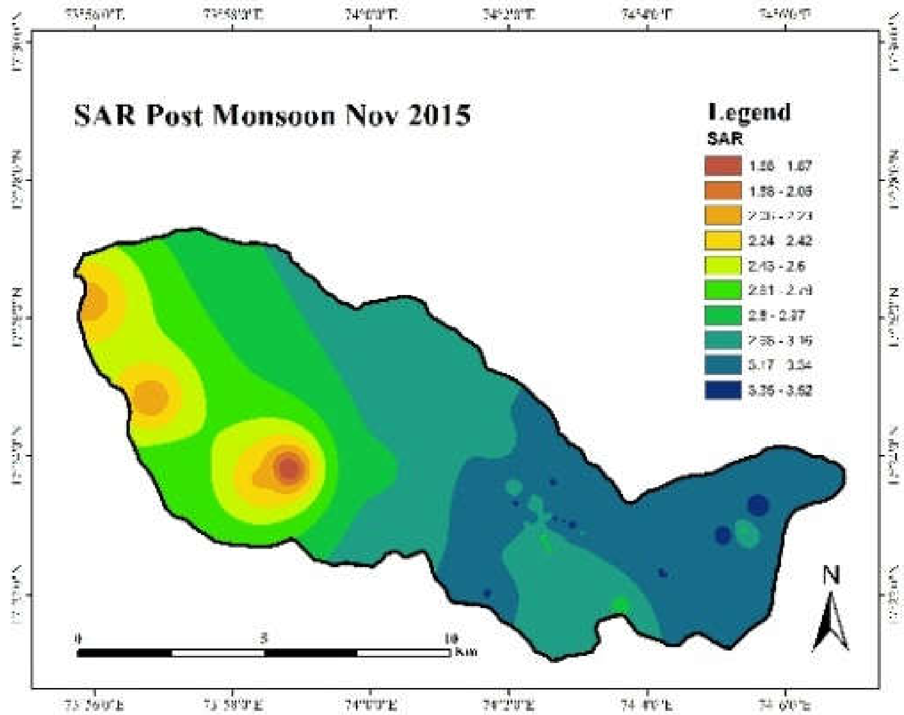
16. a


SAR Pre Monsoon May 2015
Legend
SAR
1.9 - 2.25
3.01 - 3.37
N
0
5
10
Km

16. b

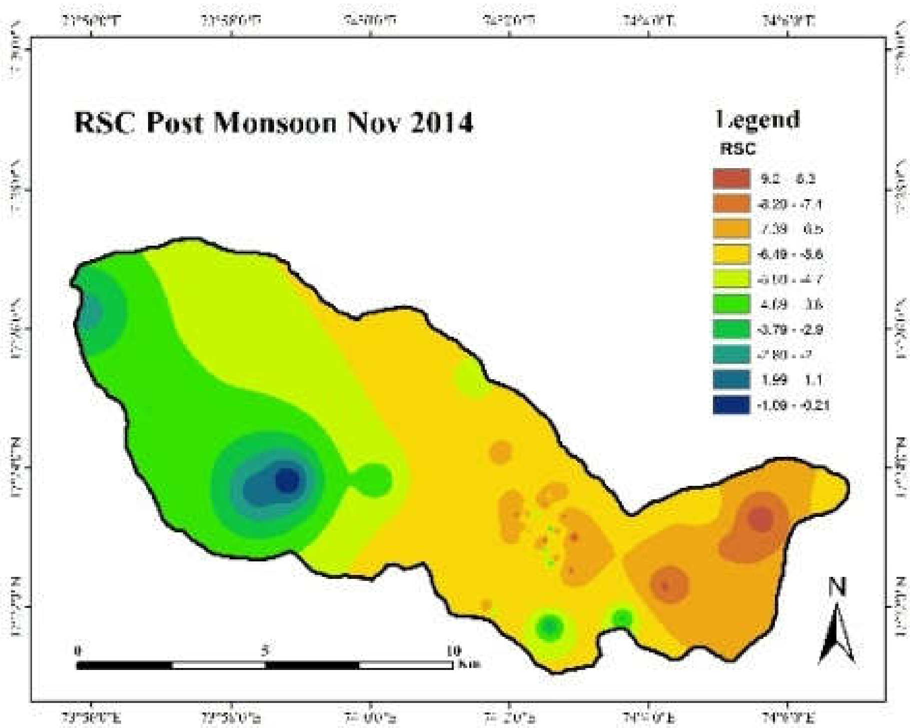

SAR Pre Monsoon May 2016
Legend
SAR
2.81 - 3.37
8.72 - 9.47
N
0
5
10
Km

16.c

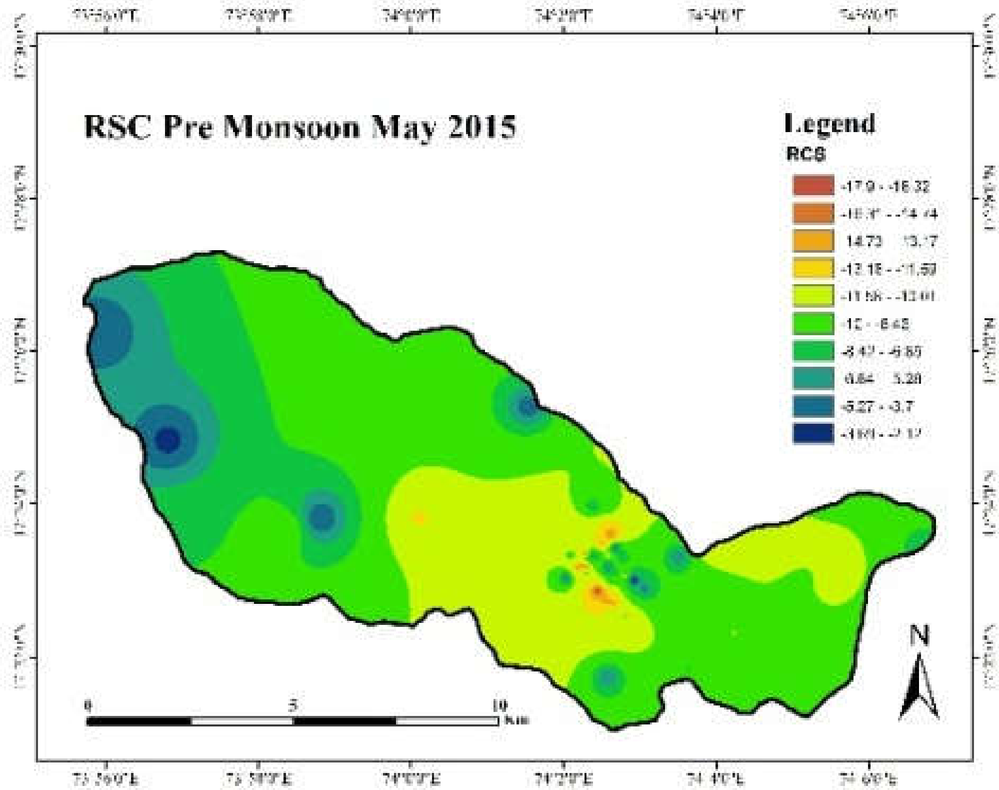


16. d

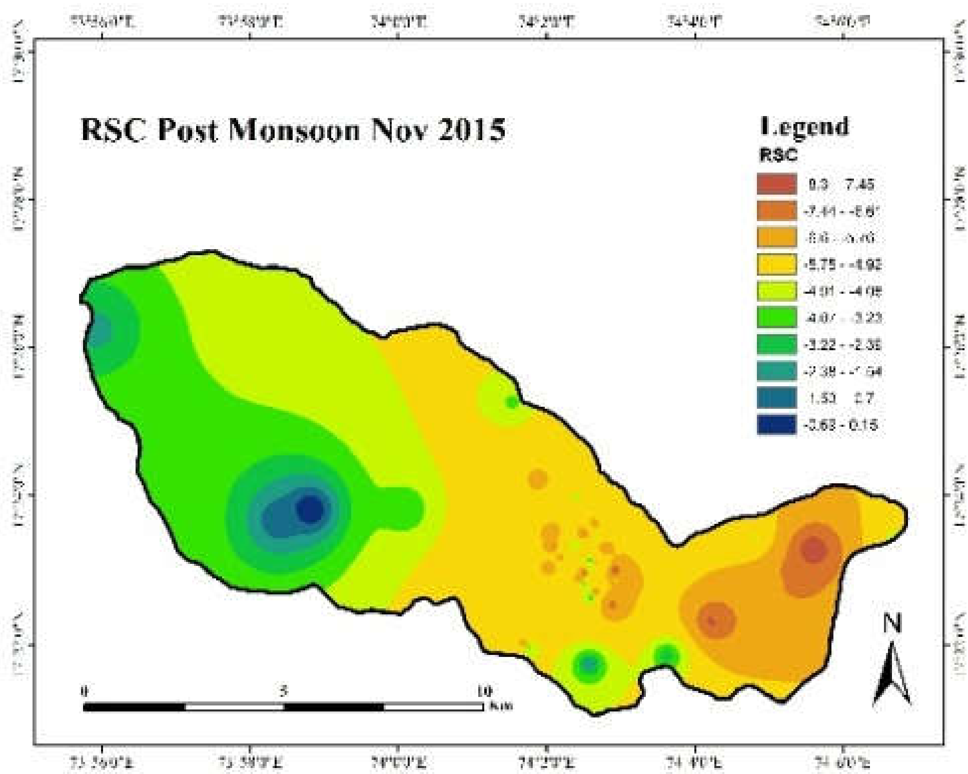
Figure 16: Spatial variation map of SAR during study period



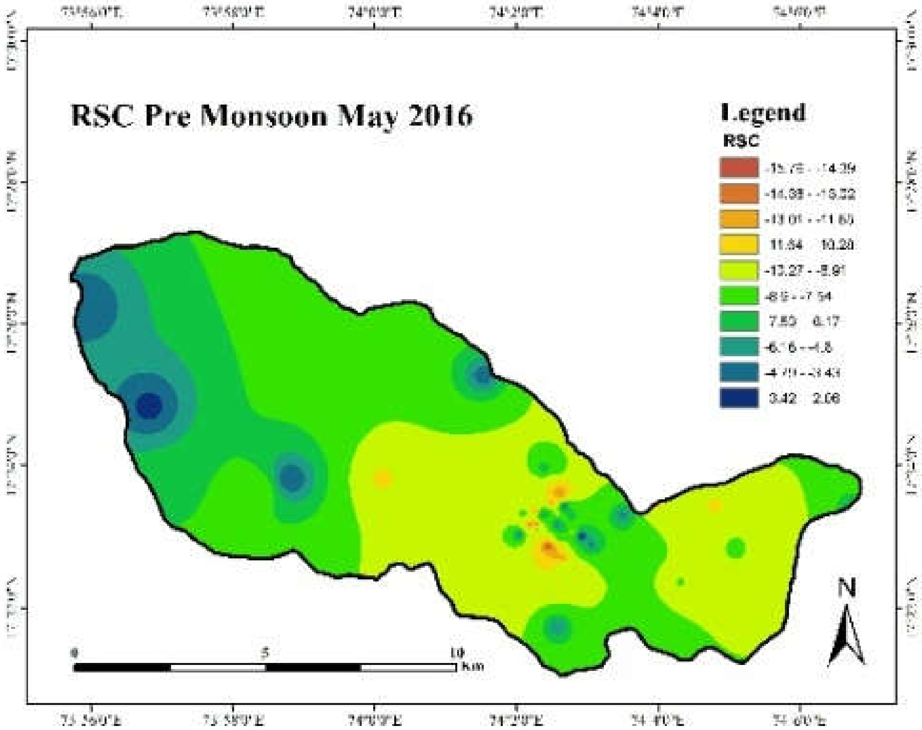
17. a


RSC Pre Monsoon May 2015
Legend
RCS
0
5
10
Km
N

17. b

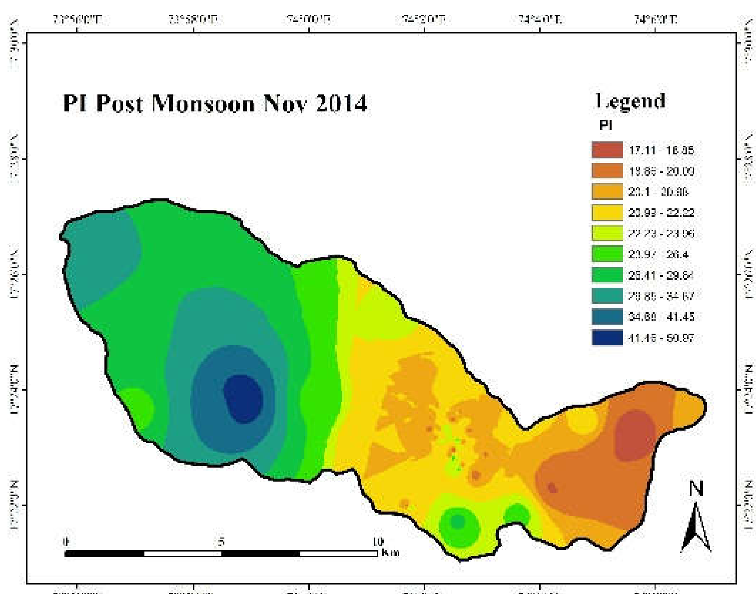

RSC Post Monsoon Nov 2015
Legend
RSC
0
5
10
Km
N

17.c

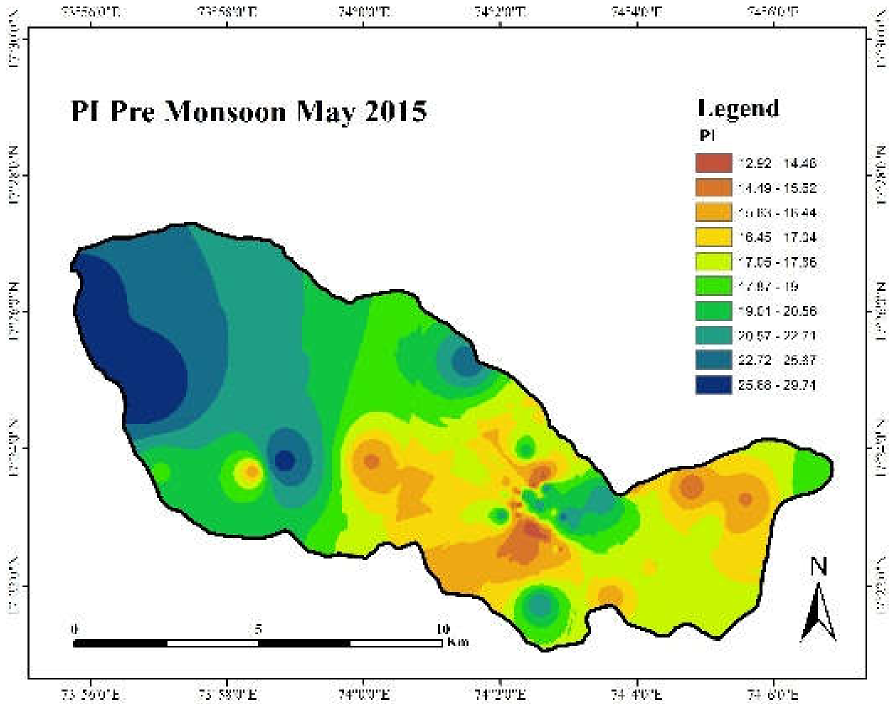


17. d

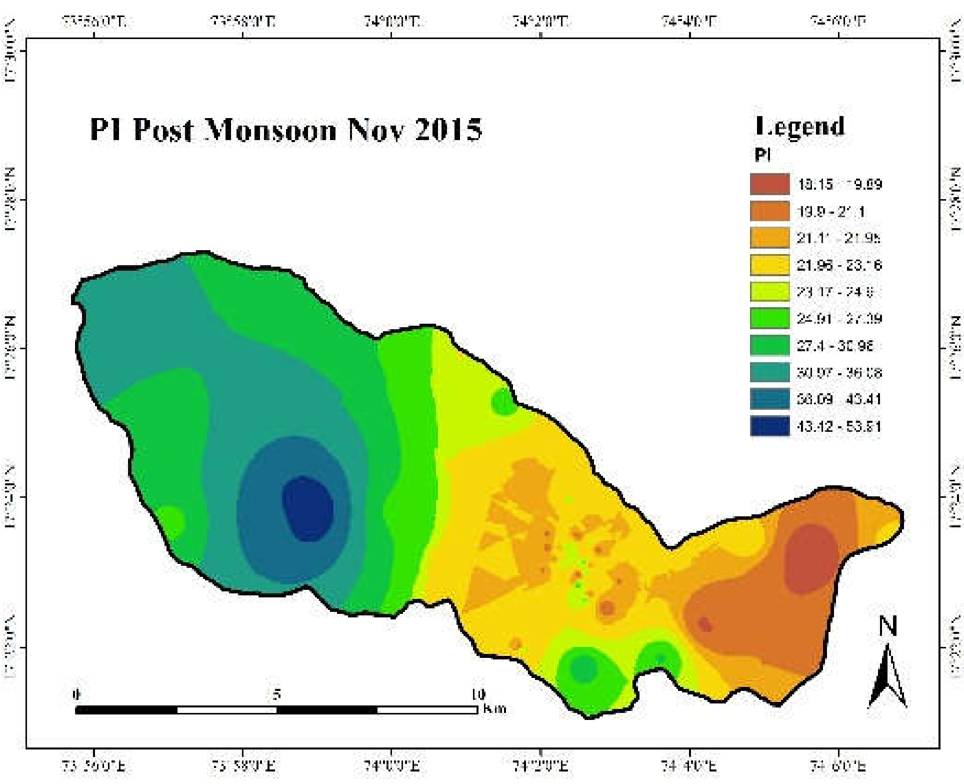
Figure 17: Spatial variation map of RSC during study period



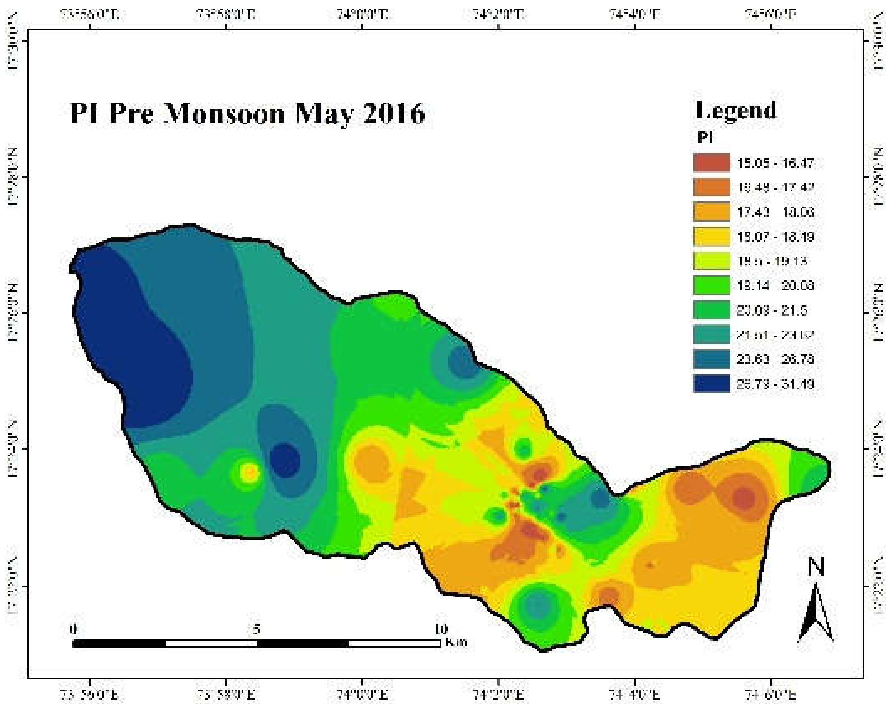
18. a


PI Pre Monsoon May 2015
Legend
PI
14.49 - 15.52
16.45 - 17.04
17.05 - 17.56
19.01 - 20.56
20.57 - 22.71
22.72 - 25.87
25.88 - 29.74
N
0
5
10
Km

18. b


PI Post Monsoon Nov 2015
Legend
PI
19.9 - 21.1
27.4 - 30.96
36.09 - 43.41
43.42 - 53.81
N
0
5
10
Km

18. c



18. d

Figure 18: Spatial variation map of PI during study period

CONCLUSION

A wide range of values of pH, conductivity, total dissolved solids, total hardness, total alkalinity, (HCO_3^-) Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^- and SO_4^{-2}, have been obtained for groundwater samples. The suitability of groundwater for drinking purpose, suggest that the water is hard to very hard type. The quality of water for irrigation purposes shows the conflicting evidences for suitability for agricultural purposes. An overall review of the data indicates that the groundwater from the studied area is marginally suitable for agriculture with few exceptions. Impact of agriculture on groundwater, suggest that the farmers are utilizing high rate of fertilizers for improving the production yield of crops will adversely have an impact on groundwater quality. The high concentration of Mg^{2+} and HCO_3^- can be related to non-geological sources like precipitation and use of chemical fertilizers.

The permeability index value indicate suitability of groundwater for irrigation, as the soil permeability is affected by long term use of irrigation water, influence by the Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- contains of soil. The permeability index values showed that the groundwater is unsuitable for irrigation especially in the eastern part of the basin.

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