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STATISTICAL ANALYSIS OF FLOWING ARTESIAN WELLS DURING WINTER AND SUMMER SEASON

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ABSTRACT

The study was conducted with the aim to analyse the co-relation and multiple linear regression analysis of water quality of flowing artesian wells located in the vicinity of Pantnagar University campus in winter season and summer season. These samples were analysed for various parameters such as pH, electric conductivity (EC), total dissolved solid(TDS), total hardness (TH), calcium hardness (Ca^{2+}), magnesium hardness (Mg^{2+}), sodium (Na^+), potassium (K^+), bi-carbonate (HCO_3^-), acidity, alkalinity, chloride, fluoride, nitrate, carbon di-oxide (CO_2) and sulphate (SO_4). In Statistical data analysis the r value between is EC-TDS, EC-Acidity, TH-Ca, TH-Mg and Alkalinity- HCO_3, shows the significantly strong positive relationship at 0.01 level in during winter season and summer season the correlation analysis between EC- TDS, TH-Ca, TH- Mg, EC-alkalinity, TDS- alkalinity, EC-HCO_3, TDS- HCO_3, alkalinity-HCO_3, EC- Cl, TDS-Cl, alkalinity-Cl^-, HCO_3^- -Cl^-, acidity-fluoride and acidity-CO_2 shows the significantly strong positive relationship at 0.01 level. The relationship developed between TDS and different values of pH, EC, Ca^{++}, K^+, acidity, chloride and sulphate which can be used to evaluate the ground water quality.

Keywords: Flowing Artesian Wells, Physical-chemical parameters, Correlation Coefficient, Multiple Regression Analysis.

INTRODUCTION

It is a lucid fact that water is essential for all forms of life. Water, due to its rapidly depleting resources and increasing demands has become a crisis commodity in today's world. India is comparatively richer in terms of natural water resources like river systems, glaciers, freshwater lakes etc. But keeping in view the haphazard urbanization, industrialization, commercialization and lack of policy level measures towards the distribution and sustainable management of water in the country, it seems really inevitable that these existing water resources will fail to suffice our requirements in coming time leading to a critical situation. Water is a prime natural resource and it is a basic human need this cum natural asset. The impurities present in water naturally merge, but due to rapid industrialization, overpopulation and indiscriminate use of chemicals, affects the chemical and physical properties. Ground water is believed to be comparatively clean and free from pollution than surface water. Drinking water may come from surface water or ground water. An aquifer is a layer of sediment, such as sand or gravel, or a layer of rock, such as sandstone, that stores and transmits water to a well. A confining layer is a layer of sediment or rock that slows or prevents the downward movement of water. A thick layer of clay is an example of a confining layer. An artesian well is a well that taps into a confined aquifer that flows upward to the earth's surface without the need for pumping. If water reaches the bottom surface below the natural pressure of the aquifer, the well is called a flowing artesian well. The word artesian properly used to refer this situation where the water is confined stressed below layers of comparatively impermeable rock. In this study statistical techniques were used to analyse the water quality data collected from Pantnagar University. Correlation coefficient is used to measure the strength of association between two continuous variables. This tells if the relation between the variables is positive or negative that is one increase with the increase of the other. Thus, the correlation measures the observed co-variation. It is also called the linear correlation coefficient because r measures the linear association between two variables (**Halsel and Hirsch, 2002**).

METHODOLOGY

STUDY AREA

The campus of renowned University i.e. Govind Ballabh Pant University of Agriculture & Technology, Pantnagar comes under Udham Singh Nagar district, Uttarakhand. The university campus lies at 29°N latitude and 79°E longitude at an elevation of 243.8m above the mean sea level. After the establishment of SIDCUL, which is first integrated industrial estate at this site, Pantnagar has emerged as a successful industrial estate in the Kumaun region of Uttarakhand. Due to the rapid growth of industry and population, the requirement of portable drinking water is increasing day by day. Pantnagar falls in Tarai region of Uttarakhand, which is found in the immediate south of Bhabar region. In high water table condition, lots of flowing artesian wells are found in this region. Flowing artesian wells located in this area are the main source of water for the people around them. For Collection of samples, all different location sites were outlined and samples were collected. The samples were collected in polystyrene bottle of 1.5 L capacity. Before sampling, the bottles were washed thoroughly with the detergent, acid (1: 1 HNO3 and H2O) tap water, and then distilled water. Chemical parameters were determined by using standard methods immediately after taking them into the laboratory. The samples were analysed as soon as it was possible. A total 30 water samples were collected from all 30 flowing artesian wells sampling station in the winter season and summer season. Each water sample were analysed for 16 parameters such as pH, electric conductivity (EC), total dissolved solid (TDS), total hardness (TH), calcium hardness (Ca^{2+}), magnesium hardness (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bi-carbonate (HCO_3^{-}), acidity, alkalinity, chloride, fluoride, nitrate, carbon di-oxide (CO_2) and sulphate (SO_4) by standard methods prescribed American Public Health Association (APHA), 1989.

STATISTICAL ANALYSIS

CORRELATION COEFFICIENTS

Coefficient of correlation (r) is commonly used to measure and establish the strength of a linear relationship between two variables or two sets of data. It is a simplified statistical tool to show the degree of dependency of one variable to the other variable (**Belkhiri et al., 2010**). The correlation coefficient (r_{xy}) is computed by using the formula as given (**Kumar and Sinha, 2010**). It was considered to be not significant when the value of the probability of significance (p) was greater than 0.05. The inter dependence of different water quality parameters on each other was evaluated on the basic of r_{xy} from equation 1.

$$r_{XY} = \frac{n\sum(X_I Y_I) - (\sum X_i)(\sum Y_i)}{\sqrt{[n\sum X_i^{\,2} - (\sum X_i)^2][n\sum Y_i^{\,2} - (\sum Y_i)^2]}} \qquad (1)$$

Where, the variables x and y represents two different water quality parameters;

n= number of data points/ number of groundwater samples.

MULTIPLE LINEAR REGRESSIONS

Multiple linear regression approach to develop a linear relationship between several independent variables and a dependent variable. This method provides equation linking a dependent variable V_d to the independent variable Vi using the following form:

$$Vd = \beta 0 + \beta 1 Vi1 + \ldots + \beta n Vin \qquad (2)$$

The intercept β0 and the regression coefficients of descriptors (βi) are determined by least square method (**Green and Carroll., 1996**). Vi descriptors are used to describe water quality and cation dependence. (n) is the number of water samples. The reduction in number of descriptors (variables) is included in the study to minimize the information overlap in variables. The best equation is selected while being based on the highest multiple correlation coefficients (R) and lowest standard deviation (SD). Relationships between variables were established using the forward stepwise regression method.

RESULTS AND DISCUSSION

The physic-chemical parameters of water quality constituents such as pH, EC, TDS, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, acidity, alkalinity, chloride, fluoride, nitrate, CO_2 and SO_4 in the study area values are given in Table 1 along with the range of minimum, maximum, mean, standard deviation and variance for winter season. Similar descriptive statistics of the analysed flowing artesian well water quality parameters for summer season are presented in Table 2.

Table 1: Basic statistics of flowing artesian wells in winter season 2015

Sr. No.	Parameters	Min.	Max.	Mean	Standard Deviation	Variance
1	pH	6.3	6.8	6.5	0.124	0.015
2	EC	280	390	351	28.172	793.678
3	TDS	170	290	228	26.008	676.437
4	TH	168	249	212	18.226	332.171
5	Ca^{++}	42	96.1	62.7	11.686	136.561
6	Mg^{++}	121	175.8	149	13.341	177.986
7	Na^{+}	13	20	16	2.050	4.202

8	K^+	1	7	4	1.661	2.759
9	Acidity	7.5	21.3	14	3.468	12.027
10	Alkalinity	58	110	90	15.568	242.378
11	HCO_3^-	140	268	221	37.901	1436.461
12	Cl^-	8.6	21.3	14	3.095	9.581
13	F^-	0.1	0.6	0.37	0.128	0.017
14	NO_3^-	0.3	20.8	1.3	3.680	13.543
15	CO_2	13.8	63.1	38.2	13.691	187.456
16	SO_4^{--}	35	70	52	9.166	84.023

Table 2: Basic statistics of flowing artesian wells in summer season 2016

Sr. No.	Parameters	Min.	Max.	Mean	Standard Deviation	Variance
1	pH	6.3	6.9	6.6	0.151	0.023
2	EC	265	450	355	40.209	1616.782
3	TDS	180	250	225	17.956	322.414
4	TH	182	370	235	32.676	1067.689
5	Ca^{++}	22.6	186.1	87.8	29.923	895.369
6	Mg^{++}	54.9	188.8	147	30.121	907.252
7	Na^+	15	25	18	2.363	5.582
8	K^+	3	10	6	1.832	3.357
9	Acidity	6.3	81.3	51	23.284	542.156
10	Alkalinity	93	145	127	13.865	192.231
11	HCO_3^-	226	354	309	33.806	1142.823
12	Cl^-	9.9	20.6	14	2.479	6.146
13	F^-	0.3	0.6	0.5	0.091	0.008
14	NO_3^-	0.2	10.7	1.12	1.852	3.428
15	CO_2	12.4	56.8	34	12.318	151.729
16	SO_4^{--}	30	90	65	17.107	292.644

CORRELATION COEFFICIENT

Correlation analysis is useful for the measurement of the strength and statistical significance of the relation exists between two variables, one taken as dependent variable. The correlation coefficient (r) was calculated and correlation matrix is obtained. Table 3 and Table 4 represent the correlation matrices for the 16 water quality parameters for both winter season and summer season. Correlation coefficients at both 0.01 and 0.05 level of significance are highlighted in these tables. The r value between EC-TDS, EC-Acidity, TH-Ca, TH-Mg and Alkalinity- HCO_3, shows the significantly strong positive relationship at 0.01 level in during winter season as r = .648, .478, .683, .769, 1and .430 respectively and Ca-Cl, Acidity- NO_3, CO_2-pH and EC-Na shows the significantly at 0.05 level in during winter season as r= .430, .390, -.388 and -.384 respectively. However, in winter season only TH-Mg are strongly correlated with r= 0.769. During summer season the correlation analysis between EC- TDS, TH-Ca, TH- Mg, EC-alkalinity, TDS- alkalinity, EC-HCO_3, TDS- HCO_3, alkalinity-HCO_3, EC- Cl, TDS-Cl, alkalinity-Cl^-, HCO_3^- -Cl^-, acidity-fluoride and acidity-CO_2 shows the significantly strong positive relationship at 0.01 level in during summer season as r = .627, .540, .548, .476, .492, .476, .492, 1, .520, .670, .464, .464, .488 and .786 respectively and alkalinity- NO_3, HCO_3-NO3 and Mg-CO_2 shows the significantly at 0.05 level in during summer season as r= -.455, -.450, .421 respectively. However, in summer season acidity-CO_2 are strongly correlated with r = 0.786.

Table 3 Correlation matrix for winter season (2 tailed, N= 30)

	pH	EC	TDS	TH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Acidity	Alkalinity	$HCO3^{-}$	Cl^{-}	F^{-}	NO_3^{-}	CO_2	SO_4^{--}
pH	1															
EC	-.120 .526	1														
TDS	-.092 .630	.648** .000	1													
TH	-.054 .777	.258 .169	.196 .299	1												
Ca^{++}	.060 .754	.103 .590	.172 .365	.683** .000	1											
Mg^{++}	-.126 .507	.262 .162	.118 .535	.769** .000	.057 .765	1										
Na^{+}	.066 .728	-.384* .036	-.276 .410	-.148 .436	.101 .595	-.290 .120	1									
K^{+}	.163 .389	.066 .728	-.001 .997	-.137 .471	-.028 .884	-.162 .391	.081 .670	1								
Acidity	-.157 .408	.478** .008	.132 .486	.108 .570	.012 .949	.137 .471	-.299 .109	.137 .471	1							
Alkalinity	-.163 .388	.237 .207	.253 .177	.220 .243	.044 .817	.262 .162	-.182 .334	.320 .085	.069 .718	1						
HCO_3^{-}	-.163 .388	.237 .207	.253 .177	.220 .243	.044 .817	.262 .162	-.182 .334	.320 .085	.069 .718	1.000** .000	1					
Cl^{-}	-.058 .761	.239 .203	.451* .012	.278 .137	.430* .018	.003 .986	-.179 .343	.296 .112	.231 .219	.206 .275	.206 .275	1				
F^{-}	.053 .782	-.064 .739	-.147 .437	.350 .058	.197 .296	.306 .101	-.045 .812	-.048 .812	.069 .718	.113 .553	.113 .553	.229 .223	1			
NO_3^{-}	-.178 .347	.050 .795	-.146 .442	.018 .923	-.112 .557	.123 .518	-.096 .613	.010 .960	.390* .033	-.125 .510	-.125 .510	-.079 .680	-.239 .203	1		
CO_2	-.388* .034	-.012 .948	-.265 .157	.060 .754	-.009 .961	.090 .637	.083 .663	-.333 .072	.153 .419	-.087 .646	-.087 .646	.005 .980	.176 .352	-.231 .219	1	
SO_4^{--}	.259 .167	.121 .523	.018 .924	.253 .177	-.005 .979	.350 .058	-.119 .532	-.306 .100	-1.10 .562	-.241 .200	-.241 .200	-.062 .743	-.019 .923	-.252 .180	.081 .672	1

Note: Upper values represent correlation coefficient and lower one represent level of significance
** represent correlation 2-tailed significant at 0.0 Level, *represent correlation 2-tailed significance at 0.05 level.

Table 4 Correlation matrix for summer season (2 tailed, N= 30)

	pH	EC	TDS	TH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Acidity	Alkalinity	$HCO3^{-}$	Cl^{-}	F^{-}	NO_3^{-}	CO_2	SO_4^{--}
pH	1															
EC	-.121 .525	1														
TDS	-.170 .368	.627** 0.00	1													
TH	-.266 .156	.101 .594	.084 .658	1												
Ca	-.182 .335	-.117 .539	-.164 .387	.540** .002	1											
Mg	.110 .563	.227 .228	.254 .175	.548** .002	-.408 .025	1										
Na	-.105 .580	.198 .294	-.107 .573	.127 .505	-.088 .643	.225 .232	1									
K	-.228 .225	-.164 .388	-.026 .893	.133 .482	.083 .665	.062 .744	-.014 .830	1								

Acidity	.179 .345	-.371 .044	-.068 .720	.035 .853	.091 .633	-.053 .779	-.325 .080	-.136 .475	1							
Alkalinity	.009 .962	.476** .008	.492** .006	.066 .728	-.257 .170	.327 .078	.019 .920	-.114 .549	-.063 .742	1						
HCO3	.009 .962	.476** .008	.492** .006	.066 .728	-.257 .170	.327 .078	.019 .920	-.114 .549	-.063 .742	1.000** .000	1					
Cl	-.086 .650	.520** .003	.670** .000	.150 .428	-.052 .787	.214 .256	-.261 .164	-.203 .282	.001 .997	.464** .010	.464** .010	1				
F	.199 .292	-.269 .151	-.084 .661	.267 .154	.082 .668	.206 .275	-.080 .673	.083 .664	.488** .006	-.153 .419	-.153 .419	.038 .842	1			
NO3	-.317 .088	-.129 .498	.031 .872	.052 .785	-.050 .794	.129 .496	-.075 .695	.195 .301	-.148 .434	-.455* .014	-.450* .013	-.036 .851	.192 .310	1		
CO2	.060 .754	-.244 .194	-.051 .787	.279 .135	.421* .020	-.117 .539	-.151 .427	-.169 .372	.786** .000	-.050 .795	-.050 .795	-.013 .946	.181 .339	-.258 .168	1	
SO4	.007 .972	-.221 .240	.013 .946	-.212 .261	.128 .502	-.358 .052	-.354 .055	.066 .727	-.064 .871	-.064 .736	-.064 .736	-.155 .414	-.011 .954	.157 .408	.008 .968	1

Note: Upper values represent correlation coefficient and lower one represent level of significance
** represent correlation 2-tailed significant at 0.0 level, *represent correlation 2-tailed significance at 0.05 level

Multi linear regression analysis

SPSS software is used to prepare linear regression analysis models relating a dependent water quality parameter to a set of statistically independent water quality parameters. Value of $R \geq 0.8$ is generally considered as strong and the value of R^2 lie between $0 < R^2 < 1$, indicates the strength of the linear association between Vd and V_i The relationship between TDS and other physico-chemical water properties like pH, EC, Ca^{++}, K^+, acidity, chloride and sulphate of Winter and summer season of all the selected parameters. The value of constant β_0, β_1, β_2, β_3, β_4, β_5, β_6, β_7 and β_8 were determined by multiple correlations using the observation 189.375, -15.799, 0.209, 0.089, 1.249, 0.118, 3.272 and 0.199 respectively. The value of coefficient of correlation R^2 was found equal to 0.647 and R value 0.804 which, show strength of linear equation. The equation for estimating the value of TDS in flowing artesian wells water for Pantnagar University command area may be written as:

$$\mathbf{TDS = 189.375 - 15.799*pH + 0.209*EC - 0.089Ca^{++} + 1.249*K^{+} + 0.118 + 3.272*Cl^{-} + 0.199*SO_4} \quad \textbf{(1)}$$

The excepted values of TDS for different values of pH, electric conductivity, calcium hardness, potassium, acidity, chloride and sulphate of summer season were calculated. The observed and excepted value for TDS for summer season was plotted in a graph (Fig. 1). The result indicated that the relationship developed can be used reasonably satisfactory to evaluate the flowing artesian well water quality.

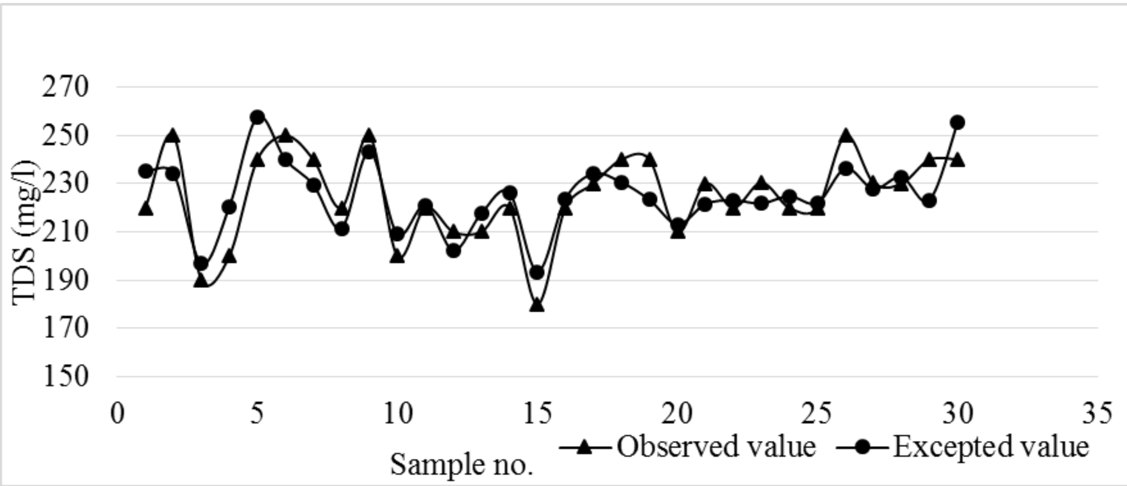

Fig. No 1. Observed vs. Excepted value for TDS (summer season)

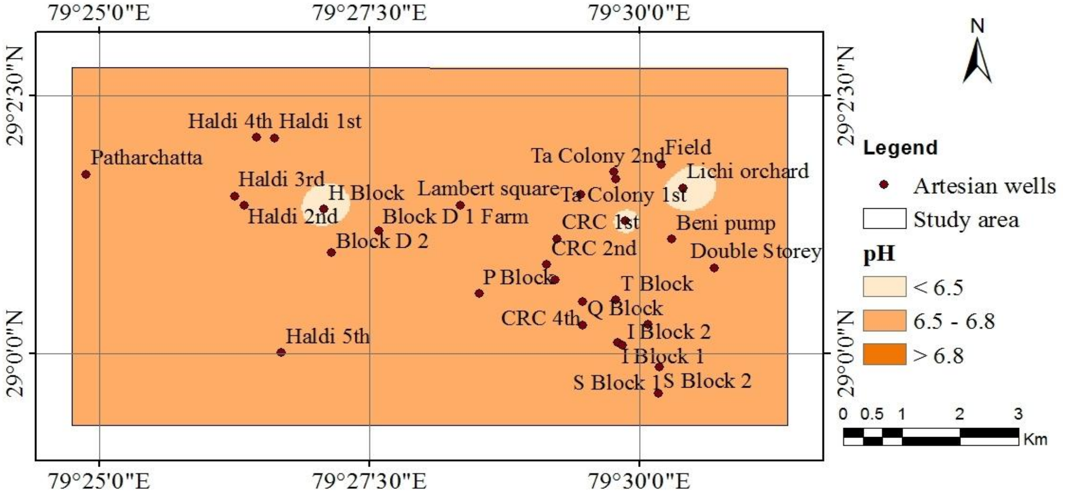

Fig. No 2 SDM of pH (winter season, N=30)

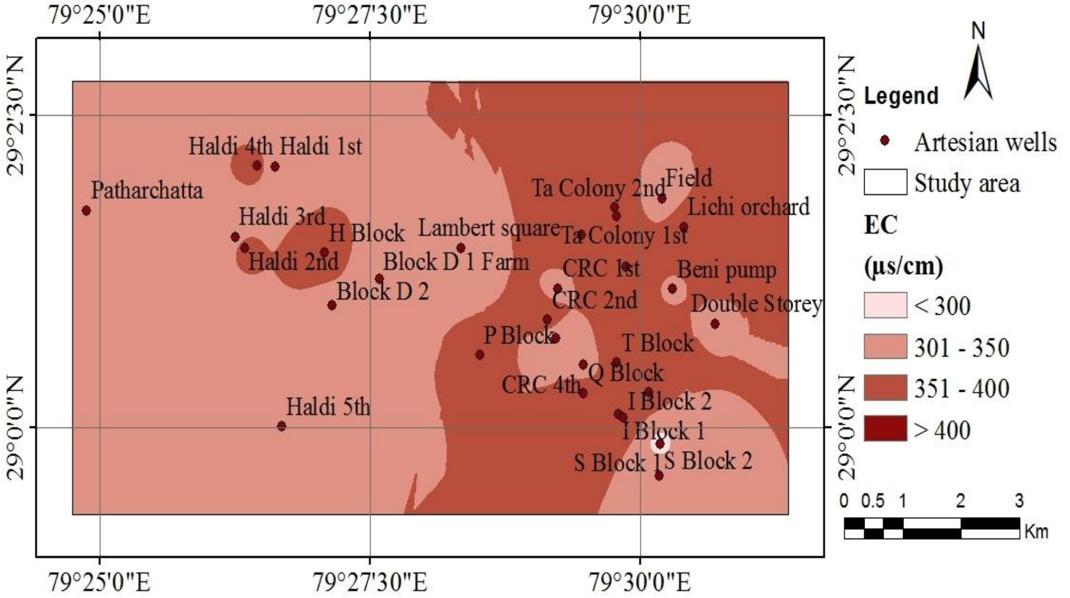

Fig. No. 3 SDM of EC (winter season, N=30)

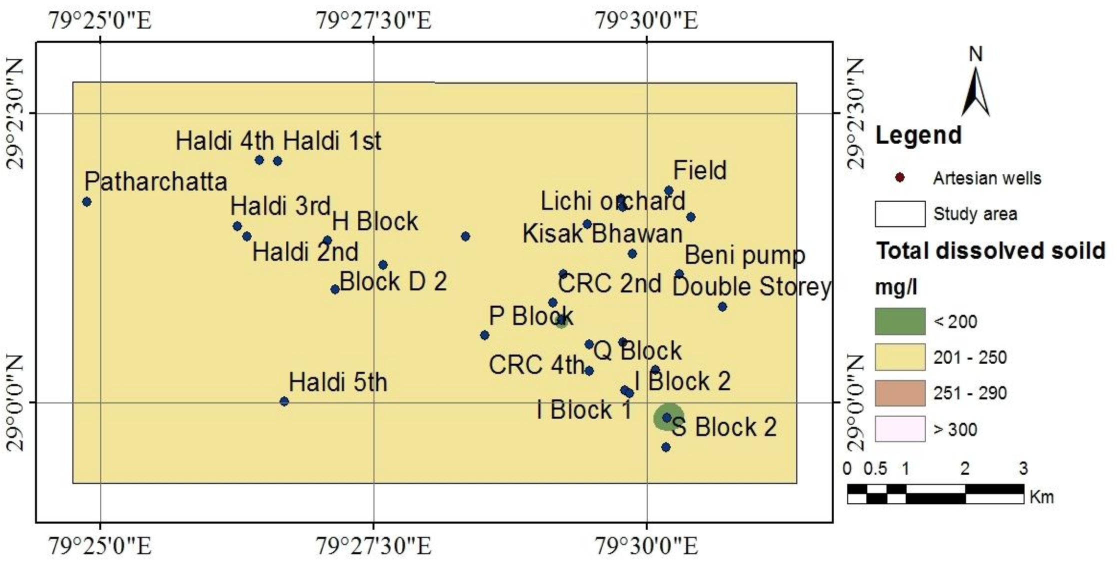

Fig. No 4 SDM of TDS (winter season, N=30)

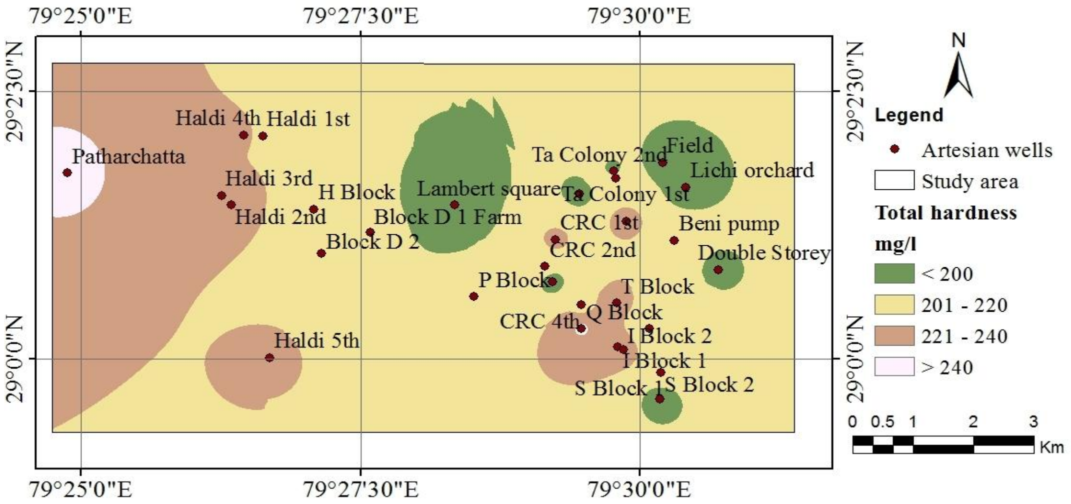

Fig. No 5 SDM of TH (winter season, N=30)

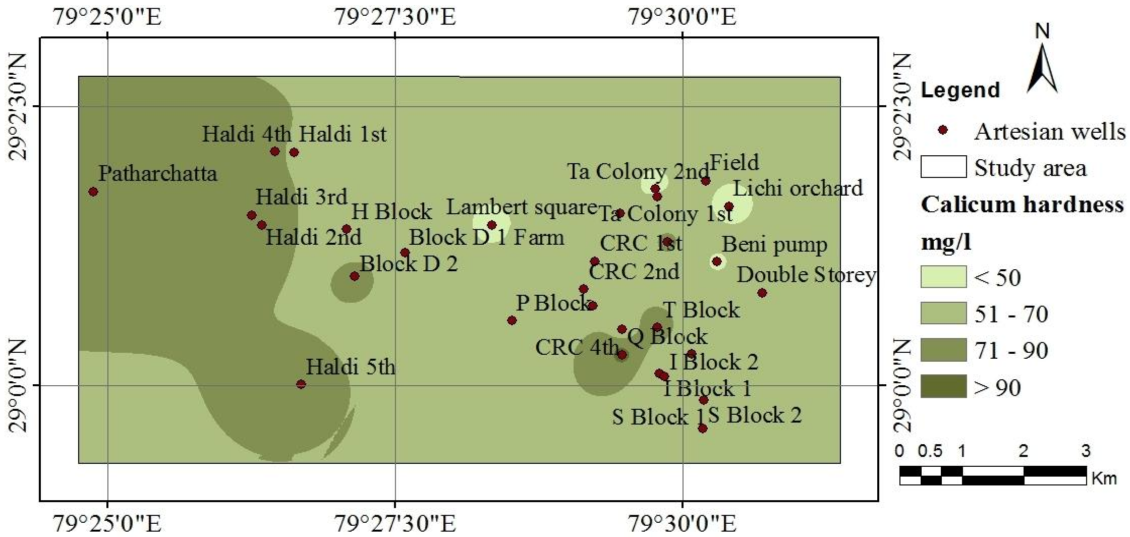

Fig. No 6 SDM of Ca hardness (winter season, N=30)

CONCLUSION

The correlation matrix indicates a strong positive relationship between EC-TDS, EC-Acidity, TH-Ca, TH-Mg and Alkalinity- HCO_3 during winter season and During summer season the correlation analysis between EC- TDS, TH-Ca, T=H- Mg, EC-alkalinity, TDS-alkalinity, EC-HCO_3, TDS- HCO_3, alkalinity-HCO_3, EC- Cl, TDS-Cl, alkalinity-Cl^-, HCO_3^- -Cl^-, acidity-fluoride and acidity-CO_2. In the Multi linear regression analysis relationship has developed between TDS and values of pH, EC, Ca^{++}, K^+, acidity, chloride and sulphate may be used reasonably to evaluate the flowing artesian wells water quality.

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