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Modelling and Assessment of Water Suitability for Agriculture in Safidon Tehsil of Jind District, Haryana, India

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ABSTRACT

Agriculture requires an enormous amount of water. The quality of water used for irrigation is essential. This study aims to add to the growing body of research on the appropriateness of water suitability of Safidon tehsil in Jind district. A total of 76 samples from different locations were collected from Safidon tehsil. The water samples were analyzed for major cations (Na^+, Ca_2^+ and Mg_2^+) and Anions (HCO_3^-, CO_3^-, Cl^- and SO_4^{2-}). The irrigation suitability will be calculated by using Residual Sodium Carbonate (RSC), Potential Salinity (PS), and Permeability Index (PI). The Result shows that 99% of samples of PI were suitable while only 1% were unsuitable, the PS of water samples lies from 20.1 to 35.92 which shows that the water is unsuitable for irrigation and the values of RSC lies between -1190 to -81 and these negative values indicate little risk of sodium accumulation due to offsetting levels of calcium and magnesium in the study area.

Keywords Irrigation suitability, Permeability index, Potential salinity, Residual sodium carbonate.

INTRODUCTION

India offers a complex landscape for agricultural suitability, especially in irrigation techniques, given its large geographic area and varied climate. Irrigation suitability becomes crucial for ensuring food security and sustainable farming practices. Analyzing a variety of parameters, including soil properties, water availability, climate conditions, and socio-economic considerations is necessary to determine whether irrigation is appropriate. By evaluating irrigational suitability, sustainable irrigation techniques that reduce adverse environmental effects including soil erosion, waterlogging, salinization, and aquifer depletion can be put into place.

To evaluate Greater Chittagong's surface and groundwater quality, various physical-chemical and microbiological parameters have been used. The collection of surface water samples was also examined in the Bangladesh region. The samples were

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collected by using the statistical sampling techniques and appropriate preservation techniques were used to preserve the samples. Rather than the monsoon season, the data on water quality indicated variance in the pre and post-monsoon season. Most of the groundwater sample concentrations of various constituents were within the BIS drinking water quality guideline permissible limits. The arsenic problem in the study area was determined by the findings of water quality assessment (Ahmed *et al.* 2010). By using indicators like sodium absorption ratio (SAR) (Wilcox 1955), Sodium percent (Na%) (Ayers & Westcot 1985), Kelley's ratio (KR) (Kelley 1963) and Electrical conductivity (EC) (Richards 1954). The suitability of water for irrigation in Ramganjmandi tehsil of Kota in Rajasthan was determined. Static modeling of these irrigational parameters was done in Arc GIS using the inverse distance weightage method of interpolation. SAR values range from 0.98 to 11.16, while Electrical conductivity values lie between 367µS and 939µS. The tehsil central and Southern regions, which are active mining belts, exhibit high SAR values while Na% values range between 11.43 to 60.14%, and high Kelly's index values are found in the northwest of the tehsil, with values ranging from 0.12 to 1.35. Land, air, and water pollution is a major issue in this area (Rana and Sharma 2022). From 2005 to 2010, hydrogeological field research was conducted in Argentina's Wet Pampa Plain. These surveys included electrical conductivity tests, water level measurements, and the measurement of the samples collected from the wells for chemical analysis. To facilitate the geographical data used in the integrated management of surface water and groundwater, a GIS-managed hydrogeological database has been created. An irrigation water index (IWI) is produced by combining variables like EC, sodium adsorption ratio (SAR), residual sodium carbonates (RSC), slopes and hydraulic gradient. An aquifer thickness and the appropriate classes from the IWI are then integrated to create a restricted water index (RIWI). According to the IWI index, 3.4% of the land has unsuitable water, whereas 61.3% of the region has "Very high" to "MODERATE" irrigation potential. Irrigation planning is necessary for effective practice in the region since about 46% of the examined area has high suitability for irrigation and moderate groundwater availability and the RIWI in the tested area is the "2" with high suitability for irrigation and moderate aquifer potential (Romanelli *et al.* 2012). In Andhra Pradesh's Chittoor district, the Tirupati region's water quality was investigated. Groundwater parameters such as calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate chloride, fluoride, TDS, calcium hardness, alkalinity, pH, electrical conductivity, Sodium adsorption ratio (SAR), Potential salinity (PS), Residual sodium carbonate (RSC), Permeability index (PI), Kelly's ratio (KR), indices of base exchange, Gibbs ratio I and Gibbs ratio II, have been analyzed using Chadha's diagram (Chadha 1999). Except for a small number of samples, groundwater is suitable for drinking and irrigation. The principal ions were found to be within the allowable limit in the majority of the locations. The most common ion is sodium and only a small percentage of samples exceed the sample limit due to intensive farming methods and the interaction of groundwater with sewage. One of the major factors contributing to the issues with groundwater quality in the Tirupati region is the migration of people from rural to urban areas (Balaji *et al.* 2017). The water quality index in Algeria's upper cliff plain was used to evaluate the groundwater suitability for agricultural and drinking uses. 19 groundwater samples were collected from the research area wells during the dry season in October 2012 and the wet season in April 2012. Physical parameters like pH, total dissolved solids, and electrical conductivity were determined in the field using a conductivity meter and conventional protocols. Among the parameters that were examined were four cations (Mg_2^+, Ca_2^+, Na^+ and K^+) and four anions (SO_4^{2-}, Cl^-, HCO_3^- and NO_3^-). The National Agency of Hydraulic Resources (NAHR) laboratory evaluated these samples. In the dry season, the pH in the study region varies from 7.4 to 8.3 while in wet periods the groundwater is slightly alkaline. The water quality for drinking purposes (WQID) ranges from 67 to 356 almost 95% of the samples exceeded 100 due to the higher values of chlorides, sulphates, nitrates, bicarbonates, calcium, magnesium and sodium. Based on the 10 groundwater quality parameters (pH, EC, Ca_2^+, Mg_2^+, Na^+, K^+, HCO_3^-, Cl^-, SO_4^-, NO_3), the WQI calculation shows that only 10% and 15% of samples in the wet and dry periods exceed the limit of WQII (equal to 150) and the EC, SAR, RSC, KR, MAR, PI, %Na and Cl indicates that groundwater quality varies from good to unsuitable for irrigation purposes (Bouderbala 2017). A hydrochemical investigation was conducted to investigate the groundwater contamination of Vayapur. The APHA (1995) analyzed various water quality parameters such as pH, and Electrical Conductivity (EC). Total Dissolved Solids (TDS) were calculated by multiplying the electrical conductivity by a factor (0.64), and Total Hardness (TH) was determined by measuring the difference in the concentration of $CaCO_3$ and calcium (Ca) were Sulphate titrimetrically, using standard EDTA. Magnesium (Mg) was calculated by taking the difference between the concentration of (TH) and (Ca). The titrimetric method was used for measuring Chloride (Cl) by standard $AgNO_3$ titration. Using an Elico Flame Photometer, Potassium (K), and sodium (Na) were determined. According to the findings, 40% of groundwater samples are unsuitable for irrigation purposes (Deshpande and Aher 2012). In a rural part of Sarpol-e-Zahab City, Kermanshah province Iran, groundwater quality for drinking and irrigation was assessed. A total of 30 samples were examined for several parameters such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Na^+, Mg_2^+, Ca_2^+, Cl^-, SO_4^{2-} ionic constituents. By using United States Department for Agriculture the water quality has been assessed. Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Sodium Percent (Na%), Permeability Index (PI), Kelly's Ratio (KR), Soluble Sodium Percent (SSP), Magnesium Hazard (MH), and Electrical Conductivity (EC) characteristics were calculated. According to 2-year monitoring, the water quality for agriculture is either good or excellent category. A strong association between physico-chemical parameters is shown by a factor analysis and Spearman's correlation analysis (Soleimani *et al.* 2018). The water quality index was integrated using the Geographical Information System (GIS) to generate variability thematic maps using Arc GIS software to assess the groundwater quality for irrigation in an agricultural area near Al Kufa City, North of Al Najaf Province, Iraq. Various factors are used such as cadmium (Cd), iron (Fe), nickel (Ni), lead (Pb), chromium (Cr), Total Dissolved Solids (TDS), Electrical Conductivity (EC), sodium (Na^+), and potassium (K^+). All the parameters are combined to determine the final WQI and the weights or relative relevance of each parameter in the final index are also established. According to the outcome, the recorded values of the index fall between o to 4.33 or higher, with a value of 2.16 denoting the line separating polluted and uncontaminated groundwater. The index map concludes that the groundwater in the area under investigation is high quality and appropriate for irrigation. The findings reveal that there is no risk to irrigation from the water in any of the reservoirs (Al Maliki *et al.* 2020). The Bharalu River in Assam, India was sampled three times between April 2016 and April 2017 for eight years and the results were evaluated using the annual database from April 2008 to April 2013 and the data on water quality obtained from the Pollution Control Board (PCB). Permeability Index (PI), Sodium Adsorption Ratio (SAR), Kelly's Ratio (KR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), and Magnesium Adsorption Ratio (MAR), and other measures were used to evaluate the water quality index for irrigation appropriateness. The United States Salinity Laboratory (USSL) and Wilcox diagrams were used to classify the water quality. The values found in the region were 1.85 to 39.35% for SSP, 0.08 to 1.37% for SAR, 31.7 to 60% for MAR, 0.0 to 5.545% for RSC, 0.33 to 2.36% for PI and 0.01 to 0.52% for KR. These values show that, except for April 2008 and April 2011, the Bharalu River water is suitable for irrigation. The finding revealed that in the study area, Residual sodium carbonate has the greatest (Singh *et al.* 2020). In the Mothkur region, the drinking and irrigation water suitability was assessed. pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^-), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+) were measured in 25 groundwater and 5 surface water samples. The analytical data were compared using WHO and BIS standards. The findings showed that the concentration of F^-, TDS, TH and Cl^- in ground- water samples unfit for human consumption are 32%, 20%, 28% and 4% respectively. Multivariate graphical methods that used the US Salinity Laboratory Diagram, Wilcox diagram, SAR, NA%, and RSC showed that most groundwater samples were suitable for irrigation (Sakram and Adimalla 2018). The quality of the Ganga from Rishikesh to Prayagraj was assessed using quality indicators from July 2019 to December

2019. The suitability of ground water for agricultural use was assessed using several physico-chemical parameters including pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Electrical conductivity (EC), and elements like Sodium Adsorption Ratio (SAR), Kelley's Ratio (KR), and Soluble Sodium Percentage (SSP). pH ranged from 132.6 to 520.4 micro Mohs/cm (µS/cm), Total dissolved solids (TDS) ranged from 86.2 to 338.4 mg/L, Salinity ranged from 0.06 to 0.26 g/L and dissolved oxygen content varied from 10.9 to 12.5 mg/L. Sodium content ranged from 12.7 to 75.8 mg/L, Potassium varied from 2.8 to 8.9 mg/L, magnesium varied from 6.3 to 21.5 mg/l. Every sample is within the maximum allowable limit set by BIS (2012). The greater conductivity and sodium-ion levels indicate that the agriculture practices of the Kanpur and Prayagraj regions involved the overuse of chemical fertilizers. Good quality water for irrigation is indicated by 97% of groundwater samples having a KR value less than 1 and 97% of samples having an SSP value less than 50. The SAR value varied from 0.2 to 4.01, showing that groundwater is in an excellent category for irrigation while only 3% of samples had an SPP value greater than 50, indicating unsuitability (Goswami *et al.* 2021).

Safidon is a tehsil of Jind district in Haryana (Fig. 1). It is located at 29˚24′21.84″N and 76˚39′41.35″E with an elevation of 221 meters above mean sea level. It is located at the center of Panipat and Jind District in Haryana, India. Situated at the bank of the Western Yamuna canal, the total area of Safidon tehsil is 489.33 km^2 including 475.45 km^2 of rural area and 13.88 km^2 of urban areas. Safidon Tehsil, which is the 35th Haryana Vidhan Sabha constituency, has 70 villages. There are 2 towns in Safidon named Safidon Municipal Committee which has a 34,728 total population and Bhuran Census Town which has a 5,603 population (Census of India 2011). Safidon

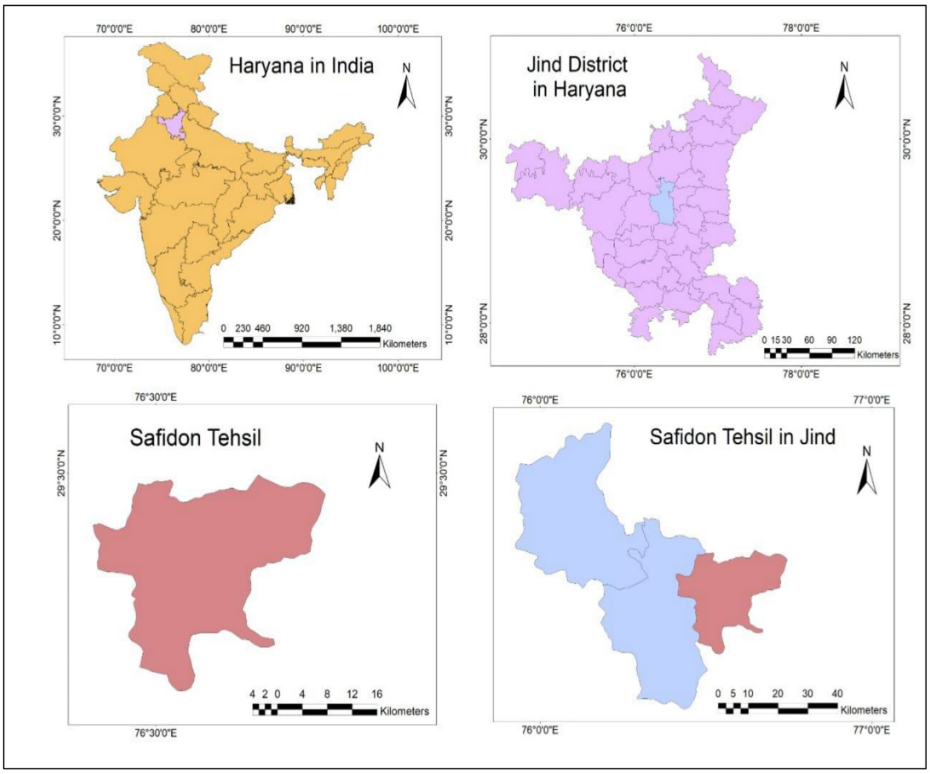

Fig. 1. The locational aspect of Safidon tehsil, Haryana.

is a tehsil, situated in the Jind district of Haryana and has an agro-based economy. Irrigation is one of the most important inputs for efficient and sustainable agricultural production.

MATERIALS AND METHODS

To assess the irrigation appropriateness, 76 samples from different locations of Safidon tehsil were collected. The random sampling method was used to acquire data. 1 L of the sample is taken and placed in dark-colored bottles first cleaned with distilled water. After data collection, the samples were analyzed in the Environmental Laboratory of Banasthali Vidyapith. The analyzed parameters included three cations (Na^+, Mg_2^+, Ca_2^+) and four anions (HCO_3^-, CO_3^-, Cl^- and SO_4^{2-}). The Sodium (Na^+) estimation is based on Spectroscopy using a Flame Photometer. Calcium (Ca_2^+) and Magnesium (Mg_2^+) were analyzed by Titration method using standard Ethylene Diamine Tetra Acid (EDTA). Carbonate (CO_3^-) and Bicarbonate (HCO_3^-) were determined by titrating them against standard sulphuric acid (H_2SO_4) using methyl orange and phenolphthalein. The Sulphate (SO_4^{2-}) will be analyzed by Spectrophotometer and Calcium (Cl^-) by titration method using potassium chromate and silver nitrate. By using Residual Sodium Carbonate (Raghunath 1987), Permeability Index (Doneen 1964), and Potential Salinity (Doneen 1964) the water suitability for irrigation purposes in the study area will be calculated. The following equations will calculate the parameters:

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \qquad \text{Equation (1)}$$

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

$$PS = Cl^- + (0.5 \times SO_4^{2-}) \qquad \text{Equation (3)}$$

Finding the unknown values that are located between the known data points is the process of interpolation. Its primary use is to predict unknown values for any data point related to geography. The inverse distance weighted method shall be used as an interpolation method. Arc GIS 10.4.1 software shall be used to interpolate the water sample data in the non-sampled portion of the Safidon tehsil.

RESULTS

For the data analysis of water suitability for irrigation purposes total of 76 samples were collected from Safidon tehsil from different sites. The results are presented in Table 1 and Irrigational Suitability Assessment is presented in Table 2.

Table 1. Irrigational suitability assessment - RSC, PS and PI.

Sample no.	Residual sodium carbonate	Potential salinity	Permeability index
1	-275	24.71	20.18
2	-349	46.43	14.00
3	-246	48.72	34.31
4	-293	66.75	28.79
5	-189	62.40	35.36
6	-372	125.83	24.53
7	-403	127.96	24.32
8	-245	65.77	32.89
9	-234	200.49	56.72
10	-323	535.87	23.55
11	-189	227.03	61.24
12	-385	302.17	53.43
13	-416	176.33	24.11
14	-433	119.04	21.72
15	-306	140.67	29.79
16	-315	209.35	55.53
17	-284	150.60	51.87
18	-310	137.80	29.53
19	-308	148.05	29.87
20	-453	153.80	21.03
21	-281	56.51	31.88
22	-467	93.13	20.47
23	-81	88.88	69.41
24	-336	58.31	27.99
25	-170	62.91	44.81
26	-334	69.87	27.78
27	-277	53.48	24.43
28	-481	143.04	21.30
29	-422	233.09	48.53
30	-341	303.81	55.31
31	-611	189.99	48.26
32	-286	67.16	31.44
33	-208	89.12	41.70
34	-232	88.46	59.52
35	-190	74.78	41.02
36	-167	105.19	48.33
37	-197	256.04	69.55
38	-93	186.47	76.46
39	-435	434.36	48.98
40	-718	706.14	33.65
41	-1190	1244.65	35.92

Table 1. Continued.

Sample no.	Residual sodium carbonate	Potential salinity	Permeability index
42	-182	312.61	67.54
43	-135	231.89	72.05
44	-352	490.11	59.50
45	-306	55.28	28.67
46	-255	32.49	36.70
47	-349	60.29	23.30
48	-218	31.02	30.98
49	-292	53.97	30.53
50	-249	57.82	34.87
51	-217	57.66	38.07
52	-321	50.53	17.55
53	-372	91.75	21.20
54	-345	76.91	23.02
55	-153	69.22	45.30
56	-242	87.98	31.20
57	-215	66.43	25.40
58	-267	258.11	58.74
59	-298	260.15	29.52
60	-383	294.83	25.75
61	-635	568.19	38.54
62	-300	295.55	56.25
63	-375	197.14	43.97
64	-203	128.38	52.63
65	-361	184.03	53.00
66	-96	458.29	54.87
67	-460	419.29	39.33
68	-193	134.95	61.02
69	-162	93.56	46.00
70	-192	184.76	65.28
71	-277	68.22	51.76
72	-294	138.37	53.74
73	-220	311.28	63.85
74	-253	171.14	60.34
75	-386	313.49	48.32
76	-276	258.16	31.27

Table 2. Statistical analysis of groundwater samples.

Parameters	Mean	Median	St Deviation	Minimum	Maximum
RSC	-311.57	-292.5	153.91	-1190	-279.5
PS	187.35	136.38	184.49	24.71	1244.65
PI	40.78	31.27	15.54	14	76.46

DISCUSSION

Residual sodium carbonate (RSC) - SAR measures the alkali or sodium hazard to crops and is an important parameter for determining irrigational suitability. RSC evaluates the sodium permeability hazard which considers the bicarbonate/carbonate and calcium/magnesium concentrations in irrigation water. All the samples lie in the Good category with a negative value (Table 3). The negative value shows little risk of sodium accumulation because the amounts of calcium and magnesium are balanced.

Table 3. Residual sodium carbonate and irrigational suitability.

Water suitability based on RSC (Richards 1954)	Category	Percent of sample
<1.25	Good	100%
1.25–2.5	Doubtful	Nil
>2.5	Unsuitable	Nil

Table 4. Potential salinity and irrigational suitability.

Water suitability based on PS (Doneen 1964)	Category	Percent of sample
<3	Suitable	0%
>3	Unsuitable	100%

Table 5. Permeability index and irrigational suitability.

Water suitability for irrigation based on PI values (Doneen 1964)	Category	Percent of sample
<75	Suitable	99%
>75	Unsuitable	1%

In Fig. 2 the spatial distribution of RSC levels in Safidon tehsil, using the Inverse Distance Weighted Method. The green zones show the low RSC value in the southwest and west regions while high RSC values are seen in the northeast and southeast areas of the tehsil shown by pink and brown zones. On the other hand, moderate values are seen in the central regions.

Potential salinity (PS) - The concentration of highly soluble salts increases the salinity. After analysis of the samples, it was found that the value of potential salinity is greater than 3 which indicates the unsuitable water quality for irrigation (Table 4).

Figure 3 shows that high PS values are seen in the southwest and western areas shown by green shades while moderate to high salinity is seen in the central

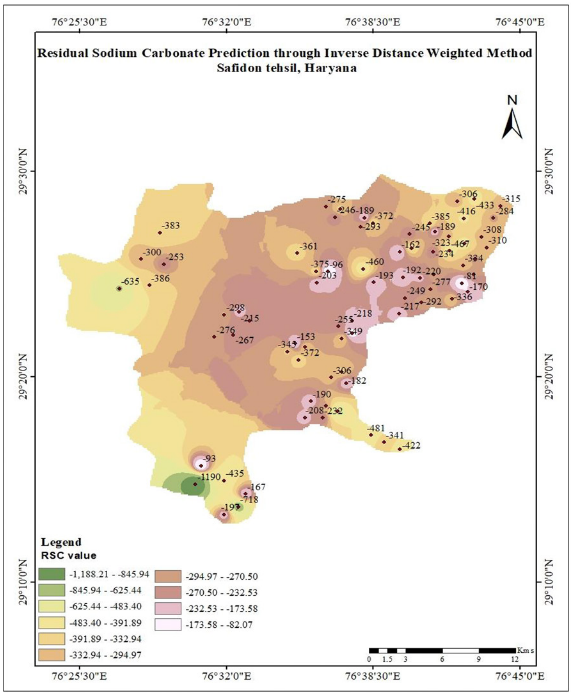

Fig. 2. Residual sodium carbonate predictive map.

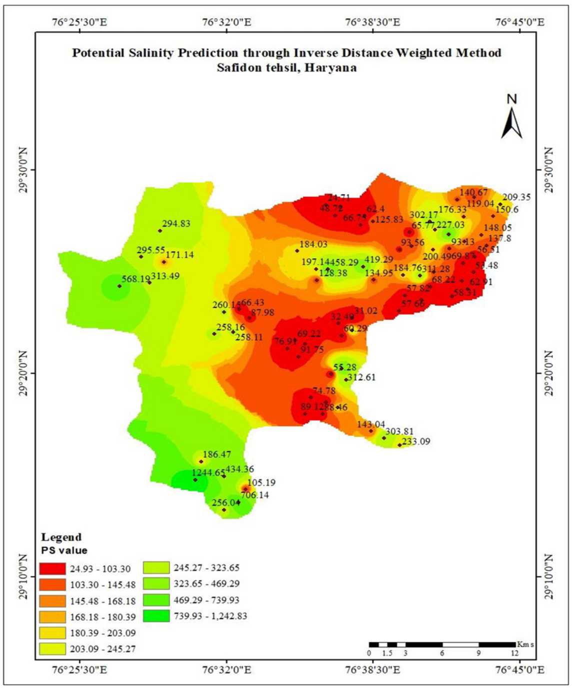

Fig. 3. Potential salinity predictive map.

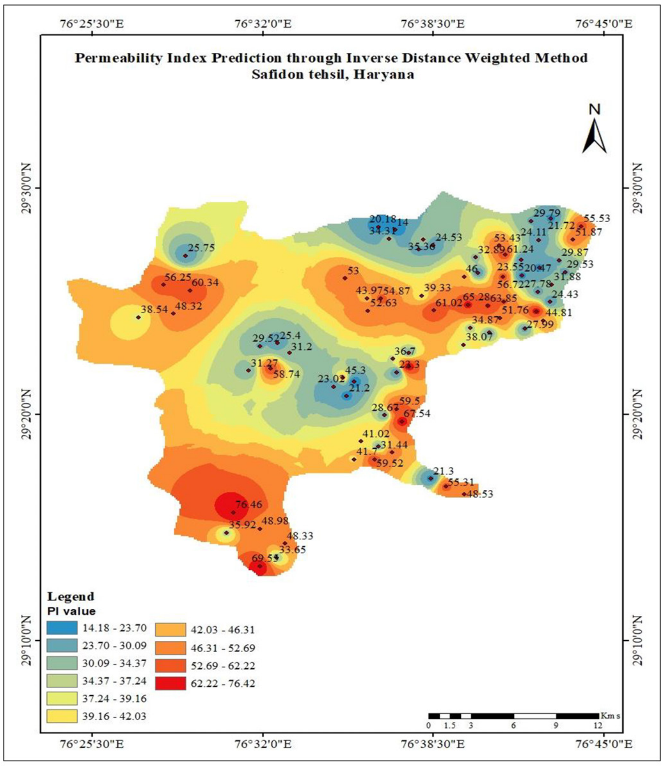

Fig. 4. Permeability index predictive map.

region represented by orange and yellow zones. Red and orange zones show very low to moderate salinity in the north-eastern area of the tehsil.

Permeability index (PI) - PI measures how fast the irrigation water moves through the soil. The value of the Permeability Index lies between "14-76.46". 99% of the sample is less than 75 and suitable for irrigation purposes and only 1% of the sample is more than 75 and indicates unsuitable water quality for irrigation (Table 5).

In Fig. 4 Red/dark orange zones show the highly suitable regions found in the central and southern parts while yellow to orange zones show the areas that were moderately suitable area. Northernmost and southernmost areas were unsuitable or less suitable for irrigation dominated by blue to green zones.

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