Irrigation mapping of Man River Basin of Akola and Buldhana District, (MH) using Spatial Interpolation techniques

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Abstract: The water samples were collected from Man river basin in Akola and Buldhana District of Maharashtra India during June 2013 to assess its suitability for drinking, irrigation, usages using various indices. A detailed geochemical study of groundwater region is described, and the origin of the chemical composition of groundwater has been qualitatively evaluated, using observations over a period of one seasons pre monsoon (June) in the year of 2013. To attempt this goal, samples were analyzed for various irrigation parameters such as Residual sodium carbonate (RSC), Sodium adsorption ratio (SAR), Permeability index (PI) etc. Gibbs boomerang exhibits most of the samples mainly controlled by evaporation and weathering process sector in both seasons. Irrigation status of the groundwater samples indicates that it was moderately suitable for agricultural purpose. ArcGIS10.1 software was used for the generation of various thematic maps and the final groundwater quality map. An interpolation technique inverse distance weighting was used to obtain the spatial distribution of groundwater quality parameters. The final map classified the ground quality in the study area.

Keywords:*GIS, Interpolation, Groundwater quality, IDW,irrigation parameter.*

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I. INTRODUCTION

The continuous circulation of water between ocean, atmosphere, and land is called the hydrologic cycle. The hydrologic cycle can be viewed as a major machine on the planet, controlling distribution of water on the earth. Groundwater is one of the major links in the hydrologic cycle. Groundwater forms the invisible, subsurface part of natural hydrological cycle. Inflow to the hydrologic system arrives as precipitation, in the form of rainfall or snowmelt. Outflow takes place as stream flow or runoff and as evapotranspiration, a combination of evaporation from bodies of water, evaporation from soil surfaces, and transpiration is delivered to streams both on the land surface, as overland flow tributary channels; and by subsurface flow routes, as inter flow and base flow following infiltration into the soil (Freeze & Cherry, 1979). Groundwater quality is mainly affected by the geological formations that the water passes through its course and by anthropogenic activities (Kelepertsis2000; Siegel 2002; Stamatis 2010; Sullivan et al. 2005).The study areais situated in Akola and Buldhana Districts, Maharashtra which is located between 20°54′ 59” N latitude and 76° 41’23’’ E longitude. Man River is the main tributary of Purna River. In some cases, natural water may contain elevated concentrations of several potentially toxic elements or microbiological contaminants that may lead to adverse effects on human health (De Figueiredo et al. 2007; Kelepertsis et al. 2006; USEPA 2001, 2006; WHO 2004; Yang et al. 2002). Because of the long coastline of the India and the overexploitation of groundwater, saline water intrusion has also become an important problem (Daskalaki and Voudouris 2008; Mimikou 2005; Sofios et al. 2008; Voudouris et al. 2004).

In the present study the available physiochemical data of 45 locations of the various tehsils of district Akola and Buldhana, was used, the data was obtained from Central ground water authorities of concerned districts. The physiochemical data contained the information about various water quality determining factors. The data was digitized and put up in ArcGIS 10.00 Software for Spatial Interpolation and based on previous experience most commonly used interpolation methods viz; Inverse Distance Weighted (IDW) and nearest Neighbor were applied to the above data for generation of continuous raster surface for studying the influence of each interpolation technique and best judging which interpolation technique is best. The aim of this study was to evaluate the potential of the groundwater to cause crop problems through toxicity, salinity and soil infiltration rate for determining the suitability of groundwater for sprinkler irrigation uses. For this, the spatial variability of groundwater quality parameters was investigated using Geostatistical tools. Ordinary and indicator IDW were usedto map the spatial distribution and the probability ofexceeding a critical threshold for some water contaminants. Through this study it is hoped that basic Interpolation method needed to study the water quality of this area further in future has been generated.

II. STUDY AREA

The Man river basin is situated in Akola and Buldhana Districts, Maharashtra which is located between 20°54′ 59” N latitude and 76° 41’23’’ E longitude. The study area is covered by Survey of India toposheets55D/7, 55D/9, 55D/11, 55D/13, 55D/14 and 55D/15 on 1:50,000 scale. The study area is occupied by alluvium and Deccan basalts

which are horizontally disposed and is traversed by well-developed sets of joints. (Fig.1)

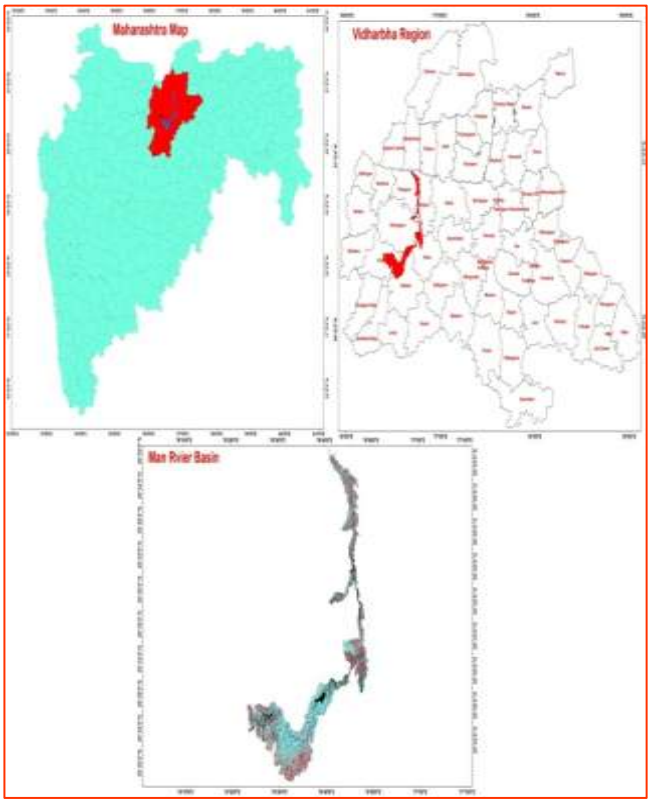

Figure1. Location Map of Man River Basin

III. METHODOLOGY

Groundwater sampling and measurement pre monsoon samples were collected from 45 locations (Fig.1). The GARMIN GPS was used to locate the exact coordinates of the sample collection to continuous monitoring purposes. Groundwater samples were collected from 25 dug well and 20 bore well during pre-monsoon (June) in the year of 2013.Methods of collection and analysis of water samples followed are essentially the sameas given by (APHA 1998). Samples were collected in one liter capacity polyethylene bottles. Prior to the collection,bottles were thoroughly washed with diluted HNO3 acidand then with distilled water in the laboratory before fillingbottles with samples. Each bottle was rinsed to avoid anypossible contamination in the bottling, and every otherprecautionary measure was taken. Groundwater samples were analyzed for chemical parameters including pH, Na, Cl-, HCO3-, electrical conductivity (EC) and sodium absorption ratio (SAR) by adapting the standard procedures of water analysis. The evaluation of water quality is a fundamental requirement for implementation of modern irrigation systems. Richards (USSL 1954) proposed a table for the classification of irrigation water based on EC and SAR. He also presented a diagram for the classification of irrigation water. Today there are many other ways for the classification of irrigation water but generally, the specified limit for all of these methods is nearly identical. One of the important water quality standards for the sprinkler irrigation systems is provided by Ayers and Westcott (1994). Then the groundwater ancillary data and the spatial data (co-ordinates) which were collected with the help of GPS were joined in the ArcGIS 10.00 software. After linking the spatial and non-spatial data the groundwater quality point layer was generated for further analysis. Later on the other analysis was carried out using the IDW (Inverse Distance Weighted) in Geographic information system environment using the Arc Map software. Interpolation creates a continuous (or prediction) surface from sampled point values. The continuous surface representation of a raster dataset represents height, concentration, or magnitude for example, elevation, pollution, or noise. Interpolation makes predictions from sample measurements for all locations in a raster dataset whether or not a measurement has been taken at the location. In the present data analysis we used IDW (Inverse distance weighted) interpolation technique.

IV. RESULTS AND DISCUSSION

A. Classification based on water use criteria

Groundwater is normally classified depending upon limitations of toxicological and ecological effects of dissolved substances for different purposes, such as domestic, agricultural and industrial etc. The suitability of groundwater in the Man river basin for various purposes is as follows:

B. Drinking water quality standards

To assess the suitability of groundwater for drinking and public health purposes, hydro geochemical parameter of groundwater of the study area are compared with guideline values recommended by World Health Organization (WHO, 1996). The groundwater has partial suitability for drinking purpose and public health because the hardness of groundwater sometimes exceeds the admissible limit.

C. Agriculture water Quality Standard

Groundwater plays an important role in Indian agriculture. A good quality of water has the potential to cause better yield under good soil and water management practices. The suitability of water depends upon many factors including the quality of water soil type, salt tolerance characteristic of the plant climate and drainage characteristic of soil, the average values of irrigation water quality parameters in the study area given in (Table.1).

Table 1.Parameters of Irrigation Ground Water Quality Pre Monsoon 2013.

Sr	Village	Wel	EC	SA	RS	Na	PI

NO.	Name	l No.	µs/cm	R mg/l	C mg/l	%	
1	Hingaonnimba	4	987	0.33	-6.56	15.2	19.14
2	Wajegaon	5	1414	1	-1.56	36.8	28.97
3	Nimba	7	987	0.73	-3.41	19.2	25.63
4	Kavtha	9	823	1.74	-5.58	31	36.92
5	Lohara	12	902	0.98	-6.67	29.8	29.86
6	Dongargaon	18	902	1.02	-5.28	24.6	32.28
7	Songiri	20	905	1.62	-5.88	30.4	36.4
8	KalambiMahagaon	23	824	1.45	-7.3	26.9	32.41
9	Manarkhed	27	913	0.84	-7.68	18.9	24.75
10	Kasarkhed	30	875	0.72	-5.5	20.8	28.26
11	Mandwabudruk	34	841	0.91	-4.93	20.7	27.28
12	BatwadiBudruk	38	987	1.41	-1.82	24.7	29.99
13	Sangola	41	978	0.63	-6.05	17	24
14	Chatari	45	905	0.63	-3.76	16.1	22.95
15	Pimpridhangar	53	857	3.41	-2.41	59.2	63.2
16	Uti	54	789	5.02	-3.67	64.4	62.36
17	Pardi	55	1500	4.48	-3.17	57.4	53.6
18	Hiwrakhurd	56	899	1.17	-0.21	51.6	40.07
19	Isoli	57	1200	1.83	-1.18	36.2	43.76
20	Karkhed	58	1006	1.68	-4.57	36.8	37.28
21	Ainkhed	66	894	1.06	2.01	42.4	35.13
22	Amdapur	69	987	0.64	-4.06	18.5	26.84
23	Kawhaia	71	879	1.42	-2.75	28.6	34.75
24	Mohadari	72	789	0.63	-5.88	21.7	21.11
25	DhatraNaik	75	956	0.26	-9.06	7.7	12.66
26	Wadali	78	645	0.5	-9.47	11.3	17.05
27	Sirla	80	789	0.31	-0.01	10.8	18.47
28	Shahapur	82	601	0.85	-8.31	18.7	23.75
29	Dastapur	85	546	1.42	-8.85	26.6	29.94
30	Loni	88	687	1.13	-0.9	29	38.13
31	Lavkhed	91	489	1.49	-1.11	28.9	35.78
32	TulangaKhurd	93	320	0.28	-8.51	9.1	14.85
33	Tandi	95	823	0.63	-7.35	16	21.07
34	Pimpalgaon	97	546	1	0.24	23.3	32
35	Modhapur	99	325	1.69	-3.82	32.8	39.01
36	Satargaon	102	359	0.3	-	9.5	16.8
					7.11		8
37	Ghui	105	456	1.48	-2.24	30.3	37.02
38	Manegaon	111	325	0.86	-8.36	18	24.23
39	Jhadegaon	113	312	0.86	-8.33	18.7	24.18
40	Palodi	115	589	0.3	-6.99	9.9	17.15
41	Padsul	121	356	0.64	-4.85	19.1	26.52
42	GolegaonKhurd	125	879	1	-4.1	22.8	31.26
43	Manasgaon	127	879	0.43	-14	9.8	12.9
44	Nimbi	129	564	1.96	2.92	39.7	48.12
45	Nimkhed	130	693	0.9	-4	20.8	26.67

V. IRRIGATION WATER QUALITY STANDARDS

A. Electrical conductivity

The Ec distribution in groundwater of the area ranges from 310 to 1586 ms/cm at 25°c. Classification of groundwater for irrigation depends upon EC value as suggested by Wilcox, (1955) Table 2. The groundwater of the study area is good to permissible.

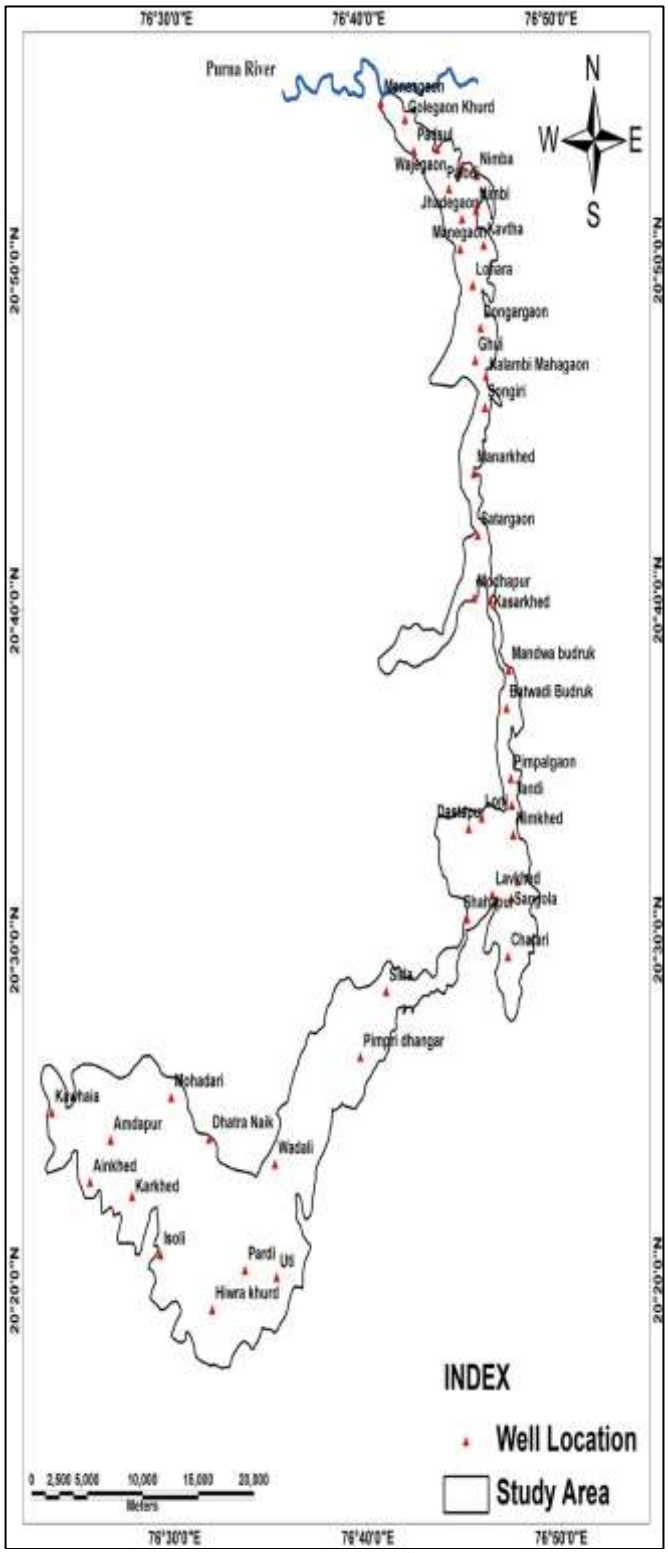

Figure 2.Well Location Map of Study Area

Table 2. Irrigation groundwater classification based on Ec (Wilcox 1955).

EC x 10^6 us /c mat 25^0c	Water quality
< 250	Excellent
250 – 750	Good
750 – 2000	Permissible
2000 - 3000	Doubtful
>3000	Unsuitable

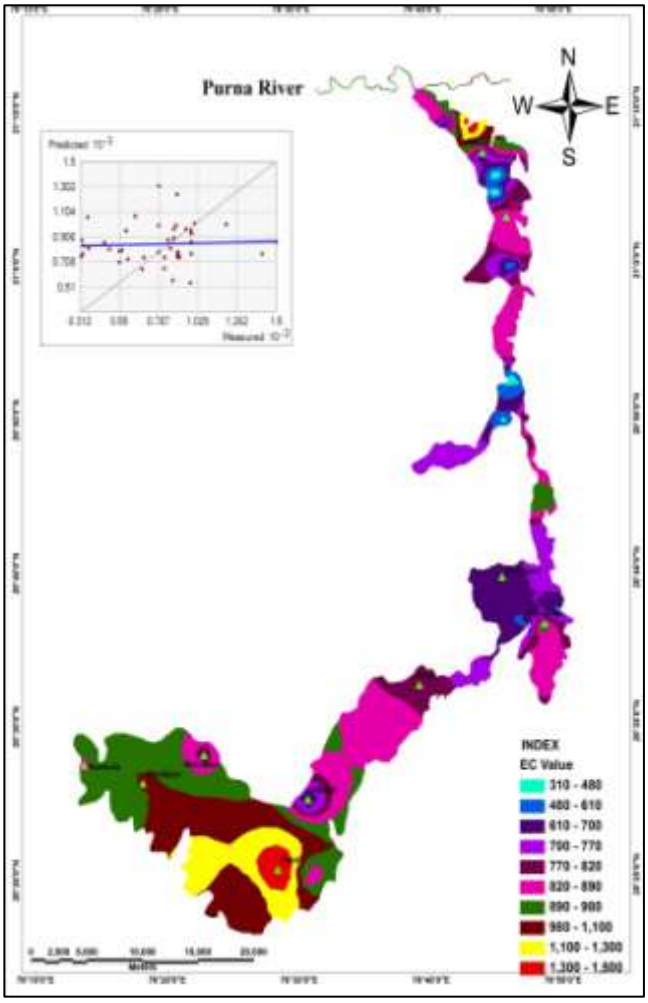

Figure 3. Spatial Distributions of EC (µs/CM) PRE-2013

B. Sodium Adsorption ratio

The Sodium or alkali hazard in the use of irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). EC and sodium concentration are very important in classifying irrigation water. The plot of analytical data on the Wilcox (1955) diagram related to EC and sodium percent indicates (Fig.4) that the shallow ground waters are excellent to good quality. The sodium adsorption ratio (SAR) parameter evaluates the sodium hazard in relation to calcium and magnesium concentrations. The United States of Salinity diagram of the water is based on the EC and the sodium adsorption ratio (SAR). SAR is an important parameter for determination of suitability of irrigation water because it isresponsible for sodium hazards. A simple method of calculation of sodium is the Sodium AdsorptionRaho (SAR) & the equation is-

$$\Sigma AP = \frac{Na}{[\,(Ca + Mg)\,/2\,]\,0.5}$$

The SAR value in the study area ranges from 0.18 to 94which implies that no alkali hazard is anticipitated in the study area and according to the quality classification of water for irrigation depending upon SAR after Raghunath, (1987) the water is of excellent to good quality. The higher

values for pre 2013 are observed in Pardi and Pimparidhangar villages of study area.

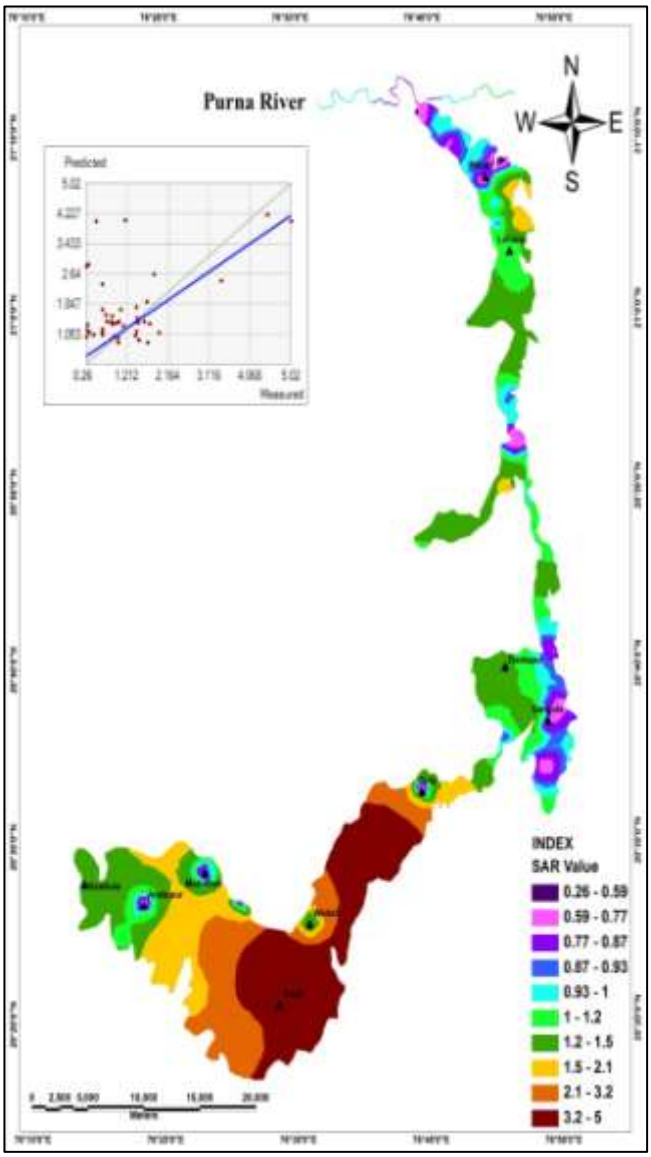

Figure 4. Spatial Distribution of SAR (Mg/L) Pre-2013

C. .Integrated Effect of EC and SAR

The SAR and EC value of the groundwater of the study area for pre monsoon period were plotted on the graphical diagram of irrigation water USDA, (1955) (Fig.5). The diagram shows that most of the water samples fall in the field of C_2S_1 and C_3S_1 in pre monsoon 2013 and one sample fall in C_3S_2 (2013) and two sample is in C_3S_3 Fig.5. The samples fall in C_2S_1 and C_3S_1 field indicate that medium to high salinity and low alkalinity water which can be used for irrigation for almost all soil with little level of development of harmful level of exchangeable sodium. The samples fall in C_3S_2field indicating high salinity and medium alkali hazards which restrict it suitability for irrigation, especially in soil with restricted drainage Karanth, (1987).

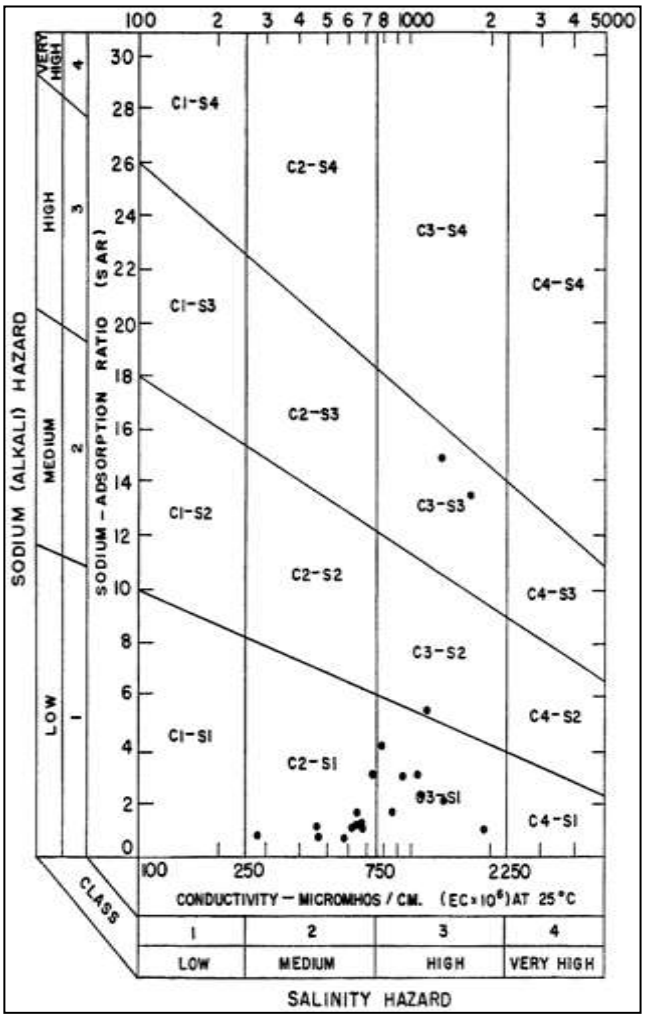

Figure 5.Rating of Water In Relation To Salinity and Sodium Hazard of Man River Basin(After U.S.S. Lab, 1954)

D. *Sodium percentage Ratio (Na %)*

It is calculated by -

$$N\alpha\ \% = \frac{N\alpha + K}{X\alpha + M\gamma + N\alpha + K} \xi\ 100$$

Where the concentration are reported in meq/1

The sodium percentage (Na %) in the study area range between 7 to 64 **%**. According to quality classification of irrigation water depending upon the Na % as proposed by Wilcox, (1955) the groundwater of the study area is good to permissible quality (Fig.6). The distribution of sodium % is shown on the map, for pre 2013, higher values are recorded in Pardi, PimpariDhangar villages of the basin, while lower values are observed in Nimba, Manarkhed, Jambi villages of the basin.

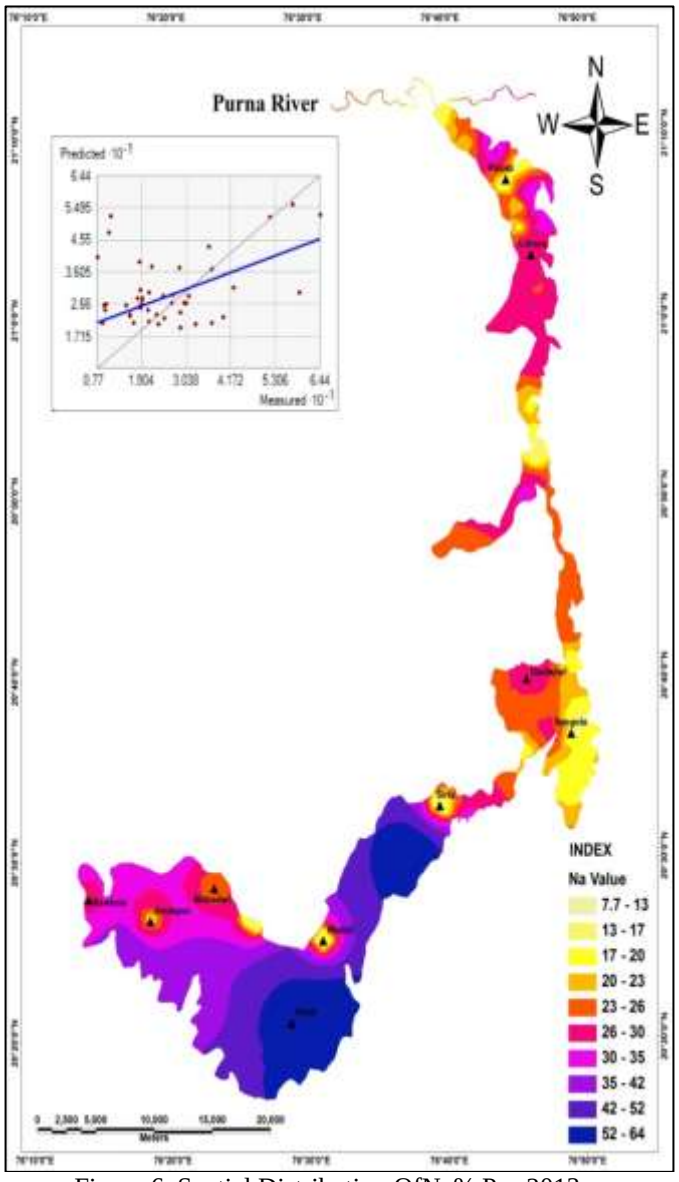

Figure 6. Spatial Distribution OfNa% Pre-2013

E. Doneen's Permeability Index.

The long term use of water affects the soil permeability. It is affected by Na, Ca, Mg and HCO_3 content of soil. Donne, (1962) has evolved criteria for ascertaining the quality of water for irrigation based permeability index (PI)

$$III = \frac{N\alpha + (HXO_3)^{0.5}}{(X\alpha + M\gamma + N\alpha)} \xi 100$$

The groundwater samples of the study area fall in class – I in Donne's chart Domenoco and Schwartz, (1990) which implies that groundwater is of good quality for irrigation purpose as per the permeability index is concerned. The distribution of PI values for pre 2013 found to be higher in Pardi, PipariDhangar, Sirla&Manasgaon villages lower values obtain in Mohadari village of the basin.

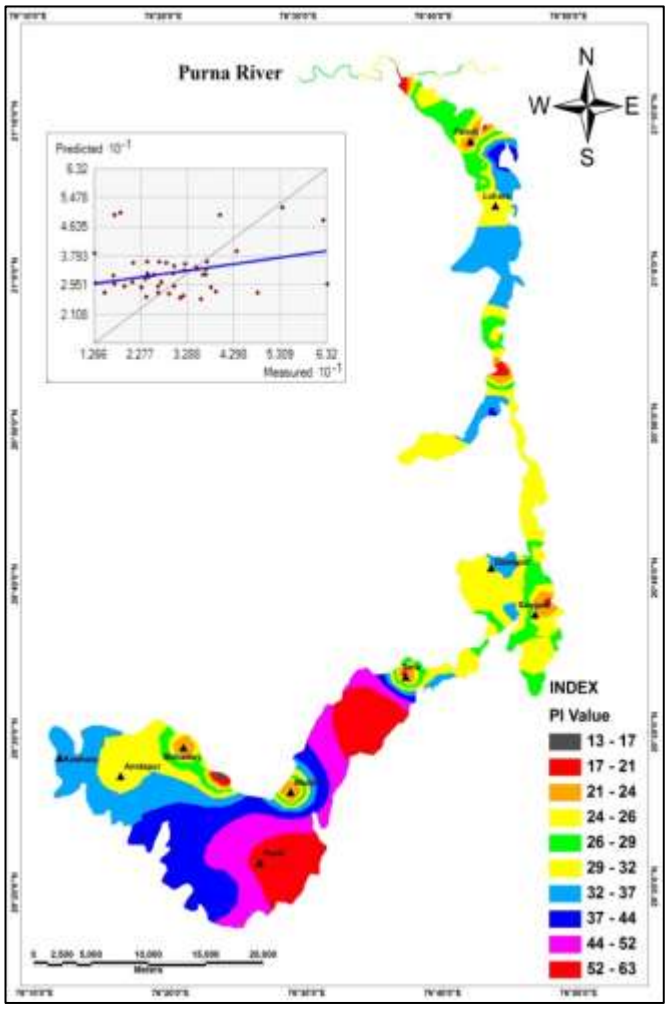

Figure 7. Spatial Distribution of Pi% Pre-2013

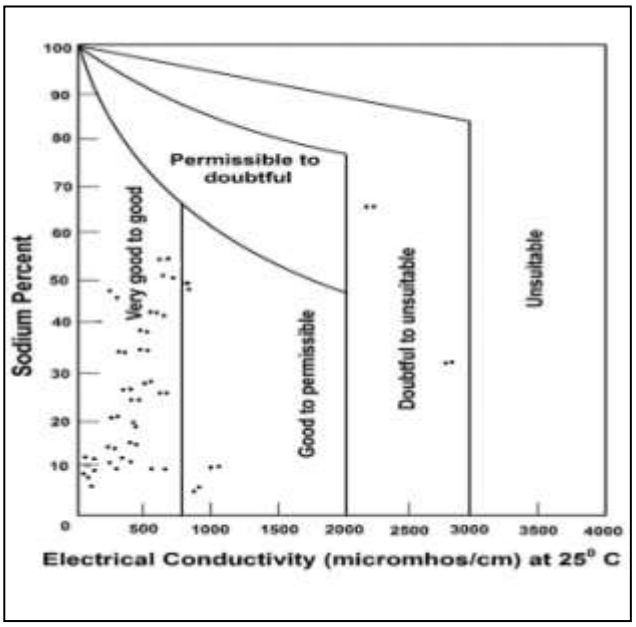

Figure8. Irrigation Quality Parameters for the study area

VI. CONCLUSION

A procedure that integrates the traditional groundwater sampling analysis methods and GIS capabilities combined with conditional overlaying techniques was adapted in order to locate the suitable areas at the lower Mahesh river Basin groundwater aquifer for drinking purposes. All analytical results compared with WHO, BIS standards and classified as desirable and undesirable groundwater in both seasons.A procedure that integrates the traditional groundwater sampling analysis methods and GIS capabilities combined with conditional overlaying techniques was adapted in order to locate the suitable areas at the Man river basin for drinking purposes. All analytical results compared with WHO, ISI standards. For the season of premonsoon, the highest concentrations of ions were observed southern side, the range of EC is 310 to 1500, SAR 0.25 to 5, Na 7.7 to 64 and the PI ranges from 13 to 63, the rating of water in relation to salinity and sodium hazard of Man River basin diagram shows that the highest value of ion which are present in C_2-S_1 and C_3-S_1.The irrigation quality parameter for study area is very good to good.Thus, the use of groundwater for irrigation in these areaswill damage crops and reduce yield. However, more tolerablecrops could be cultivated with a good drainagesystem installation to prevent soil salinization. Theresults of this study show that a combined utilization ofgeostatistics and GIS can be useful in decision-makingprocesses such as identifying suitable areas for implementationof the sprinkler irrigation systems and reducingthe risk of losing the national capital.

VI. ACKNOWLEDGMENT

The authors are thankful to the Hon'ble Vice-Chancellor, SGB Amravati University for providing the necessary research facilities

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