ASSESSMENT OF GROUND WATER QUALITY FOR IRRIGATION SUITABILITY IN SOUTH SINDHUDURG DISTRICT USING GIS TECHNOLOGY

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ABSTRACT

The present study was conducted to evaluate the groundwater quality parameters and prepare the spatial distribution maps for south Sindhudurg district through the Geographical Information System (GIS). In South Sindhudurg district, some villages face water scarcity during summer months in spite of heavy rainfall. Therefore, all the agricultural as well as domestic need of water are fulfilled by using groundwater. The Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP), Percent Sodium (%Na), Permeability Index (PI) were analysed for five years in this study. The IDW technique was used to prepare the geospatial distribution maps of ground water parameters which will beneficial for deciding the water quality status. The groundwater status of south Sindhudurg good for irrigation purpose. The results SAR, RSC, SSP, PI, and % Na implying that the 100% of the groundwater fall under excellent to good category.

Keywords: Groundwater quality, Irrigation, Geographical Information System, Spatial Distribution Map.

1. INTRODUCTION

The water is the fundamental constituent of about all the customs of life and it is chiefly achieved through two sources, i.e., surface water which includes streams, canals as well as fresh water lakes, rivers, etc. and ground water like borehole water and well water (Hasan *et al*. 2017). About 71% of the Earth's surface is covered by water, still there is a severe crisis of freshwater for drinking, agriculture and industries because 97% water on the earth is salt water in the form of seas and oceans, about 2% water is glaciers in the polar region, and remaining 1% is a form of stream channels and groundwater (WWAP 2009). This shows that the greater part of the Earth's water is saline. However, not all water available may be suitable for human consumption as well as human activities like irrigation of crops, fish farming or even all agricultural activities.

Groundwater is used for domestic and industrial water supply and irrigation all over the world. Groundwater has gained great global importance due to the need it of use in various purposes like agricultural, industrial and domestic. Many reports indicate that more than 33% of human water needs and more than 50% of drinking water needs in villages around the world are provided by groundwater and the world's food that produced by irrigation depends on groundwater by 40% (Al-Sudani and H.I.Z. 2019). Whenever groundwater is used as irrigation water, the quality is important for successful crop production. The poor quality of the irrigation water may affect crop yields and soil also. Therefore, water quality analysis is one of the most important aspects in groundwater studies. Groundwater salinity is a growing problem in several Indian states particularly in coastal areas where previously sweet (fresh) groundwater sources are becoming saline due to overexploitation.

The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. The Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP), Percent Sodium (%Na), Permeability Index (PI) are the most important quality criteria, which influence the water quality and its suitability for irrigation. Hence water quality is a very sensitive and important for long-term economic development and environmental sustainability.

In recent years, the assessment and monitoring of groundwater quality on a regular basis is being carried out using Geographic Information System (GIS) technique added with the IDW interpolation method and has widely adopted as a powerful tool for evaluating and analysing spatial information of water resources. It is an economically feasible and time saving technique for transforming huge data sets to generate various spatial distribution maps.

The intention of the study is to assess the groundwater quality for irrigational suitability in south Sindhudurg district. To estimate the spatial distribution of the water quality parameters, Inverse Distance Weighed spatial interpolation technique was used.

2. MATERIAL AND METHODS

Study area: Sindhudurg district is located in the Konkan region and covers a geographical area of 5207 sq.km. The district is located between north latitude varying from 15°37’ to 16° 40’ and east longitude varies from 73° 19’ to 74° 13’. The district is bounded in the north by Ratnagiri district, west by Arabian Sea and in the east by Kolhapur district and in the south by Goa State and Belgaum district of Karnataka State. The average rainfall is 3650 mm annually. The district falls under the ‘Assured and High Rainfall zone’. The climate is generally humid. The relative humidity during the southwest monsoon is very high (86 to 90%). The relative humidity during winter and summer months is also above 57%. About 40 to 50% of the area in the district is hilly (CGWB, 2014). The study area includes four talukas of the district namely Sawantwadi, Vengurla, Kudal and Dodamarg.

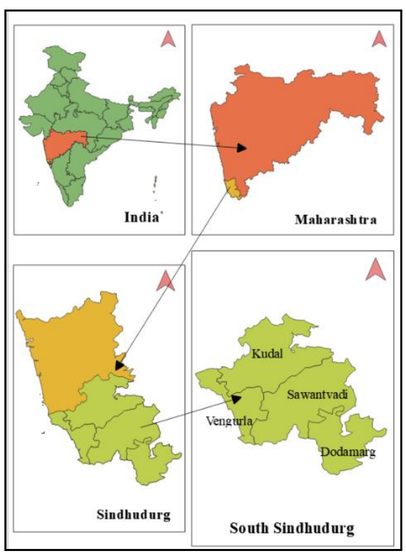

Fig.1. Study area

Input Datasets: Groundwater quality data of year 2016 to 2021 was procured from Groundwater Survey and Development Agency, Sindhudurg.The parameters such as pH, EC, Total Hardness, Alkanity, TDS, Cl, SO_4, Ca, Mg were included in collected data. Figure shows the locations map of the study area.

Groundwater quality parameters for Irrigation suitability: Long term application of water affects the soil property depending upon the quality of water used for irrigation. The characteristics and amount of dissolved salts mainly depend on the water source and its chemical composition. The mostly found dissolved ions in water are calcium (Ca), sodium (Na), magnesium (Mg), sulphate (SO_4) etc. The concentration of these dissolved ions in water are used to determine the suitability of water for irrigation. Suitability of groundwater for irrigation use is evaluated by Residual Sodium Carbonate (RSC), Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Permeability index (PI),Percent Sodium (%Na).

Residual Sodium Carbonate (RSC)

The concentration of bicarbonate and carbonate influences the suitability of water for irrigation purpose. RSC will calculate simply by subtracting the quantity of Ca+ and Mg from sum total of CO_3 and HCO_3 (Eaton 1950) and it expressed in meq/l thus,

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

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio gives a clear idea about the adsorption of Sodium by soil. It is the proportion of sodium to calcium and magnesium which affect the availability of the water to the crop. Sodium adsorption ratio is calculated by the following equation given by Richards (1954),

$$\mathbf{SAR} = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)}}$$

Soluble Sodium Percentage (SSP)

High percentage Sodium water for the irrigation purpose may reduce the plant growth and also reduce soil permeability. Wilcox (1955) has proposed classification scheme for rating irrigation water on the basis of soluble sodium percentage (SSP). The SSP was calculated by using following formula,

$$SSP = \frac{(Na^+ + K^+) \times 100}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)}$$

Where, the concentration of ions is expressed in meq/l.

Percent Sodium (% Na)

Sodium makes chemical bonding with soil to reduce water movement capacity of soil. The Percent Sodium values are calculated by following equation (Todd, 1995),

$$\% \text{ Na} = \frac{Na^{+}}{Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}} \times 100$$

Where, concentration of all ions expressed in meq/l

Permeability Index (PI)

Permeability Index formula developed by Doneen (1964) to assess water movement capability in the soil as the suitability of any kind of source of water for irrigation and it is calculated by using equation,

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

Where, concentration of all ions is expressed in meq/l

Table 1. Irrigation parameters and status of water

Sr. No	Irrigation parameter	Type of water	Source
1	Sodium adsorption ratio		Richards (1954)
	< 10	Excellent	
	10 to 18	Good	
	18 to 26	Permissible	
	> 26	Unsuitable	
2	Residual Sodium carbonate		Eaton (1950)
	< 1.25	Good	
	1.25 to 2.5	Marginal	
	> 2.5	Unsuitable	
3	Soluble sodium percentage		Wilcox (1955) and USDA (1954)
	< 50	Good	
	> 50	Unsafe	
4	Permeability index		Doneen (1964)
	> 75	Good	

	75 to 25	Permissible	
	< 25	Unsuitable	
5	Percent sodium		
	< 60	Suitable	Todd (1995)
	> 60	Unsuitable	

Spatial distribution maps: Spatial analysis extension of GIS allows interpolation of the water quality parameter at unknown location from known values to create a continuous surface which will help us to understand the scenarios of water quality parameter of the study area. Though there are a number of spatial modelling techniques available with respect to application in GIS, spatial interpolation technique through Inverse Distance Weighted (IDW) approach has been used in the present study to making groundwater quality parameters distribution maps as shown in Fig.2

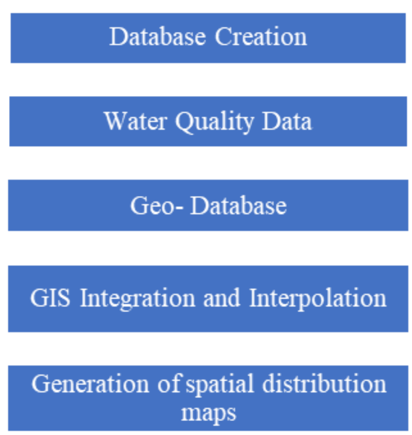

Fig.2. Spatial distribution by IDW interpolation method

3.RESULTS AND DISCUSSION

The calculated parameters such as SAR, SSP, RSC, PI and % Na and their results based on standard classification are given in Table.2

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Table.2 Suitability area of groundwater for irrigation

Parameter	Class	Percent area (km^2)				
		2016-17	**2017-18**	**2018-19**	**2019-20**	**2020-21**
SAR	Excellent	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)
	Good	0.00	0.00	0.00	0.00	0.00
	Permissible	0.00	0.00	0.00	0.00	0.00
	Unsuitable	0.00	0.00	0.00	0.00	0.00
SSP	Good	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)
	Unsafe	0.00	0.00	0.00	0.00	0.00
RSC	Good	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)	100.00 (2488.75)
	Marginal	0.00	0.00	0.00	0.00	0.00
	Unsuitable	0.00	0.00	0.00	0.00	0.00
PI	Unsuitable	0.60 (14.91)	3.27 (81.46)	0.40 (10.05)	0.58 (14.45)	1.08 (26.76)
	Permissible	76.07 (1893.20)	94.64 (2355.24)	92.26 (2296.22)	86.43 (2151.05)	85.54 (2128.79)
	Good	23.33 (580.63)	2.09 (52.04)	7.33 (182.47)	12.99 (323.25)	13.39 (333.19)
%Na	Suitable	99.89 (2486.0)	100.00 (2488.75)	100.00 (2488.75)	99.27 (2470.51)	99.65 (2480.12)
	Unsuitable	0.11 (2.75)	0.00	0.00	0.73 (18.24)	0.35 (8.63)

Legend: SAR – Sodium Absorbtion, SSP – Soluble Sodium Percentage, RSC – Residual Sodium Carbonate, PI – Permeability Index, %Na – Percent Sodium

Groundwater quality parameters status for year 2016-17

The ground water having SAR values less than 10 are excellent, 10 to 18 as good, 18 to 26 as permissible, and above 26 are unsuitable for irrigation use (USDA, 1954). In the present study, the SAR values were less than 10 for year 2016-17 and therefore, it was categorized as excellent for irrigation purpose as depicted in the Fig. 3.

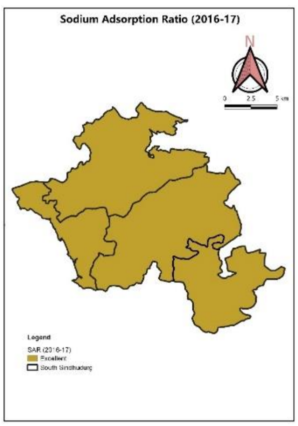
Wilcox (1955) has suggested classification for rating irrigation waters on the basis of soluble sodium percentage (SSP). The values of SSP less than 50 are good quality of water and higher values (i.e. > 50) shows that the water is unsafe for irrigation. Results for year 2016-17 indicated all the SSP values are in good category as shown in Fig 4.

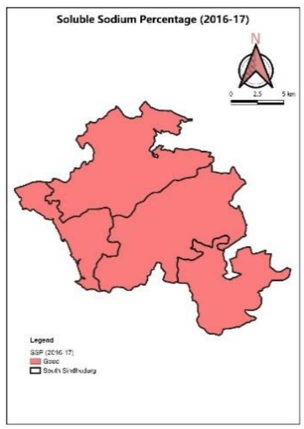
The Residual Sodium Carbonate (RSC) value exceeds 2.5 meq/l, the water is unsuitable for irrigation. If the value of RSC is between 1.25 and 2.5 meq/l, the water is marginally suitable, and value less than 1.25 meq/l indicates good water quality (USDA, 1954). RSC values for study area are less than 1.25 and area under safe limit for irrigation use as depicted in Fig 5.

The waters having Permeability index values less than 25 are unsuitable, 25 to 75 as permissible, and above 75 are good for irrigation use. In the present study, the maximum PI values are between 25 to 75 for year 2016-17 and therefore, it was under permissible limit for irrigation use. Very less that is 0.60 per cent area comes under unsuitable limit as shown in Fig 6.

The waters having Percent sodium values less than 60 are suitable while above 60 are unsuitable for irrigation use. In the present study, the maximum per cent sodium values is less than 60 for year 2016-17 and therefore, it was under suitable limit for irrigation use. Very less that is 0.11 per cent area comes under unsuitable limit as shown in Fig 7.

For all the Five years (2016-2021) spatial distribution maps of water quality parameters were prepared.





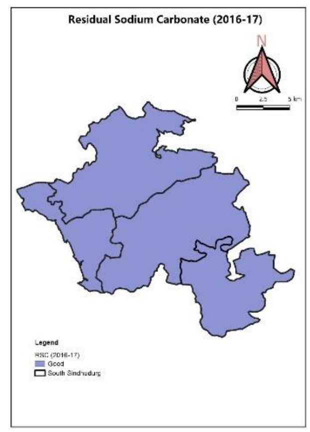
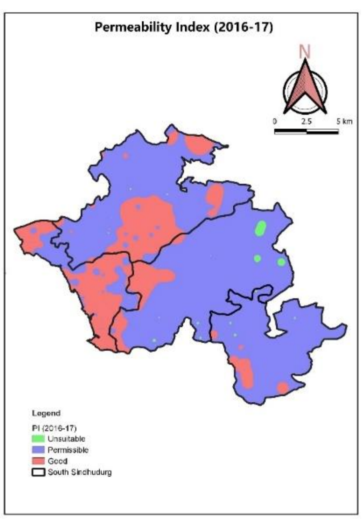


Fig.3 Variation of SAR for 2016-17 **Fig.4 Variation of SSP for 2016-17** **Fig.5 Variation of RSC for 2016-17**



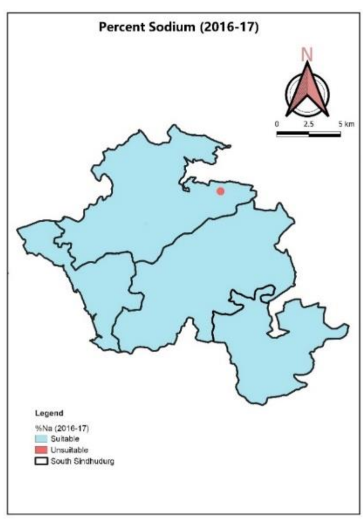


Fig.6 Variation of PI for 2016-17 **Fig.7 Variation of %Na for 2016-17**

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Graphical representation of water quality parameters

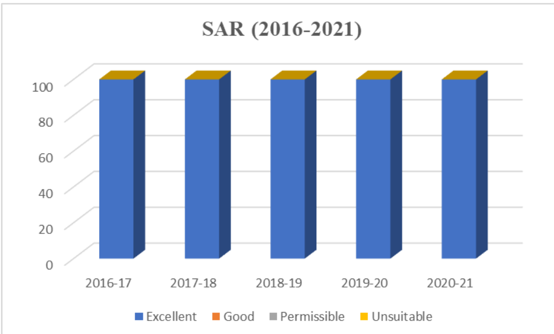

Fig.8 Graph for SAR (2016-2021)

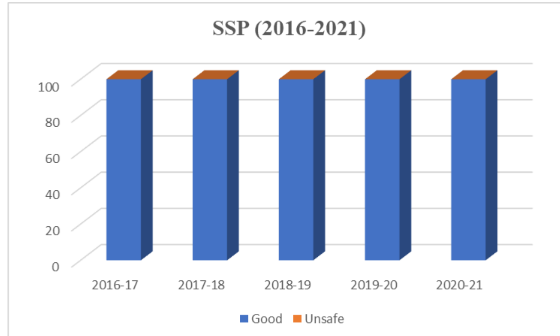

Fig.9 Graph for SSC (2016-2021)

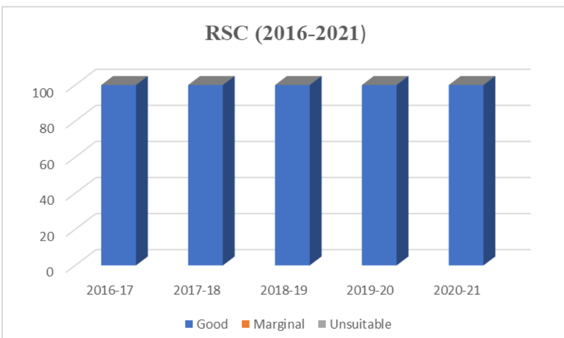

Fig.10 Graph for RSC (2016-2021)

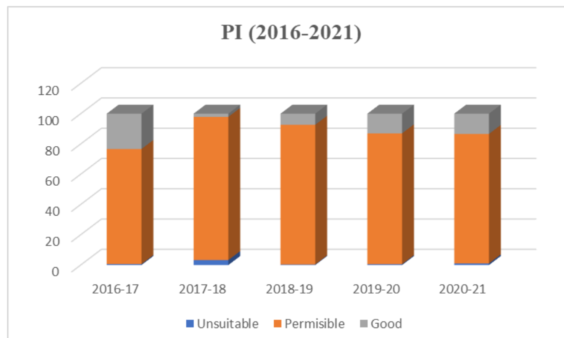

Fig.11 Graph for PI (2016-17)

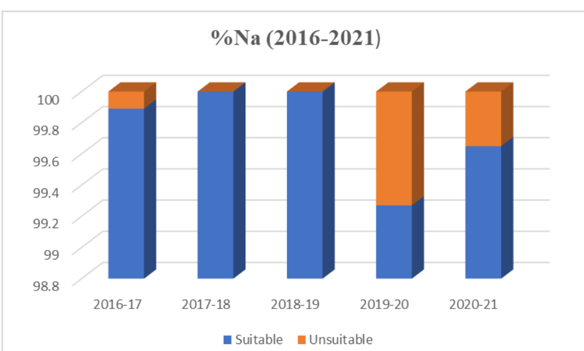

Fig..11 Graph for %Na (2016-2021)

4. CONCLUSION

The groundwater data from 2016 to 2021 were evaluated for their suitability for irrigation. Evaluation of groundwater quality for irrigation were carried out using different index methods like SAR, RSC, SSP, PI, and % Na. The results SAR, RSC, SSP, PI, and % Na implying that the

100% of the groundwater fall under excellent to good category. The spatial distribution maps generated for various physicochemical parameters using GIS techniques could be useful for planners and decision makers for groundwater quality in the area. The higher sodium content is harmful to the crop or damage the crop yield. It may produce troublesome sodium problems in most soils and will require special management like good drainage, high leaching, and additions of organic matter. If there is plenty of gypsum in the soil, a serious problem may not develop for some time. The results confirmed that Q GIS software found suitable for prediction of water quality used for irrigation purpose. It can be even used with limited data conditions. The groundwater of study area was found suitable for irrigation purpose as per irrigation water quality standards.

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