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EVALUATION OF SPATIAL DISTRIBUTION OF GROUNDWATER IRRIGATION QUALITY OF DINDI RIVER CATCHMENT AREA USING GIS, MAHBUBNAGER AND NALGONDA DISTRICTS, TELANGANA, INDIA

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ABSTRACT Ninety one samples from different villages in the study area were analysed for analysis of irrigation suitability of the groundwater. The study area situated at catchment of Dindi reservoir in the Nalgonda district. Geographically the study area is located longitude between 78°19'31.2"E and 78°54'35.8"E to latitude between 16°50'40.6"N and 16°11'24.9"N; covering survey of India toposheet numbers 56L/5, 56L/6, 56L/7, 56L/10, 56L/11, 56L/14, 56L/15. SAR of pre monsoon and post monsoon groundwater samples are categorised as excellent. KR and SSP of groundwater in pre monsoon are categorised as good; and post monsoon 99 % groundwater samples are good and 1 % are unsuitable for irrigation. In pre monsoon 70% of the samples are categorised as class-III, 27% are class –II and only 3% are class-I. In post monsoon 44% of the samples are categorised as class-III, 48% are class –II and only 8% are class-I. As per RSA values in pre monsoon 94% of samples has classified as good and of remaining 6% doubtful characteristics has3% as well as unsuitable groundwater characteristics has 3%. In post monsoon 91% are good, 2% are doubtful and remaining 7% are unsuitable. In pre monsoon all samples are fresh water and in post monsoon 67% are fresh and remaining 33% are brackish water. According Wilcox in classification in the pre monsoon 1% of the water samples belongs to excellent, 7 % are good, 88 % are medium and 4 % are unsuitable for irrigation. In post monsoon 9 % are good, 81 % belongs to medium and remaining 10 percent are un-suitable for irrigation. Spatially, in pre monsoon only north-north west area has unsuitable, where as in post monsoon season central northern tip and south eastern tip of the study area has unsuitable groundwater for irrigation; remaining area has good groundwater respect to Kelly ratio. In pre monsoon season regarding SSP 'Bad" groundwater has been observed at North West, south east and central south part; and in post monsoon same has been identified at north tip, central and south central part of the study area. Remaining area has 'Good' for agriculture use with respect to SSP. Regarding RSC in the post monsoon unsuitable water has been increased with respect to residual sodium carbonate in the entire study area compared to the pre monsoon.

KEYWORDS : Groundwater quality, spatial analysis, GIS, Irrigation

Introduction

Groundwater is a form of water occupying the all the voids within the geological stratus. Of the global fresh water about 30.1% constitutes the groundwater; therefore it is one of the major sources fresh water and is used widely for drinking purpose [1]. According to the report of WHO 80% of all the diseases in human being are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source, therefore it becomes very important to regulate monitor the quality of groundwater and to device ways and means to protect it [2]. Groundwater is a valuable natural resource that is essential for human health, socio-economic development, and functioning of ecosystems. In several parts of the India, especially in arid and semi-arid regions severe water scarcity is becoming common. Due to rapid growth of population and anthropogenic activities, the quality of groundwater is deteriorating day by day. The possibility of groundwater contamination is due to the prevailing drought-prone conditions, the improperly treated and unplanned release of effluents of industry, municipal and domestic into the nearby streams and ponds and the majority usage of groundwater for irrigation are increasing the ionic concentration of the groundwater and making it more saline[3,4,5]. GIS is a power tool for collecting, storing, transforming the spatial information and arriving decision from the real world for particular set of purpose in real time, where the stored information are geo-references. In this paper the water quality is analyzed using GIS and mapped. A geographic information system may be defined as an integrated system designed to collect, manage and manipulate information in a spatial context. A geographic information system provides an abstract model of the real world, stored and maintained in a computerized system of files and databases in such a way as to facilitate recording, management, analysis and reporting of information. It can be more broadly stated that a geographic information system consists of a set of software, hardware, processes and organization that integrates the value of spatial data [6, 7]. Estimation of groundwater quality is vital for planning sustainable management of this vital natural resource, and thus requires handling of large amount of spatial and non-spatial data. Geographical Information System (GIS) is an important tool for dealing with such types of data [8].

Study area:

Geographically the study area is located longitude between 78°19'31.2"E and 78°54'35.8"E to latitude between 16°50'40.6"N and 16°11'24.9"N; covering survey of India toposheet numbers 56L/5, 56L/6, 56L/7, 56L/10, 56L/11, 56L/14, 56L/15. Figure 1 shows the location map of study area. The study area lies at the north and south of Dindi reservoir covering part of Dindi River catchment which is tributary of Krishna River. Geographical area of the study area is 14,840 sq.m. Administratively it could be found in Mahabubnagar district of Telangana state, India which is about 115 kilometers by the road from the Hyderabad to Kalvakurthy at Dindi Village, boarder of Nalgonda district on east.

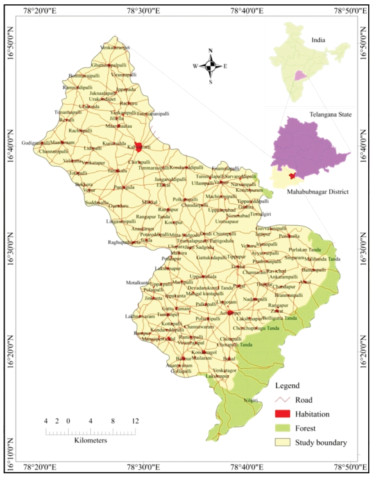

Figure 1 : Location map of the study area

Methodology

About 91 water samples for pre and post monsoon water samples were analysed for assessment of groundwater quality for irrigation suitability for pre and post monsoon in the study area. Figure 2 shows the location map of groundwater samples. These water quality data has been collected from rural water supply department

Nagarkarnool division of Telangana State. All the samples were analyzed as per the test procedures given in the standard Text book (APHA, 1985). GIS software is used to analysing the spatial analysis of the quality in the study area. Spatial analysis maps were prepared using the "Spine" interpolation spatial analysis tool of Geographic Information System (GIS). Spatial representation i.e., Richard's (1954) and Wilcox's diagram (1955) are used for classification of groundwater for irrigation purposes. Suitability of ground water for irrigation in the study area is evaluated by computing Sodium Absorption Ratio (SAR), Kelly's Ratio (KR), Soluble Sodium Percent (SSP), Permeability Index (PI), Residual Sodium Bi-Carbonate (RSBC), and Residual Sodium Carbonate (RSC).

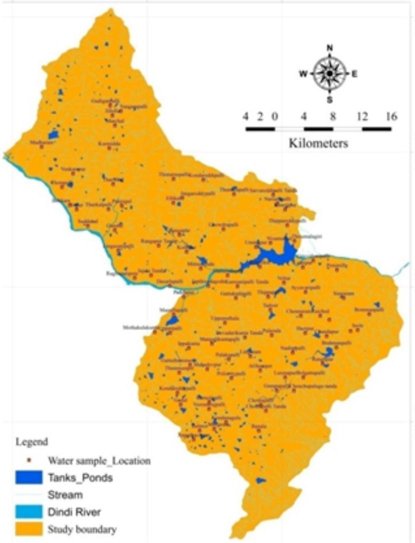

Figure 2: Location map of infiltration test

Results and Discussions

Sodium Absorption Ration (SAR): In 1954, Richards proposed this ratio as an indicator of adsorption of sodium by soil and soil structure damage. A higher proportion of Na+ related to Ca2+ and Mg2+ affects the suitability of water for crops. This ratio is used to calculate the degree to which cations dissolved in irrigation water tend to enter into cation exchange sites in soil. The main problem with high sodium concentrations, as mentioned before, is its effect on soil permeability. Sodium also contributes directly to total salinity of water and may be toxic to sensitive crops [9, 10]. SAR can be calculate the following formula

$$\text{Sodium Absorption Ratio (SAR)} = \frac{Na^+}{\sqrt{[Ca^+]+[Mg^+]/2}} = |$$

Table 1: Irrigation groundwater classification according to SAR (after Richards, 1954)

SAR	Water class		Pre monsoon	Post monsoon				
		No. of samples	Maximum	Mini mum	%	Maxi mum	Mini mum	%
< 10	Excellent (S1)	91	3.0	0.3	0	9.5	0.1	00
10 – 18	Good (S2)	-	-	-	-	-	-	-
18 – 26	Doubtful (S3)	-	-	-	-	-	-	-
>26	Unsuitable (S4)	-	-	-	-	-	-	-

Table 1 reveals that all groundwater samples (100%) in the study area in pre monsoon SAR varies from 0.3 to 3.0 where as in post monsoon it varies from 9.5 to 0.1 which is classified as Excellent (S1) for irrigation use. Figure 3 shows that regarding SAR there is no different in SAR values in pre and post monsoon of the study area.

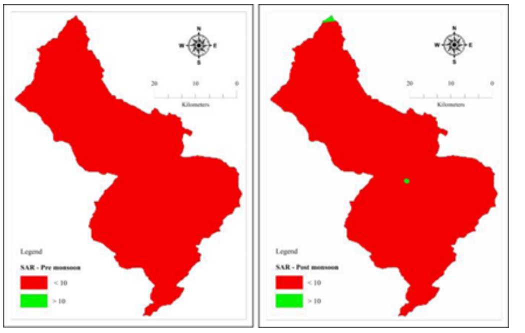

Figure 3: Spatial map of SAR in Pre and post monsoon

Kelly's Ratio (KR): The level of Na+ measured against Ca2+ and Mg2+ is known as Kelley's ratio, and it is used to rate irrigation waters (Kelley, 1940). The following formula can be used in calculation of Kelly's Ratio [11, 12, 13].

$$\text{Kelly's Ratio (KR)} = \frac{[Na^+]}{[Ca^+] + [Mg^+]}$$

Table 2: Irrigation groundwater classification according to KR (after Kelley, 1940)

KR	Water class	Pre monsoon	Post monsoon						
		No. of samples	Maxi mum	Mini mum	%	No. of samples	Maxi mum	Minim um	%
< 1	Good	91	1.0	0.04	100	90	-	0.02	99
>1	Un Suitable	-	-	-	-	1	3.5	-	1

Table 2 reveals that in pre monsoon all samples where as in post monsoon 99 % of the samples are in the study area classified as Good that has less than 1 KR value. 1 percent of samples are not suitable for agriculture regarding KR has more than greater than 1. Figure 4 reveals that in pre monsoon only north-north west area has unsuitable groundwater which has greater than 1 of KR value, where as in post monsoon season central northern tip and south eastern tip of the study area has unsuitable groundwater for irrigation; remaining area has good groundwater respect to Kelly ratio.

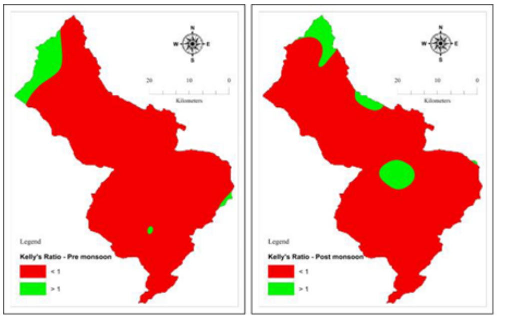

Figure 4: Spatial map of KR in Pre and post monsoon

Soluble Sodium Percent (SSP): Sodium concentration plays an important role in evaluating the groundwater quality for irrigation as sodium increases the hardness of the soil and reduces its permeability [14, 15]. Wilcox (1948) used percent sodium and specific conductance in evaluating irrigation waters use. Following formula can be used to calculate the SSP in assess the suitability of groundwater for irrigation.

$$\text{Soluble Sodium Percent} = \frac{Na^+}{[Ca^{2+}] + [Mg^{2+}] + [Na^+]} \text{ X } 100$$

Table 3 reveals that in pre monsoon all samples and where as in post monsoon 99 % of the samples are in the study area classified as Good that has less than 50 SSP value. 1 percent of sample is not suitable for agriculture regarding SSP has more than greater than 1.

Table 3: Irrigation groundwater classification according to SSP

SSP	Water class	Pre monsoon				Post monsoon			
		No. of samples	Maximum	Minimum	%	No. of samples	Maximum	Minimum	%
< 50	Good	91	46.8	3.5	100	90	-	1.5	99
>50	Bad	-	-	-	-	1	75.4	-	1

Figure 5 shows that in pre monsoon season respect to SSP 'Bad" groundwater has been observed at North West, south east and central south part; and in post monsoon same has been identified at north tip, central and south central part of the study area. Remaining area has 'Good' for agriculture use with respect to SSP.

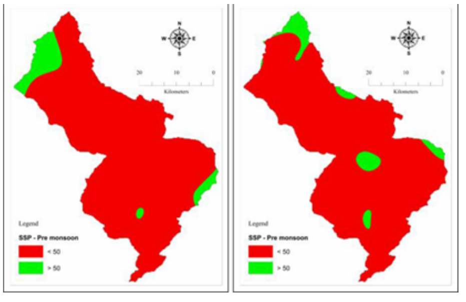

Figure 5: Spatial map of SSP in Pre and post monsoon

Permeability Index (PI): The permeability of soil is affected by long-term use of irrigation water and is influenced by sodium, calcium, magnesium and bicarbonate contents in soil. Doneen (1964) set a criteria for assessing the suitability of water for irrigation based on permeability index (P.I), accordingly, waters can be classified as Class I, Class II and Class III. The Class I and Class II waters are categories as good for irrigation with 50-75% or more of maximum permeability whereas, Class III water is unsuitable with of 25% maximum permeability [16,17]. Therefore, soil permeability is affected by consistent use of irrigation water which increases the presence of sodium, calcium, magnesium and bicarbonate in the soil. The effect of permeability has been calculated by the term Permeability Index (PI) which is calculated by the following formula

$$\text{Permeability Index (PI)} = \frac{\{[Na^{+}] + \sqrt{[HCO^{3-}]}\}}{[Ca^{2+}] + [Mg^{2+}] + [Na^{+}]} \times 100$$

Table 4 reveals that in pre monsoon PI varies from 9.7 to 126.5 where as in post monsoon it varies from 9.6 to 182.8. PI has been categorized into three class via., Class-I which has more than 75, Class-II that are PI between 25-75 and Class-III as less than 25. In the Pre monsoon 3 % of samples falls in Class-I; 27 % of samples are Class-II and remaining 70 percent has Class-III characteristics. In post monsoon 8% are categorized Class-I, 48 % categorized as Class-II and remaining 44% are Class-III.

Table 4: Irrigation groundwater classification according to PI

PI	Water class	Pre monsoon				Post monsoon			
		No. of samples	Maximum	Minimum	%	No. of samples	Maximum	Minimum	%
75	Class-I	3	126.5	-	3	7	182.8	-	8
75	Class-II	25	-	-	27	44	-	-	48
25	Class-III	63	-	9.7	70	40	-	9.6	44

Residual Sodium Carbonate (RSC): Residual sodium carbonate is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water used for agricultural activity [18, 19]. The land irrigated with the water having high RSC value becomes infertile owing to the deposition of sodium carbonate as known from the black colour of the soil and long term application of high RSC water affects the crop yield. The Residual Sodium Carbonate (RSC) calculated by the following formula:

Residual Sodium Carbonate (RSC) $= \{[HCO^{3-}] + [CO^{3-}]\} - \{[Ca^{2+}] + [Mg^{2+}]\}$

Table 5 reveals that in pre monsoon RSC varies from -53.5 to 9.1 where as in post monsoon it varies from -42.2 to 9.9. RSC has been categorized into three class via., 'Good' which has less than 1.25, Doubtful that are RSC between 1.25-2.50 and Unsuitable as greater than 1.25. In the Pre monsoon 94 % of samples 'Good' for irrigation; 3 % of samples are 'Doubtful' and remaining 3 percent are unsuitable for irrigation for pre monsoon. In post monsoon 91 samples are 'Good', 2% are Doubtful and remaining 7 % are unsuitable for irrigation.

Table 5: Suitability of RSC in Pre and post monsoon

PI	Water class	Pre monsoon				Post monsoon			
		No. of samples	Maximum	Minimum	%	No. of samples	Maximum	Minimum	%
<1.25	Good	85		-53.5	94	83		-42.2	91
1.25-2.50	Doubtful	3			3	2			2
>1.25	Unsuitable	3	9.1		3	6	9.9		7

Figure 7 shows that in the post monsoon unsuitable water has been increased with respect to residual sodium carbonate in the entire study area.

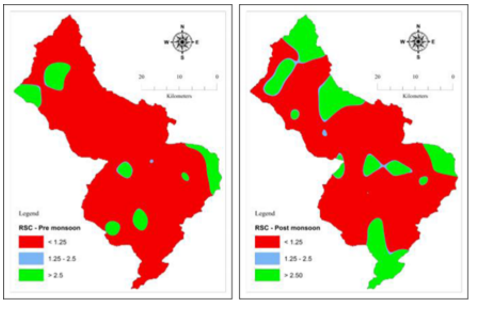

Figure 7: Spatial map of RSC in Pre and post monsoon

Residual Sodium Bi-Carbonate (RSBC): This is another important parameter for irrigation water quality [20, 21]. Gupta and Gupta (1987) expressed residual sodium bicarbonate (RSBC) as following formula

$$\text{RSBC} = [HCo^{3-}] - [Co^{3-}]$$

In pre monsoon RSC varies from 2.4 to 22.1 where as in post monsoon it varies from 2.4 to 22.0.

Classification of groundwater based on the Total Dissolved Solids (TDS): Based on the Total dissolved solids in the groundwater; it can be classified into four categories such as fresh water, brackish water, saline water and brine. Dissolved solids in the fresh water contains between 0-1,000 mg/l, in brackish water it ranges between 1,000-10,000 mg/l, in saline water total dissolved solids have 10,000 to 100,000 mg/l, in brine water total dissolved solids have greater than 100,000 [22,23].

Table 6: Classification of groundwater as per TDS

Sl. No	Water Class	Weight in mg/l	Pre monsoon	Post monsoon		
			No. of samples	Percentage	No. of samples	Percentage
1	Fresh water	0 - 1,000	91	100	61	67
2	Brackish water	1,000 - 10,000	-		30	33
3	Saline water	10,000 - 100,000	-	-	-	-
4	Brine	>100,000	-	-	-	-

Table 6 reveals that in the study area in pre monsoon groundwater is classified as fresh water where as in post monsoon 67 percent of samples are fresh water and remaining 33 percent are brackish water.

Salinity hazard: The total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance [24, 25, 26]. According Wilcox in Table 7 shows classification in the pre monsoon 1% of the water samples belongs to excellent, 7 % are good, 88 % are medium and 4 % are unsuitable for irrigation. In post monsoon 9 % are good, 81 % belongs to medium and remaining 10 percent are un-suitable for irrigation.

Table 7: Salinity hazard classification of irrigation water in relation to EC

Sl. No	Electrical Conductivity (umhos/cm)	Type of quality	Type of water	Suitability for irrigation	Pre monsoon		Post monsoon	
					No. of samples	%	No. of samples	%
1	< 250	Excellent	Low saline (C1)	Entirely safe	1	1		
2	250 -750	Good	Moderately saline (C2)	Safe	6	7	8	9
3	750 – 2250	Medium	Moderately to high saline (C3)	Safe only with permeable soil and moderately leaching	80	88	73	81
4	>2250	Unsuitable	High to Excessive saline (C4)					
a	2250 – 4000		High saline	Un fair for irrigation	3	3	6	7
b	4000 – 6000		Very high saline		1	1	3	3
c	> 6000		Excessive saline					

Similarly to classify groundwater suitability for irrigation Wilcox (1955) gave a diagram using sodium content as percentage Sodium and electrical conductivity [27, 28, 29]. A Wilcox plot can be used to quickly determine the viability of water for irrigation purposes. The Wilcox plot is also known as the U.S. Department of Agriculture diagram. The Wilcox plot is a simple scatter plot of Sodium Hazard (SAR) on the Y-axis vs. Salinity Hazard (Conductivity) on the X-axis. Figure 8 shows that only 7 % of the samples have C2-S1 category, 4% of the samples have C4-S1 category, 1 % of samples have C1-S1 category and remaining 88% of samples have C3-S1 category.

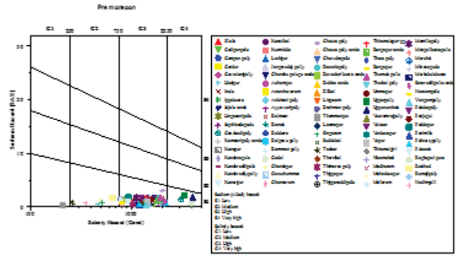

Figure 8: Wilcox diagram of Pre monsoon samples

Figure 9 shows that only 9 % of the samples have C2-S1 category, 8% of the samples have C4-S1 category, 1 % of samples have C3-S2 category and remaining 82% of samples have C3-S1 category.

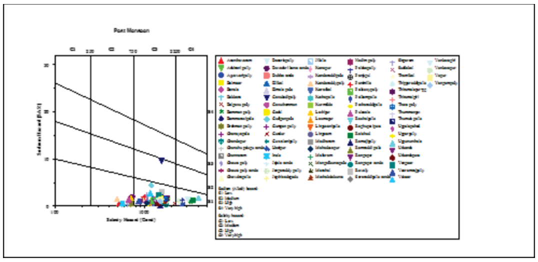

Figure 9: Wilcox diagram of post monsoon samples

Conclusions

Based on the analysis majority of the samples in the study area were suitable for irrigation. Kelly's ratio and Soluble sodium percentage values shows that in post monsoon at northern part of the study area sodium concentration has been increasing compared to pre monsoon, which might be happened by dilution either geogenic process or utilisation of sodium rich fertilisers for agriculture in the study area. According to PI, about 30% samples in pre monsoon and 56% samples in post monsoon were suitable for irrigation; and regarding RSC majority of samples i.e. 94 % in pre monsoon and 91% in post monsoon were good for irrigation. Increasing brackish water in post monsoon is indicating the dilution of constituents during rain in the study area. Percentage of high to excessive saline samples which was un suitable for irrigation was increased.

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