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Assessment of Groundwater Quality using Geographical Information System: A Case Study of Faisalabad, Pakistan

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Abstract: Existing surface water resources are inadequate to meet the rapidly increasing water requirements of humans. Hence, a significant increase in the demand of groundwater is observed and further rise is predicted. Groundwater quality and quantity monitoring are necessary to control anthropogenic activities in Faisalabad. This paper deals with the mapping of spatial variations of the groundwater quality in pre- and post-monsoon seasons, in the industrial city Faisalabad, Punjab, Pakistan. There are mostly major three parameters as EC, SAR, and RSC are used to evaluate the quality of water for irrigation purposes. Pre and post-monsoon seasons water quality were assessed with the best fit model using GS+ and GIS applications. The required parameters were analyzed according to the standards of WAPDA, PID (Punjab Irrigation Department) and PCRWR (Pakistan Council of Research in Water Resources). The adverse area from the detailed study during pre- and post-monsoon season was about 22.50% and 15.22% respectively. The area affected in pre-monsoon season was more than post-monsoon season. The maximum part of the area is affected due to the sodium adsorption ratio (SAR). The results of this research conclude that after the monsoon season quality of groundwater becomes better in the Faisalabad region, due to the addition of a large amount of water in both surface and groundwater. Low rainfall records and more temperature of this region have bad effects on groundwater level and quality due to more extraction of water and effluent discharge of industries.

Keywords: Water recharge, mapping, Ordinary kriging, EC, SAR, RSC.

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1. Introduction

Water is most important for all living plants, animals and human beings (Rosa et al., 2020; Yoon et al., 2021). Water is universal solvent and nautre's gift for all living things. Human survival on earth, modern ecosystem sustainability and food security of increasing population are largely dependent on the availability of water (Purwanto et al., 2021; Willet et al., 2019). Rapidly deacresing water availability, population growth, and changing climatic conditions lead to crisis of freshwater in several regions (Sarwar et al., 2021; Yoon et al., 2021).

The agriculture sector is the largest source of Pakistan's economy, whose irrigation water needs are completed by groundwater (Natasha et al., 2021; Zulfiqar and Thapa, 2017). Groundwater is one of the best sources to meet the requirements of irrigation in In Pakistan, there are major three water sources such as groundwater, surface water and rainwater. All these sources depend upon the hydrological cycle that is continuously changing all patterns (Allen et al., 2002; Jia et al. 2019; Sarwar et al., 2021). About 33 MAF water is extracted from groundwater to complete the needs of irrigation in the Indus Basin Irrigation System. Groundwater is the second-largest source and it completes about 50% of water needs (Mongat et al., 2015). The one-third population of the

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world is dependent on groundwater due to easily accessible (Nickson et al. 2005; Verma et al., 2020). Groundwater quality and depth level is necessary to maintain through rainwater harvesting and recharging of groundwater through wells. The contaminated groundwater cannot be controlled due to the increase in population and industrialization but its poisoned material can be minimized with daily base monitoring (Stanly et al., 2021).

According to US Geological Survey (USGS, 2016), freshwater quantity present on earth water resources is about 2.5%. and groundwater quantity is about 30%. After the census of 2017, the 2019 scenario of Pakistan's population was about 216 million that shows water quantity per capita is decreasing from 1000 cubic meters. The groundwater decreasing quantity has a bad effect on quantity (Atawneh et al., 2021; Xue et al., 2018). The rainfall divides the seasons into two parts such as pre- and post-monsoon seasons (Malik et al., 2021; Ullah et al., 2018). The rainfall events of different intensities affect quality as well as quantity (Bashir et al., 2019). The Faisalabad is known as the Manchester of Pakistan due to the industrial zone area. Most of the part of city groundwater is lower in quality and level due to pressure potential. The untreated effluents of industries consist of organic, inorganic solids and heavy metal, that become part of groundwater through canals seepage, and percolation process and affect its quality (Nasir et al. 2016; Qadir et al. 2008; Nasir et al., 2016). The main objective of my project study was to investigate the seasonal impact of rainfall on groundwater quality during pre- and post-monsoon seasons.

2. Materials and Methods

2.1. Study setting

The study area consists of Faisalabad district, Punjab province of Pakistan. About 1300 km^2 of the area was selected for groundwater sampling. The major crops of this area are paddy, sugarcane, cotton and wheat that are cultivated mostly in this area. The map of the study area is shown in Fig. 1.

The groundwater samples were collected from 288 monitoring sites of Faisalabad. The samples were collected and analyzed by PID according to their standard protocol procedure. The groundwater quality data was taken from PID Faisalabad. The GIS and GS+ (Gamma design) software were used for mapping of groundwater quality with the help of the best fit model (Jalali et al. 2017; Zehtabian et al. 2013; Yamamoto et al., 2000; Stein et al., 1999, Gringarten and Deutsch 2001).

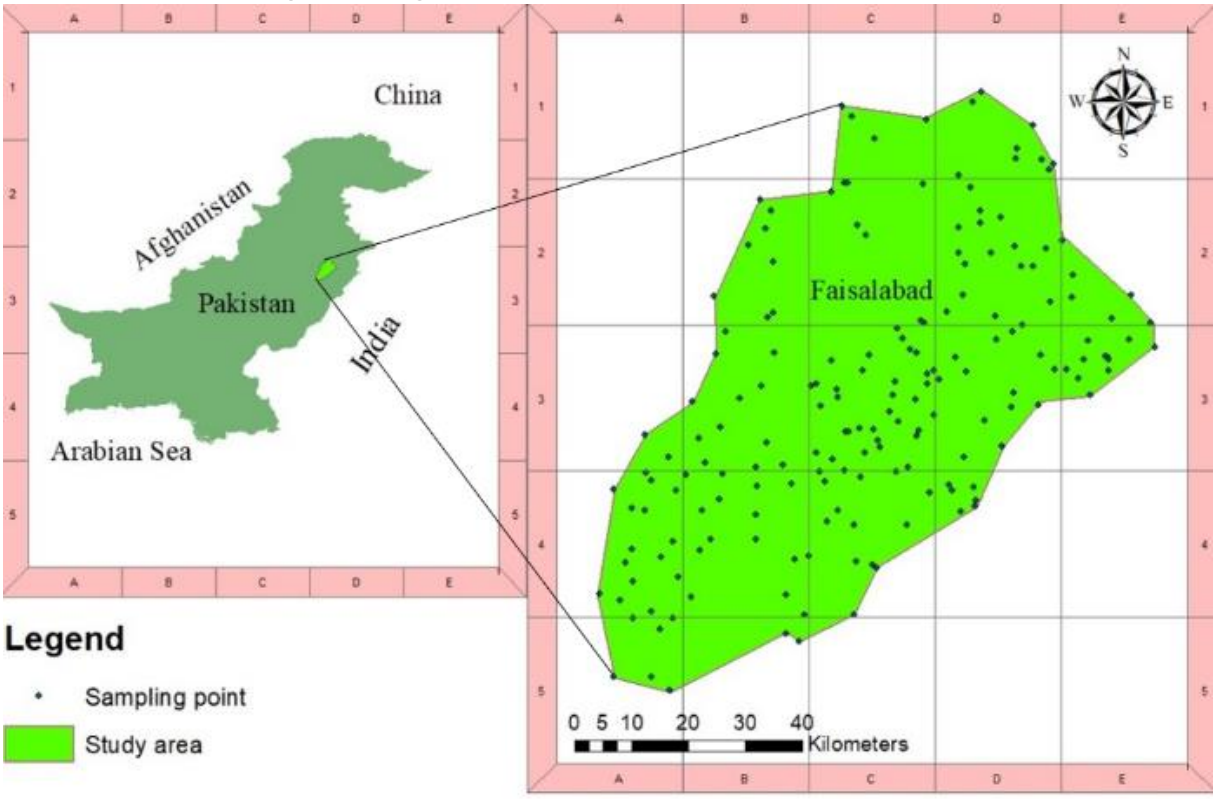
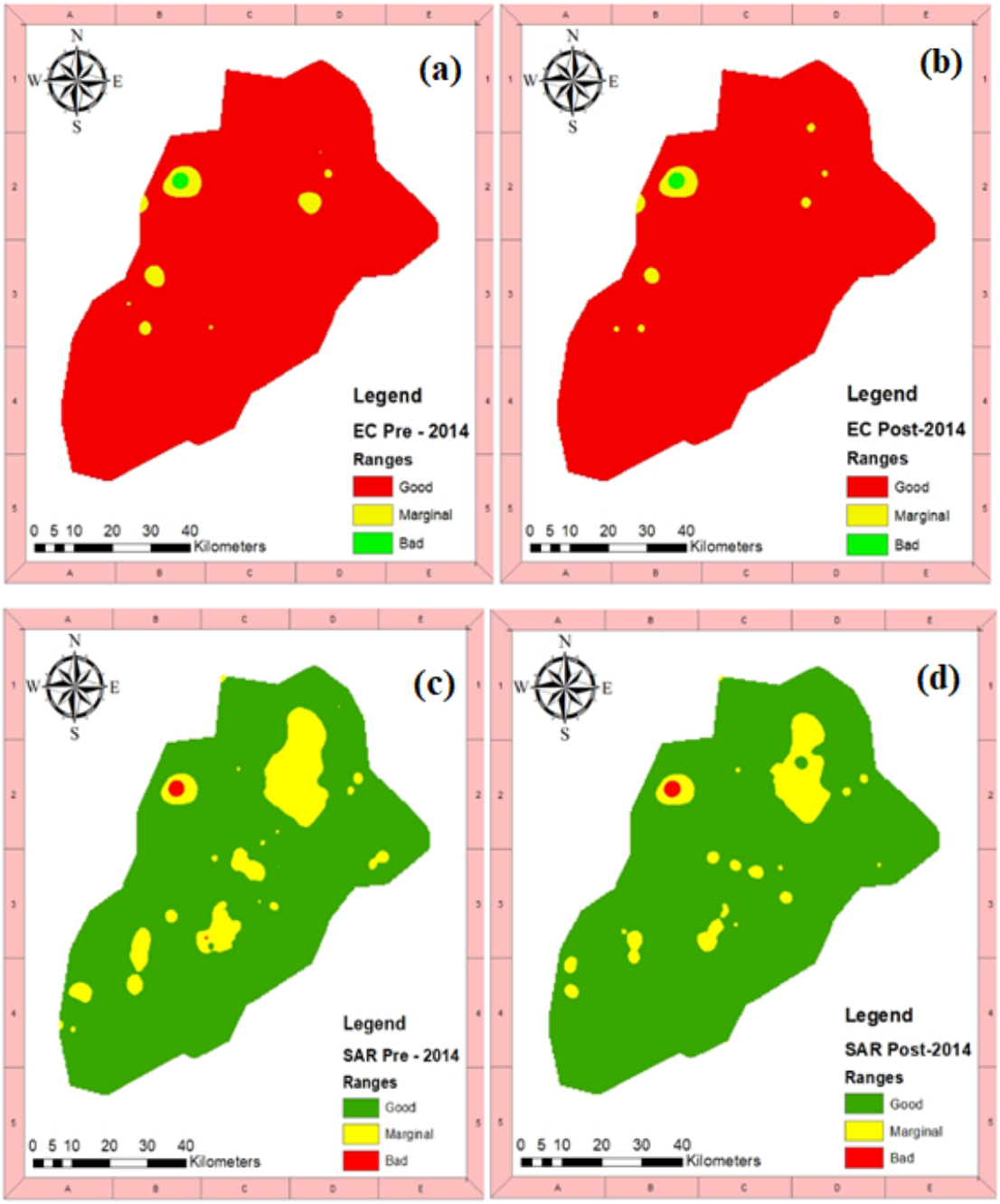


Fig. 1. Map showing study area

The best fit models were selected by using gamma design software for kriging interpolation techniques. Standard ranges followed by Punjab Irrigation Department of parameters, Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are ≤ 1.5 dS/m, 10 meq/L and 2.5 meq/L respectively.

3. Results and Discussion

There were three parameters of different samples that were investigated to fit and unfit the observation wells. According to PID standards, the groundwater quality parameters (EC, SAR and RSC) are divided into three categories such as good, marginal and bad. The best fit model was adopted using gamma design software (GS+) for ordinary kriging in GIS applications. The area having adverse effects in pre-monsoon (3.13 to 22.50) was more than post-monsoon (2.92 to 15.22) as shown in Fig. 2(a-f).



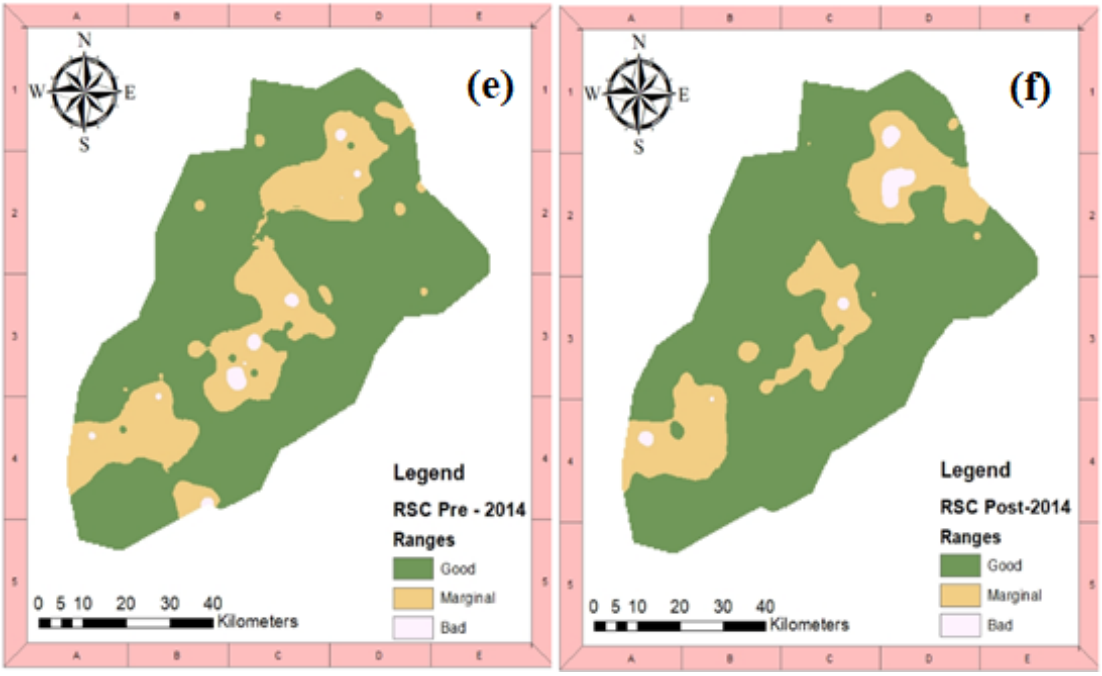


Fig. 2. Groundwater quality of parameters., a, Pre-Monsoon 2014 EC; b, Post-monsoon 2014 EC; c, Pre-Monsoon 2014 SAR; d, Post-monsoon 2014 SAR; e, Pre-Monsoon 2014 RSC; f, Post-monsoon 2014 RSC.

Table: 1. Maximum and minimum range of groundwater quality parameters

Parameter	Minimum	Maximum
EC Pre-14	o.29	11.21
EC Post-14	0.28	13.03
SAR Pre-14	0.02	56.20
SAR Post-14	o.16	57.76
RSC Pre-14	0	17.60
RSC Post-14	0	20

The bad quality was more during pre-monsoon due to low rainfall and more temperature. But this industrial city effluent is discharged without a proper way into canals and on the ground. After monsoon season, excess water assimilates the effects of pre-monsoon water through leaching, percolations and recharging wells. So, the water quality for irrigation as well as for drinking purposes is gradually decreasing day by day due to the increase of population growth and industries. The minimum and maximum range of all studied parameters is indicated is shown in table 1. All concluded results of all EC, SAR and RSC during pre- and post-monsoon seasons are shown in table 2. Maximum groundwater quality was affected by SAR parameter in both seasons. The Faisalabad city is the biggest textile city in Pakistan like Manchester. Therefore water, air and soil pollution is increasing on large scale. The amendments should be made to move the installation of new industries to under-developed areas instead of overpopulated areas.

Table: 2. Results of groundwater quality of EC, SAR and RSC Parameters.

Water Quality Parameters	Mapping pattern	Best fit model by GS+ software
EC, SAR and RSC	Affected area	Autofit
EC Pre-2014	3.13 %	Linear model
EC Post-2014	2.92 %	Spherical model
SAR Pre-2014	10.22 %	Spherical model
SAR Post-2014	6.11 %	Spherical model
RSC Pre-2014	22.50 %	Linear model
RSC Post-2014	15.22 %	Linear model

4. Conclusion

In most of the previous studies of groundwater in Pakistan, most of the area was affected after monsoon but in the Faisalabad region**,** during pre-monsoon seasons was affected more due to low rainfall water and more temperature as well as more effluents discharge of industries and toxic releasing chemicals. The maximum area was affected due to SAR parameters in pre- and post-monsoon. After rainfall of monsoon season, this water assimilated this effect after mixing but it depends upon the intensity of rainfall. The effluent discharged cannot be stopped but mix toxic materials can be separated and

decreased according to standard rules given by environmental protection rules. This effluent discharge can be minimized by mixing it into nearby flowing streams up to the required limit to assimilate its effects. This research will be helpful for the policymaker to make such strict rules that industries will minimize the toxic effects at one point source instead of non-point sources**.** Following recommendations are given for industrial district Faisalabad. The special standard should be applied strictly according to the environmental act. The installation of new industries in nearby areas should be banned and transferred to small cities. Nearby streams and areas should be checked daily at different points to control water and soil pollution. Water harvesting should be adopted during rainfall and a recharging well should be installed to maintain groundwater quality and quantity that are both correlated. The awareness of water quality and quantity is most important on both the primary and secondary levels to protect our coming generations.

Competing Interest Statement: All the authors declare that they have no competing interests

Author's Contribution: All authors have contributed equally for data collection, arrangement and manuscript preparation.

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