J. Qual. Assur. in Agri. Sci. Vol. 1(1), 30-36, 2021 https://doi.org/10.52862/jqaas.2021.1.1.5
www.jqaas.org

EVALUATION OF MONSOON EFFECT ON GROUNDWATER QUALITY USING GIS MAPPING: A CASE STUDY OF BAHAWALNAGAR DISTRICT- PAKISTAN

*Asif Ali, Arees Nasir, Muhammad Muaaz

Department of Agricultural Engineering, Bahauddin Zakariya University, Multan, Pakistan

***Correspondence**: jamasif5775@gmail.com

Article Received: 27-06-2021, Revised 27-08-2021, Accepted 30-08-2021

ABSTRACT

A research was carried out in Bahawalnagar, South Punjab. Both water quality and quantity have great importance for the existence of agriculture sector that is a backbone of economy of Pakistan. Water is necessary for all living creatures. The groundwater quality was assessed using GIS (Geographical Information System) applications and GS+ software. The three major indicators Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) were analyzed during pre and post monsoon season. These three major parameters and pH of groundwater quality are mostly checked in both seasons. The water quality parameters of 183 monitoring sites were analyzed according to standard protocol by Punjab Irrigation Department and PCRWR (Pakistan Council of Research in Water Resources). The groundwater quality was mainly affected by EC, SAR and RSC parameters. The area effected during pre and post monsoon was "75 and 70%" respectively. The groundwater quality maps showing adverse effects increasingly from north-east to south-west. But most of the area affected due to EC parameter and high adverse effect was observed during post monsoon season in case of SAR and RSC parameters.

Keywords: Groundwater, GIS, mapping, Ordinary kriging, EC, SAR, RSC

INTRODUCTION

Water plays a major rule in agricultural, industrial as well as for domestic purpose. Pakistan agricultural sector is dependent upon water resources. Therefore, water quantity and quality both having equal importance. Agriculture sector contribute GDP up to 25% and about 70% labor force is attached to this sector (Malik, 2001). There is scarcity of water is in Pakistan but scarcity of resources exists in case of presence of few dams and barrages for water storage. Water quality is affected in summer season due to leaching process after more rainfall, temperature and due to presence of impure metals (Fisher and Mullican 1997). Chaudhary et al (2002) and Farid et al (2017) stated that about 50% of water is used for irrigation purpose from the wells. So advanced technique of highest efficiency should be adopted to maintain its quality and quantity (Shaofei, et al 2011). Safe and clean water is basic requirement of all living things to sustain in life. The main reason of bad groundwater quality is human industrial, commercial and field activities in different part of Pakistan. If you want to identify the health problem of any city then regular checking of groundwater quality mapping is necessary (Hassan and Nawaz 2014). The extreme groundwater extraction for various purposes like for fulfilling agricultural crops need, livestock and human needs has led to a decline in groundwater depth. On other hand, the areas having low groundwater extraction cause water logging and salinity problems. Such type of areas having brackish groundwater and perennials canal (Ali et al., 2020; Krishan et al., 2015; Krishan et al., 2013). In this era, geographical information system (GIS) is mostly used as an application tool in the field of water resources monitoring, flood management, natural environment and groundwater monitoring (Stanly et al., 2021; Venkatramanan et al. 2019). In this research, pre and post monsoon effects were observed in a year using GIS mapping system.

MATERIALS AND METHODS

Study area

The research was carried out in Bahawalnagar district of Punjab, Pakistan in order to assess the variations that occur in groundwater quality. An area of about 8,878 km² has been selected as the study area. The district Bahawalnagar have 5 Tehsils (Bahawalnagar, Chishtian, Fort Abbas, Haroon Abad, Minchin Abad). Most of the area of Bahawalnagar consist of sandy and loamy soil. The study area belongs to tropical climatic zone. Paddy, Sugarcane, Cotton and wheat are the major crops that are cultivated mostly in the area. Map of the Study area and the sampling point details are presented in Figure 1.

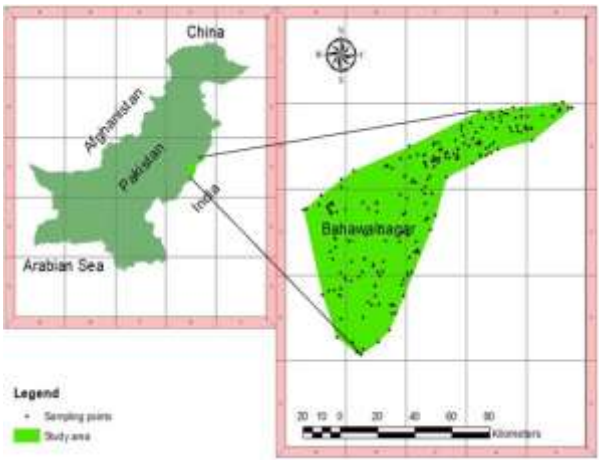

Figure 1: Map of study, dots indicating location of sampled wells

Data collection and analysis

The samples of groundwater were collected from 183 different monitoring sites in cleaned and sterilized polythene bottles, filled without air bubbles with preeminent care at each sampling site by the Bahawalpur Irrigation Department, Punjab, Pakistan. According to the standard procedures, the physicochemical parameters were measured by the Punjab Irrigation Department after sampling. The four major indicators used and appraisal for irrigation to fit and unfit wells, are pH, EC, SAR and RSC. From given techniques some samples fall within the poor, marginal and good categories.

The data was analyzed using statistical techniques, GIS and GS + software. Gyma Design software was used to select best fit model to normalize given data. The interpolation technique kriging is used for mapping of groundwater quality and finding adverse affected area like previous studies (Rossi et al. 1994; Rahmawati et al., 2013; Nikroo et al., 2010; Ebrahimi et al., 2011; Nwankwoala et al.,2012). The pre and post monsoon mapping of EC, SAR and RSC indicate different results with different weightage. Results are summarized as below section.

Standard criteria adopted by PID

Standard water quality parameter and their normal ranges that are followed by PID (Punjab Irrigation Department) WAPDA (1982) as shown in Table 1.

Table 1. Weights of different layers under different irrigation water quality parameters.

Parameters	Quality	Criteria	Weight
EC (dS/m)	Good	<1.5	3
	Marginal	1.5–2.7	2
	Poor	>2.7	1
SAR	Good	<10	3
	Marginal	10–8	2
	Poor	>18	1
RSC (meq/L)	Good	<2.5	3
	Marginal	2.5–5	2
	Poor	>2.5	1

Determination of other Irrigation Parameters

EC (Electrical Conductivity) is conducting ability of electric current to pass through water. Based on the cations and anions determined through the laboratory testing, Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are calculated as per following formulae:

$SAR = Na^{+}/[(Ca^{2+}+ Mg^{2+})/2]^{½}$……..*(Equation 1)*

(Cation's concentration = $mmol_c\ L^{-1}$)

$RSC = (CO_3^{2-}+ HCO_3^{-}) - (Ca^{+++}\ Mg^{++})$ ……. *(Equation 2)*

(Cation's concentration = meq L^{-1})

RESULTS AND DISCUSSIONS

The results of pre-monsoon and post-monsoon season of all parameters and best fit model was adopted using GS+ software for mapping in GIS software as shown in Table 3. In Table 2. indicates the minimum to highest ranges of all samples with respect to different parameters. Our observation revealed that dissolution processes were involved for the high EC values under study area (Figure 2 a, b). High values of SAR were observed due to the same reasons (Figure 02 c, d). Such factors indicate the leaching effect in the soil due to which ionic and non-ionic particles mineral dissolution. In this way, the leached down water enters the groundwater is enriched with salts. The higher values of EC during pre-monsoon 2018 was recorded as 11.21 but during post-monsoon 2018 was 13.03.

Figure 02 (c and d) depict the relationship of SAR values that exists during different periods of the study. The maximum observed values of SAR recorded in 2018 were 56.20 and 57.76 for pre-monsoon and post monsoon correspondingly. It was further evaluated that maximum SAR values recorded during the post monsoon season may be due to the high precipitation rate recorded as depicted in the Figure 2 (c, d). The reason behind this is the release of Na under high precipitation as residual effect from the exchange sites followed by desorption from the adsorbed sites under thermal motions along with other physical forces. Moreover, different chemical processes in the soil are accelerated under high temperature conditions particularly pedoturbation, in which it meets with various ions in the soil water and are added in the groundwater thus affecting its chemistry (Gupta, et al. 2017; Ghazavi, et al. 2012). As depicted in the Figure 2(e, f), there was no corresponding relationship present between the varied RSC values and recorded environmental conditions. A maximum value (17.60 and 20) was noted in pre-monsoon and post monsoon 2018 respectively. Maximum quality was affected (70 to 75%) due to EC parameters respectively. The surface water, groundwater quality and groundwater depth are important factors for the management of water bodies in Pakistan. The lower depth of groundwater has adverse effects on water quality. According to the world bank reports, Pakistan is facing threshold level of scarcity of water. There is no response of policy maker on quantity and quality of water that is decreasing year by year due to more private tube wells water extraction. The strict laws should be implemented from small to large farmers as well as installation of new industries.

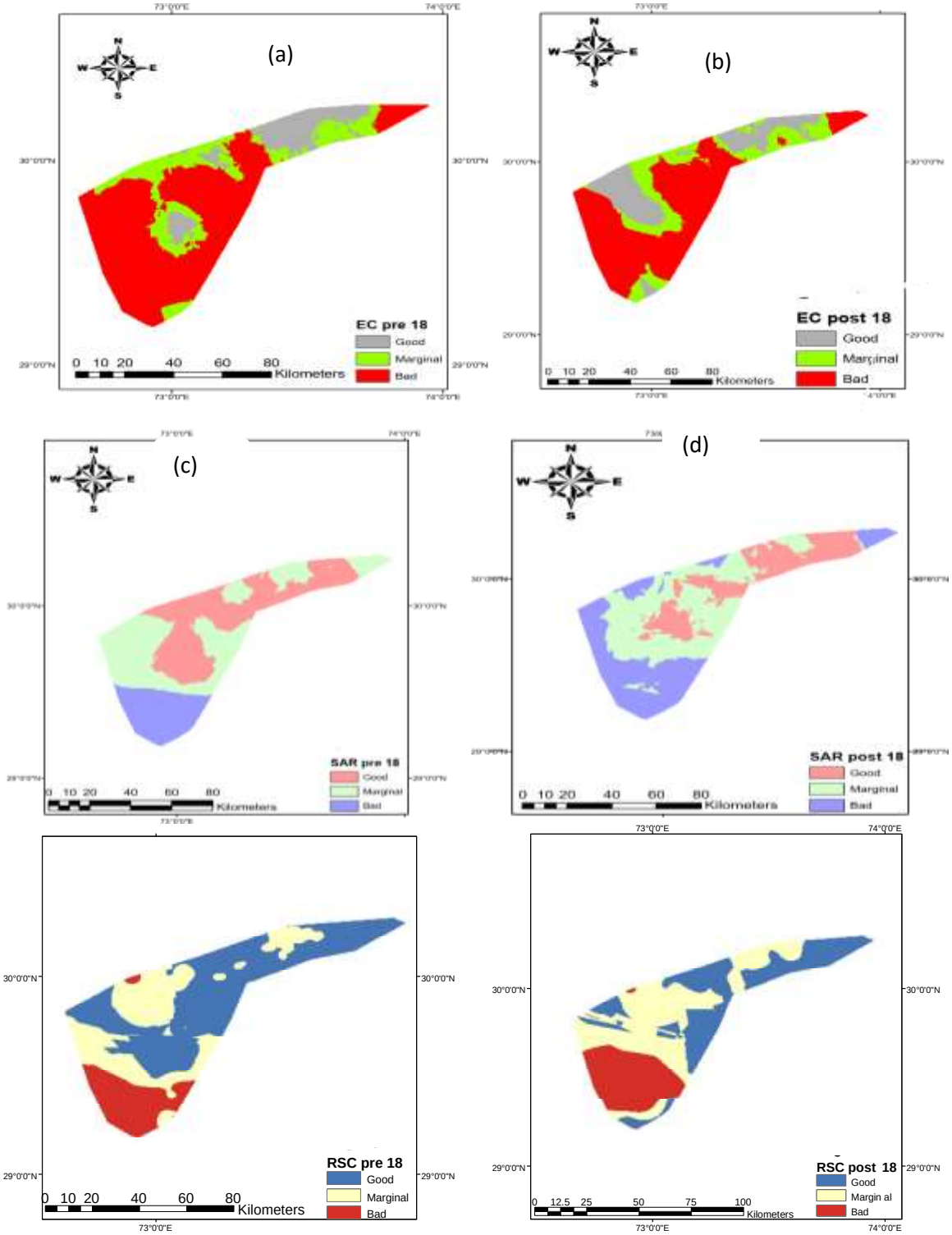

Figure 2 (a) EC-Pre-2018, (b) EC-Post-2018, (c) SAR-Pre-2018, (d) SAR-Post-2018, (e) RSC-Pre-2018, (f) RSC-Post-2018

Table 2. Maximum and minimum range of groundwater quality parameters

Parameter	Season	Minimum	Maximum
EC Pre-18	Pre-monsoon 2018	0.29 dS/m	11.21 dS/m
EC Post-18	Post-monsoon 2018	0.28 dS/m	13.03 dS/m
SAR pre-18	Pre-monsoon 2018	0.02	56.20
SAR post-18	Post-monsoon 2018	0.16	57.76
RSC pre-18	Pre-monsoon 2018	0 meq/L	17.60 meq/L
RSC post-18	Post-monsoon 2018	0 meq/L	20 meq/L

.

Table 3. Results of groundwater quality of EC, SAR and RSC Parameters

Water Quality Parameters	Moonsoon-208	Good	Marginal	Bad	Mapping pattern	Best fit model by GS+ software
		% area	% area	% area	% Affected area	
EC Pre-2018	Pre	25	37	38	75.00	Gaussian model
EC Post-2018	Post	30	43	27	70.00	Spherical model
SAR Pre-2018	Pre	40	40	20	60.00	Spherical model
SAR Post-2018	Post	35	40	25	65.00	Exponential model
RSC Pre-2018	Pre	60	20	20	40.00	Linear model
RSC Post-2018	Post	45	40	15	55.00	Linear model

CONCLUSION

Almost all of the Groundwater comprises salts, however the type and amount of salts is dependent on many factors like source of water and movement. . The study area adverse effected with poor quality in pre- and post-monsoon was about 75% and 70% unfit for irrigation purpose respectively due to change in temperature, rainfall and canal discharge in Bahawalpur Irrigation Zone. But in post monsoon, more area affected the pre-monsoon in case of SAR and RSC parameters. Most of the area in pre-monsoon was affected more than post-monsoon in case of EC parameter. Bad quality with weightage 1 was captured in industrial area. The water present in the soil solution is prone to variable effects due to the presence of crops in field, rhizosphere and rhizoplane. The ground water composition may ameliorate because of ions and cations uptake and discharge through the plant roots, however it is only possible if soil drainage is good enough and water table is not too low. Owing to such reasons, a wide spatial variation is observed in groundwater quality of different cultivated and non-cultivated lands. Plantation has an immense effect on soil, physical, chemical and other biological processes which ultimately affect groundwater. Maximum unfit points occur because of electrical conductivity, residual sodium carbonate and sodium adsorption ratio respectively throughout the period under deliberation. Following recommendations are given to minimize this affected quality.

HEIS (highest efficiency irrigation system) should be adopted to save more water. Water harvesting techniques should be adopted to use water at exact time for irrigation and for the use of well recharge to maintain water quality and level. Minimization of more water extraction especially through private tubewells, Industrial effluent discharge maintenance. So, policy maker should make such standard rules that help to maintain ground water quality as well as groundwater level. Because decrease in groundwater level also effects groundwater quality. So, there should be defined standardized rule to install number of tube wells within limited range and at standard depth and distance. Water quality becomes poor after extracting .

REFERENCES

Ali, A., H.U. Farid and M.M.H. Khan. 2020. Divergent effect of rainfall, temperature and surface water bodies on groundwater quality in Haveli Canal Circle of Multan Irrigation Zone, Southern Punjab, Pakistan. J Envir Agric Sci. 22(4): 25-36.

Chaudhary MR, Bhutta NM, Iqbal M, Subhani KM (2002) Groundwater resources: use and impact on soil and crops. Paper presented at the second South Asia Water Forum. Islamabad, Pakistan

Ebrahimi, K., S. Feiznia , M.J. Rostami and K. Ausati. 2011. Assessing temporal and spatial variations of groundwater quality (a case study: Kohpayeh-Segzi). J. Rangeland Sci. 1:193-202

Farid H, Mahmood-Khan Z, Ali A et al (2017) Site-specific aquifer characterization and identification of potential groundwater areas in Pakistan. Pol J Environ Stud 26:17–27. https ://doi.org/10.15244 /pjoes /64645

Fisher R.S., Mullican W.F. and III. 1997 'Hydrochemical Evolution of Sodium-Sulfate and Sodium-Chloride Groundwater Beneath the Northern Chihuahuan Desert, Trans-Pecos, Texas, USA', Hydrogeology Journal February 1999, Volume 7, Issue 1, pp 15–27|

Ghazavi R., Vali A. B. and Eslamian S. 2012 'Impact of Flood Spreading on Groundwater Level Variation and Groundwater Quality in an Arid Environment', Water Resour Manage (2012) 26:1651–1663

Gupta V.S.S.R, Rao R.S and Divya K. 2017 'Evaluation of groundwater quality using multivariate statistical techniques and gis - a case study', Intern J Civil Engin Tech (IJCIET) 8, (8): 1165-176,

Hassan, A. and M. Nawaz. 2014. Microbiological and physicochemical assessments of groundwater quality at Punjab, Pakistan. African J. of Micro Research. 8 (28): 2672-2681

water more than need and at lower level, because groundwater chemistry hydrology involves in this cycle. The results of this research will be helpful for the policy maker, and will help in planning, regulating , designing, maintenance and operation of water resources. It will also help to improve the groundwater utilization for agricultural use, to complete the vision of current situation such as save water save life.

Acknowledgments:
The authors acknowledge the continuously support of Land Reclamation Division Punjab Irrigation Department, Multan and Department of Agricultural Engineering, Bahauddin Zakariya University, Multan during final year project 2019-20

Krishan, G., and Chopra, R. P. S. 2015. Assessment of Water Logging in SW (South Western) Parts of Punjab, India-A Case Study from Muktsar District. NDC-WWC Journal 4 (1): 7-10.

Krishan, G., Rao, M. S., Kumar, C. P., and Semwal, P. 2013. Identifying Salinization Using Isotopes and Ion chemistry in Semi-arid Region of Punjab, India. J Geol Geosci 2: (4): 1-6.

Malik MA 2001. Agriculture. Emporium Publisher Lahore, Pak. p.15 Muhammad H, Qureshi RH, Rajoka MI, Sandhu GR (1975). Use of saline sodic water for crop production and effect of ammende and unammende saline sodic water on growth of maize and properties of normal loam soil. Lyallpur, Pak. P. 10.

Nikroo, L., M. Kompani-Zare, A.R. Sepaskhah and S.R.F. Shamsi. 2010. Groundwater depth and elevation interpolation by kriging methods in Mohr basin of Fars Province in Iran. Environ. Monit. Assess.166:387-407

Nikroo, L., M. Kompani-Zare, A.R. Sepaskhah and S.R.F. Shamsi. 2010. Groundwater depth and elevation interpolation by kriging methods in Mohr basin of Fars Province in Iran. Environ. Monit. Assess.166:387-407

Rahmawati, N., J.F. Vuillaume and I.L.S. Purnama. 2013. Salt intrusion in coastal and lowland areas of Semarang City. J. Hydrol. 494:146–159

Rossi RE, Dungan JL, Beck LR (1994) Kriging in the shadows: geostatistical interpolation for remote sensing. Remote Sens Environ 49:32–40.

ShaoFei, L., YangRen, W., ShuHong, S. and XiaoHong L. 2019 'Effect of different water-saving irrigation schemes on water use efficiency and benefit of winter wheat' , 2011 No.3 pp.1-5, 8 ref.4 https://www.cabdirect.org/cabdirect/abstract/20123053699

Stanly R., S. Yasala1, K. Emperumal, A. Subash, D. Hudson Oliver and N. C. Nair. 2021. Hydro chemical appraisal of groundwater quality for

drinking and irrigation: a case study in parts of southwest coast of Tami Nadu, India. Appl. Water Sci. 11 (3): 1-20.

Venkatramanan S, Viswanathan PM, Chung SY 2019. GIS and geostatistical techniques for groundwater science. Elsevier, Amsterdam

Verma P, Singh PK, Sinha RR, Tiwari AK 2019. Assessment of groundwater quality status by using water quality index (WQI) and geographic information system (GIS) approaches: A case study of the Bokaro district, India. Appl Water Sci 10(1): 1-16.