Pakistan Geographical Review, Vol.76, No1, June. 2021, PP 191-202

ASSESSMENT OF PHYSIOCHEMICAL CHARACTERSTICTS OF GROUNDWATER QUALITY IN DISTRICTS OF PUNJAB: A GEOINFORMATICS PERSPECTIVE

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ABSTRACT

The existence of Pakistan in the global perspective is of a developing country, engulfed amongst variegated sorts of economic, social and environmental conflicts and concerns. Even though Pakistan possesses a very significant geographical location, yet still it suffers the consequences of being in the environmentally stressed zone. Hence, this study has been performed to evaluate the impacts of interdependency of two vital natural resources (water and land). The status of groundwater quality was examined in Faisalabad, Jhang and Toba Tek Singh of Punjab province. Water quality was observed for the pre and post monsoon of the year 2018. Salinity, Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) were taken as primary quality parameters. Secondary data of 328 water wells was extracted from the Punjab Irrigation Department, which was firstly sorted, then filtered and tabulated to apply Geo-informatics techniques. IDW technique of Interpolation was applied in ArcGIS environment. The obtained results through maps and graphs were discussed in accordance with the Pakistan Water and Power Development Authority (WAPDA) standards, which designates the limit of 3 in each category and units. Electrical Conductivity was found high in 22% of wells after the rainfall spell, which could possibly be due to the undulating slope of the study area. SAR was observed in low concentrations in majority of the wells. RSC was found highest as 17.8 me/L in Faisalabad. The statistics for land utilization and vegetation patterns were also observed to mitigate the impacts. The amplification in concentration of these parameters have been stated to decline crop productivity. Therefore, in conclusion, strict implementation of laws for a proper check and balance system is urgently required. "Drip Irrigation" is highly recommended for sustainability of agricultural land and healthy food production.

KEY WORDS: Environmental hazard, Groundwater quality, GIS, IDW, Salinity.

INTRODUCTION

Water is the most vital resource and basic need for every living soul to survive. Planet Earth is surrounded by 70% water from which only 3% is found in consumable form. The consumable water resource is found in different forms, however most of it is present underground (Blondes et al., 2016). This leaves the presence of 1% water on the surface, mostly in the form of glaciers (more than 60%). Whereas the remaining aquifers are found in the shape of lakes (0.26%), rivers (0.006%), swamps (0.03%) etc. (Igor, 1993). Anthropogenic activities has been witnessed to increase since the development of industrial regions on the dry land areas of the world. These activities have altered the natural environmental design, resulting in deleterious impacts on the existing ecosystems. The global analysis for water availability in 2015, revealed that by the start of the century where 6.6 billion people were deprived of safe and clean water, have now reached to the ratio of 780 million (Connor, 2015; Azizullah et.al., 2011). Considering the concerning situation, the United Nations (UN) upgraded the Millennium Development Goals (MDGs) of 2000 as Sustainable Development Goals (SDGs) in 2015. The agenda of SDGs is to accomplish and implement its 17 goals for a better life on this planet. Goal 6 of the SDGs focuses on “Accessibility and sustainable management of water resource and sanitation” with its 6 sub-targets to focus on every type of water usage around the world (Hering et al., 2016; Ki-Moon, 2013).

An agriculture country such as Pakistan, is majorly dependent on its water resource for its stable economy. In the world, Pakistan has the largest irrigation system and in the South-Asian region, it is the 2nd largest consumer of groundwater. Due to enhanced efficiency of the irrigation system and reduction of labor, the usage of groundwater has exceeded from 85%. It is estimated that extraction of groundwater in Pakistan is about 60 bm^3 (billion cubic meter) (Qureshi, 2015). Due to inconsistent trends in the surface water through river Indus, farmers have shifted their dependency more towards groundwater. The annual availability is 820 mm/hectare to the surface water canal system. This amount of water is only useful in irrigating 16 mha of the agricultural fields (Qureshi, 2020).Whereas, during the monsoon season, from July till September, only 15% of the water needs are accomplished through rain. The increase in dependency on groundwater to meet agricultural needs has resulted in unsupervised overexploitation of the natural resource. In the main agriculture province of Punjab, more than 50% of the irrigational requirements are accomplished through groundwater (Bastiaanssen & Feddes, 2005). This practice has significantly dropped the water table from 40 feet to 800 feet (Kahlown et al., 2007). Deep drilling of groundwater alters the water quality in terms of varying salinity levels, carbonate ions and basicity. The amplification in usage is now posing serious threats on groundwater quality and is also becoming responsible in diminishing the resource at a much faster pace (Khan et al., 2017).

This research study is aimed to monitor the groundwater quality, used in agricultural activities, in terms of Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC). These parameters not only degrades the water quality, but have also known to decrease crop production, alter plant structure, decline or diminish soil fertility, resulting in decrease in agricultural productivity (Aboukarima et.al., 2018). Spatial dispersion is also analyzed through GIS by producing maps to promote an understanding based on accuracy and scientific approach. The spatial distribution pattern is an important tool that has helped to locate the precise amount of the prime parameters at their root locations.

Study Area

Areas selected for this study includes district of Faisalabad, Toba Tek Singh and Jhang, which lies from longitude 72.87°E-72.74°E latitude 31.90°N-30.50°N, at the elevation of 184.5m from mean sea level. The climate of central and southern Punjab possesses the dry semi-arid, agro-climatic characteristics but well-managed canal irrigation system has placed it among the highly productive agriculture zones. Summer monsoon produces more rainfall and winter rain has little contribution. Day time temperature reaches above 40°C during summer from April to September except some occasional relief from monsoon rains which decreases the evaporation demand of the atmosphere. The winter season starts from November and continues till March. December, January and February are the coldest months. In winter, night time temperature drops below 0°C. The highest amount of rainfall occurs during Rabi season in the months of March followed by April and February respectively. Day-time mean-maximum and night -time mean-minimum temperature gradually decrease from November to January and then start rising (Pakistan Meteorological Department-2018).

MATERIALS AND METHODS

Data Collection and Sorting

Secondary raw data of ground water quality was obtained from the website of Irrigation department of Punjab (Pakistan). Huge data of more than 400 wells for pre and post monsoon season of year 2018 was sorted and arranged using Microsoft excel. Selected parameters were Electrical Conductivity (EC), Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) respectively

Data Analysis

Inverse Distance Weighted (IDW) interpolation was incorporated to form isopleth maps showing spatial and temporal variation of water's physiochemical quality. For this purpose, data of shape file of all selected districts were exported from Pakistan map shape file downloaded from Diva GIS website. Sampled wells were classified according to the concentration and hazard. Tables and maps were organized in order to compare the variations found in selected years. Additionally, to analyze the effects on vegetation and land utilization patterns, statistics of agricultural lands of the study areas and vegetation cover was displayed through land utilization statistics and Rapid Response MODIS subsets downloaded from NASA website respectively.

RESULT AND DISCUSSION

The subsurface water of the study area is largely used for agricultural purposes. The feasibility of groundwater for watering of crops is based on the mineral content of the water. Good quality of groundwater is necessary to retain the soil-crop productivity at a considerable amount. Dissolved salts and their ions are a key threat to plant production which increases osmotic pressure in soil solution, which in turn, reduces the functionality of water absorption for osmosis (Throne & Peterson, 1954). To assess the suitability of irrigation groundwater, its salinity, sodicity and toxicity are measured as the key factors to make its use fit for practices of agricultural activities (Hagras, 2013), keeping in consideration that these ions play a major role in water's changing chemistry especially that of groundwater (Raza et.al., 2017).

Table 1: *WAPDA Standards for Irrigation Water Quality (1981)*

PARAMETERS	WAPDA IRRIGATION WATER QUALITY CRITERIA (1981)	
Electrical Conductivity (dS/m)	Suitable	<1.5
	Unsuitable	>3
Sodium Absorption Ratio (SAR)	Suitable	<10
	Unsuitable	>18
Residual Sodium Carbonate (RSC) (me/L)	Suitable	<2.5
	Unsuitable	>5

Electrical Conductivity (EC) is the calculation of the extent of the mineralization of the water, which is based on water-rock correspondence, and hence the stay time of moisture in the rock (Eaton, 1950). EC measurements are performed to detect two major physical specific parameters:

a) Total dissolved salts (T.D.S)

b) Salinity Hazard

EC value is converted into TDS by multiplying with a constant factor to determine the effects. While salinity hazard is simply a range of EC values on which there is likely some deformity to happen in the crops due to physiological drought, which is a condition in which in spite of moisture in the soil, plant leaves wilt because of inability of plants root to absorb water. It is expressed in **dS/m (deci -siemens/meter).**

SAR is used to predict the danger of sodium accumulation in soil. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability and soil structure (Kelly, 1957). The SAR is used to estimate the sodicity hazard of the water and it also determines the alkalinity of soil selected for agriculture. SAR is calculated by the following formula:

SAR= [Na+/√Ca2++Mg2+/2] (Eq.1)

SAR value is an important indication of sodium hazard (Infiltration problem), that is, the reduction of the permeability of the soil. This loss in permeability cause the soil to shrink and swell in clayey soil when irrigation water flows through (Saleh, Al-Ruwaih & Shehata, 1999).

RSC is used to determine the extent of aptness of groundwater consumed in irrigational terms (Raza et.al., 2017). It is the evaluation of surplus CO_3 and HCO_3 ions which precipitates the calcium and magnesium ions present in the disbursed asset. The RSC factor is computed through the following formula:

RSC= (CO3 + HCO3) – (Ca + Mg) (Eq.2)

This estimates the level of toxicity to the flora as it aids the augmented accumulation of sodium and saline ions causing a threat to the irrigational lands and crop production and is expressed in **me/L (mili-equivalent per liter)** (Riaz et.al., 2018).

3.1: WATER QUALITY DURING PRE AND POST MONSOON 2018:

3.1.1: Electrical Conductivity: Highest Value of EC in unit dS/m was 10, found at Chak Jhumra in the district of Faisalabad and in Gojra district, Toba Tek Singh, in pre-monsoon. Increase in TDS values results from the leaching of wastewater of industries and salts, which in terms lead to decrease in soil fertility and its ability in crop yield (Aniyikaiye et.al, 2019). Distribution of Salinity showed that about 39% and 50% of the wells in the pre-monsoon and post-monsoon were above standard. While Salinity Hazard limitation in the field showed 136 wells in the “Medium” range in pre-monsoon, which dropped to 132 wells after rainfall, as clearly visible in figure 1. This suggests that overall the sampled area shows wells with suitable water quality in terms of salinity. However, the increase in salinity concentration can be due to high evaporation from top moist soil, leaving the nutrients to leech down during precipitation, or it could have increased because of the undulating slope, providing less retention time for the aquifer to recharge properly (Mohammad, Abdullah & Alzoghoul, 2017).

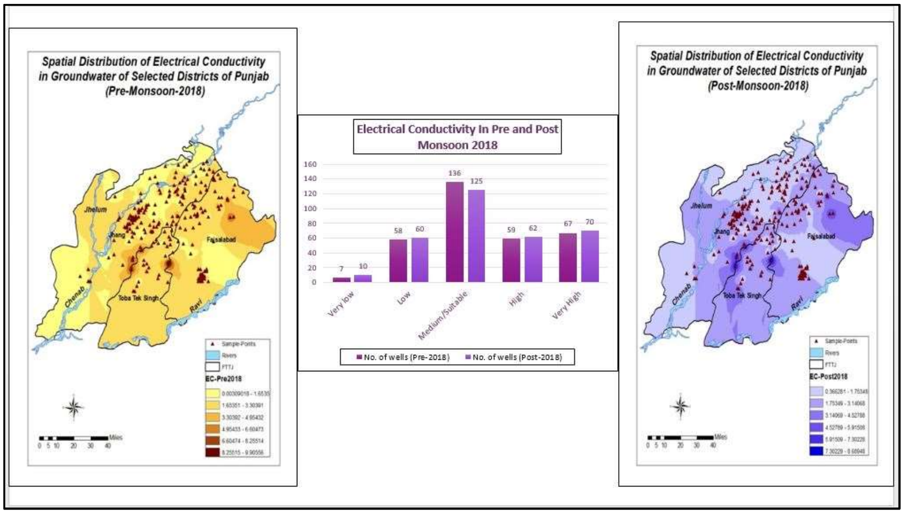

Figure 8: Electrical Conductivity in Pre and Post Monsoon 2018

A study of irrigational groundwater quality of district Kasur reported high values of EC, SAR and RSC, concluding that the water extracted is unfit for consumption and usage. (Shakir, Ahmed & Khan, 2002). Faisalabad is situated in the lower Chenab canal circle and receives its surface water from it (Punjab Irrigation Department). In 2018, an evaluation of Khurrianwala Industrial Estate groundwater quality, situated between Chenab and Ravi Rivers in the vicinity of Faisalabad showed alarming results for TDS and EC. The TDS values in drinking water varied from 987 to 2114 mg/L. While the EC concentrations of irrigation groundwater were between the ranges of 1590-3490 µS/cm (Aleem, 2018).

3.1.2: Sodium Absorption Ratio (SAR): Enrichment of sodium ion in the soil cause the decline in crop yield. A study on Bahawalpur in 2018 showed that through GIS analysis, 21% of the samples were explored to be unfit for irrigational purposes, while 65% were fit leaving 14% as marginally fit. SAR helps and supplement the movement of sodium ions which reacts with Ca^+, Mg^+, CO_{3-}, HCO_{3-} and form such complexes that causes damage to the soil stability and its structure (Riaz et.al, 2018). In this performed study, in the pre-monsoon, the lowest value of SAR was found 0.32 in district Jhang. While the corresponding highest value was 52.3 in tehsil Gojra of district Toba Tek Singh. Whereas, the highest value in post-monsoon reduced to 52.11 at the same district. In comparison with the standard recommended by WAPDA, the highest value is witnessed as significantly elevated in both seasons, while the categories in which the sodium hazard is classified reveals the fact that most of the wells have been found to low and safe limits. Results are shown in the below figure 2.

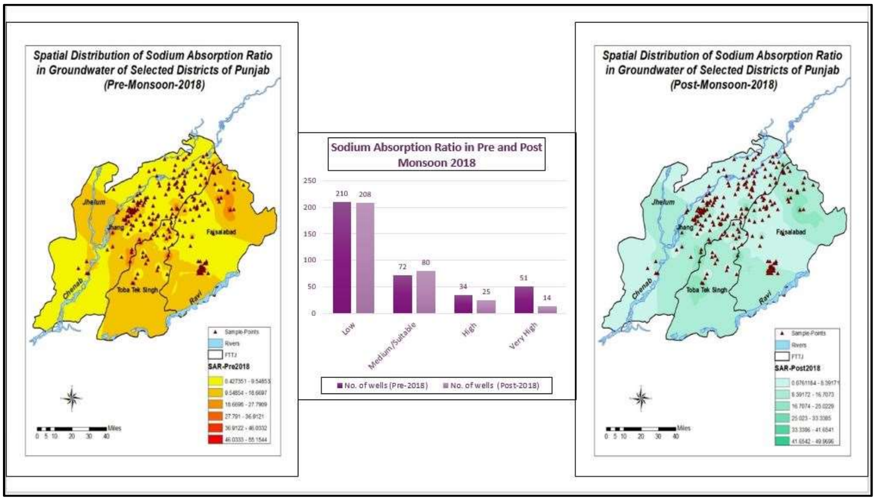

Figure 9: Sodium Absorption Ratio in Pre and Post-Monsoon 2018

In Sargodha, the analysis of groundwater quality revealed that out of 12 sampled areas, only 5 had sodium concentration under the WHO guidelines (200 mg/L) whereas all the samples had EC concentrations more than 1000 µS/cm and an alarming concern was reported (Riaz et.al, 2016).

3.1.3: Residual Sodium Carbonate: Unceasing usage of irrigation water containing high levels of RSC causes the soil to lose its permeability by obstruction of pores levels to tolerate subsequent toxic effects and result in hindrances in appropriate growth pattern (Nishanthiny et.al., 2010). In this study the value for RSC is observed in the range of 0-18 me/L, revealing the highest value in pre-monsoon in Tehsil Jarranwala of District Faisalabad of 17.8. Majority of the wells have shown no or low value for RSC and hence it can be stated that most of the samples are under safe and fit limits, which can be seen in figure 3. In GIS study conducted at Bahawalpur, it was reported that about 9 locations had increased concentration of RSC and that the indication of vulnerability to the soil infrastructure and crop production was stated (Riaz et.al, 2018).

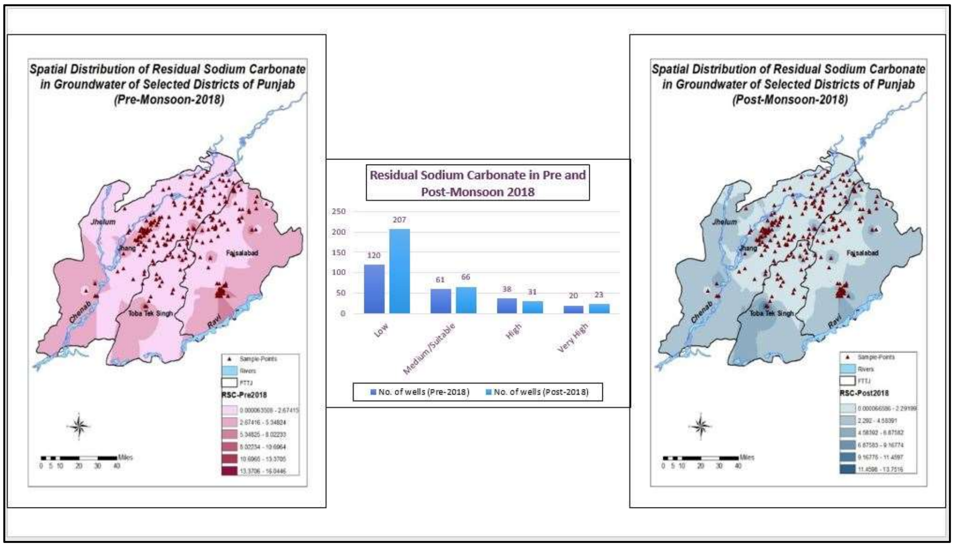

Figure 10: Residual Sodium Carbonate in Pre and Post Monsoon 2018

While finding the relationship between SAR and RSC in both seasons, the results showed that in the pre-monsoon season the value was reaching the high-scale. However, after the rainfall spell, it showed evident decline, revealing that groundwater recharge through rainfall is the reason for decline in the value. The graphical presentation is shown in figure 4a and 4b.

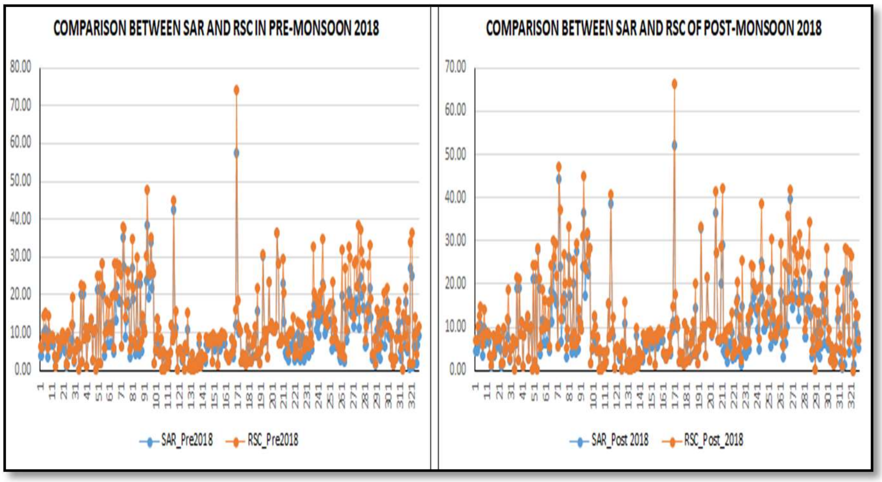

Figure 11a and 4b: Comparison of Values between SAR and RSC in Pre and Post-Monsoon 2018

Vegetation and Land Utilization Patterns

Comparing the pre-monsoon to the post, decrease in vegetation and contraction of river channels show very reduced flow and reduction in resources. River Chenab and Ravi on the south ends of Jhang and Faisalabad are completely diminished or dried up. Vegetation reduced at the center where all the three boundaries converge. Where as in the post monsoon, vegetation has greatly increased, towards the east and west ends of the study area. The patterns of land utilization show that cropped area has increased in Faisalabad, and the areas sown more than once has declined in Jhang. Reasons can be numerous for this evidence, such as, the soil type present in the area could of such composition which supports erosion and increased flushing; resulting in enhanced salt stress on plants (Sabir et.al, 2017). As groundwater supports saline concentrations, therefore depth of water table should be kept in balance and increase in depth could provoke outbreak of much more salty nutrients in the soil resulting fertility loss. Timely recharge of surface water aquifer is as essential as much it is required for groundwater. Surface waters are significant in dispersion and dilution of nutrients inland and groundwater (Wang et.al, 2011).

CONCLUSION

Pakistan is a third world country whose economic, social and regional development is under various threats and challenges. Now with the changing world, environmental challenge is also added to the list. Safe water with optimum quality is one of the main concerns which affects every kind of consumption activity.

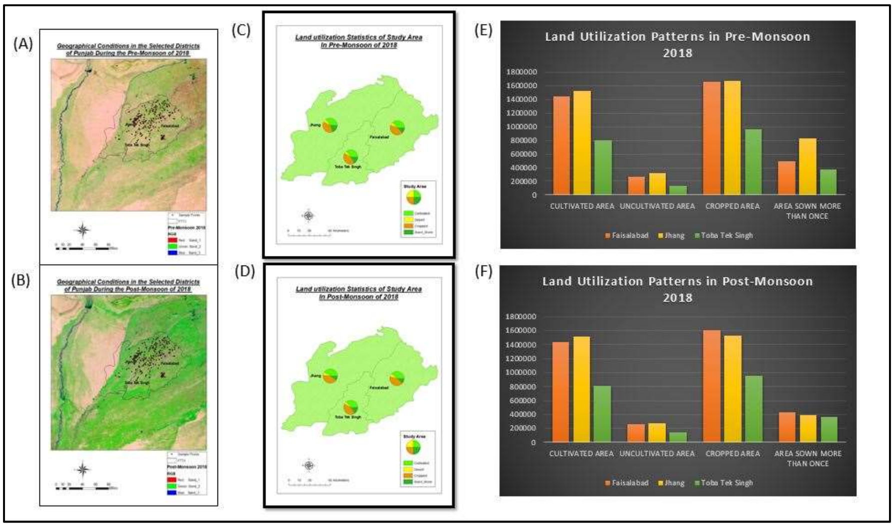

Figure 5: Vegetation Index and Land Utilization Patterns (A) Vegetation in Pre-2018 (B) Vegetation Post-2018 (C) Land-Use Pre-2018 (D) Land-Use Post-2018 (E) Graph of Land-Use in Pre-2018 (F) Graph of Land-use of Post-2018

In terms of being an agrarian country, it can be concluded from this study that a proper legal and recognized body should be made vigilant to maintain and work for the safety of the essential water resource, produce timely research on quality of all types of water and implement strict legislations to promote sustainability. “Drip irrigation” is a common strategy used in the developed countries, if applied here, Pakistan can move out of water-stressed countries. Moreover, it would be very beneficial in long run if the solution of constructing small dams and protecting watersheds can be adopted. This would not only recharge groundwater aquifer, but also prevent from decrease in water table and reduce the high and very high gradient of quality parameters.

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