ISSN 2664-4169 (Print) & ISSN 2664-7923 (Online)
South Asian Research Journal of Biology and Applied Biosciences
Abbreviated Key Title: South Asian Res J Bio Appl Biosci

| Volume-4 | Issue-1 | Mar-Apr -2022 | DOI: 10.36346/sarjbab.2022.v04i01.001

Original Research Article

Assessment of Variation in Groundwater Quality and Level for Irrigation Using Long-Term Data

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Article History
Received: 09.02.2022
Accepted: 12.03.2022
Published: 17.03.2022

Abstract: In Pakistan, the symbols of water stress are ubiquitous in the form of water resources depletion, water scarcity, quality, depletion of level and contamination. Water is a precious gift of God for all living and non-living things to complete the cycle of ecosystem. This research was conducted to check the trends groundwater level and its quality analysis using long term data of same study area. In this study area, groundwater quality and level data of 421 piezometric wells of 15 years were used to analyze through graphical analysis, from a region in Pakistan. The four major indicators for irrigation as recommended by Punjab Irrigation Department are; pH, EC, RSC and SAR. These parameters were used and appraisal for irrigation to fit or unfit the monitoring sites. The results indicate the significant increasing trend of level as well as quality of water. Average declining of groundwater table is 0.0963 meter per year in study area. As 20% of the groundwater depth is declining per year. Sites unfit ratio is 50% of the total monitoring sites being installed with respect to quality parameters. These trends indicate more water extraction in region that cause adverse effect on quality and level. This research is an excellent recommendation for water experts, to amend new law for operation of water resources and its extraction from groundwater through tubewells. The heavy metal concentration, hazardous waste to soil and sewerage of colonies should be supervised on daily basis.

Keywords: Groundwater, Quality, Level, EC, SAR, RSC.

ABBREVIATIONS
EC = Electrical conductivity
SAR = Sodium Adsorption Ratio
RSC = Residual Sodium Carbonate
HCC = Haveli Canal Circle
PCRWR = Pakistan Council of Research in Water Resources
PID = Punjab Irrigation Department.

1. INTRODUCTION

Water is important natural resource to save the livings including human beings, plants, and animals to sustain their life. Water plays a capital role in the field of agriculture, economy and industrial use. Industrial usage also effects on quality of water (Taylor *et al*., 2013; Famiglietti *et al*., 2104; Annapoorna and Janardhana, 2015). According to the report of (USGS, 2016), 2.5% freshwater availability exist in the form of resources water of earth and 30% of freshwater availability exist underground. According to 2019 scenario, Pakistan population is more than 216 million. Pakistan is countering water scarcity about less than 1000 cubic meters every year. In Pakistan, 50% of the total water used for the irrigation purpose (Chaudhary *et al*., 2002; Farid *et al*., 2017). Groundwater quality is decreasing every year due to agricultural runoff, poisonous effluent from industries, domestic and sewerage discharge. All these factors cause bad quality for drinking and irrigation water. More than 50 million-acre feet groundwater is extracted per year (Farid *et al*., 2019). The installation procedure should be changed.

Mostly extracted groundwater is used for drinking purpose. Glaciers are depleting due to climate changes and global warming. Therefore, surface water quantity in Indus Basin Irrigation System is decreasing and groundwater extraction is mandatory for every farmer to complete the needs of irrigation water for agriculture purpose. In Pakistan, groundwater extraction is increasing day by day to complete the needs of human, livestock, agriculture and industries. There is no proper installation procedure of tubewells with respect to spatial and temporal variability. Therefore, depth of groundwater has reached at its critical level. The adoption of highest efficiency irrigation system techniques is at low level as compared to developed countries. The awareness of furrow, bubbler, sprinkler and drip techniques is mandatory to small farmer of Pakistan because of more efficient than flood irrigation (Zou *et al.*, 2013).

Mandatory crops should be grown according to needs of people, that is best strategy to save water of ground and surface. From last decades water and climate scenario have become a global issue. Economy preference has becomes top priority for every country over global warming and ecosystem life. There are 1200000 number of private tubewells from which more than 90% tubewells are used for agricultural irrigation purpose and about 62 BCM (billion cubic meter) water is extracted from ground to complete the requirement of food and drinking (Arshad *et al*., 2013; Ali, 2021; Qureshi, 2012).

Pakistani economy is dependent on agriculture. But water is mandatory for crop and livestock. According to Pakistan geography and soil, rainfall, surface and groundwater are considered obligatory to sustain all living things. According to water accord 1991, 55.54 MAF (Million Acre Feet) shares of surface water are given to Punjab. About 26 MAF surface water is available on farm gate. To complete the needs of irrigation water for crops 33 MAF of groundwater is extracted from ground. While rainfall contribution is about 7 MAF. Therefore, groundwater need as become more in Punjab. But there is no policy to save groundwater quantity that is depleting. The depletion of groundwater cause bad quality of water. During seepage and infiltration process, rocks, metals and water combination exist in aquifer that cause toxic and water-borne diseases, where groundwater movement also cause bad quality. This cause prolonged effects on flow path of groundwater. Water harvesting techniques should be mandatory to control this strategy (Varol *et al*., 2015; Abbasnia *et al*., 2018; Yousefi *et al*., 2018; Fisher *et al*., 1997). The main focus of this study is to analyze the impact of groundwater quantity as well as quality of same area at a time. The four major indicators used and appraisal for irrigation to fit and unfit irrigation wells from 2005 to 2019 are groundwater level, pH, EC, SAR and RSC.

2. METHODOLOGY

2.1 Study Area

Study area of Haveli Canal Circle (HCC) was constructed in 1939, by Punjab Irrigation Department. That include the tehsil Shorkot, Kabirwala, Khanewal, Multan, Shujabad, Jalalpur Pirwala and kamalia under analysis of groundwater level and quality. It covers the area of River Chenab from about 16 kilometers upstream of Trimmu Headwork's (District Jhang) down to Jalalpur Pirwala in a length of about 290 Km. Perennial canals passes from Shorkot due to presence of brackish groundwater. In most of the area, farmers are dependent on perennial canals water, due to low quality groundwater of Shorkot.

The study area is selected to check the groundwater monitoring for quality and level for the trend analysis of past, present and for the upcoming years. For the calculations and observation of ground water quality and level, data was collected from monitoring sites, and their locations are shown on ArcGIS map in Figure 1.

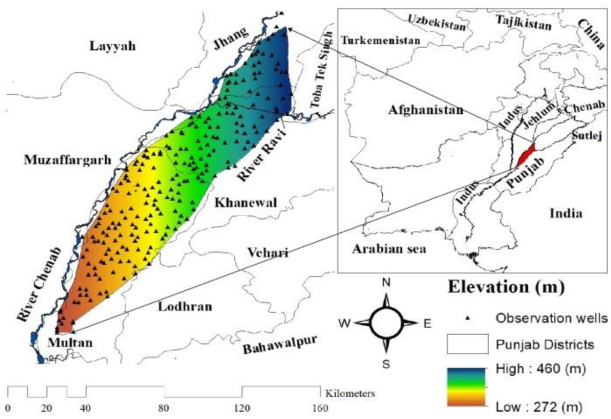

Figure 1: Location of the study area

2.2 Sampling, Data Collection and Screening

The samples from 421 monitoring sites (wells) of Irrigation department were collected for last 14 years from major part of study area of HCC, Punjab, Pakistan. The Irrigation Department chemically analyzed the data of monitoring sites, using standard protocol. The data was analyzed to determine the following four major indicators pH, EC, SAR and RSC. Data collection method adopted was systematic sampling pattern, that is easy, parallel lines and sample spaced uniformly at fixed X, Y intervals. Monitoring site's location is grid type (4 x 4) km^2. The distance from one site to another is 4 km. Data was collected in both monsoon season respectively. Water is valuable natural resource for the human being for drinking as well as for the agricultural purpose. River water is also result of mostly more rainfall in the catchment area and flows through terrains and dissolves the soluble salt and minerals that present in the soil such as Ca^{+2}, Mg^{+2}, Na^{+2}, CO_3^{-2}, HCO_3^{-2}, Cl^{-1}, SO_4^{-2} and Fe^{+2}.These are the major salts present in the form of anions and cations. Organic matter present in river are result of the decompositions of the plants, sand particles and suspension of rock. But about 10 % of total freshwater resources are in the form of groundwater, this water also a result of percolation process of rainwater, which percolate after seepage. Due to more extraction of water, groundwater decreases continuously. To assess the geochemistry of groundwater, water and industrial chemistry involve due to presence of impure metals (Gupta *et al*., 2017). So, standard water quality parameter and their normal ranges adopted by Punjab Irrigation Department are pH = 6.5-8.4**,** EC ≤ 1.5 dS/m SAR ≤ 10 meq/L**,** RSC ≤ 2.5 meq/l.

3. RESULTS AND DISCUSSION

3.1 Trend detection and estimation with graphical analysis of groundwater level:

The first part of research area is for trend detection and estimation of groundwater level monitoring. The data collected from Pre-2005 to Pre-2019 is adequate to analyze, level of groundwater level. Average, maximum, standard deviation and median are shown in Table 01, that shows average and maximum data of every year of depth of Khanewal and Multan is more than other of study area and water table is falling with more limit than other tehsils, due to low rainfall and low discharge of river. And Figure 02 indicate overall water table is falling in the overall study area. Trendline for the tehsil Multan is more than 10 degree with indicating decreasing ratio of level year to year. This pattern is increasing every year with more value addition as compared to last year. The rise-fall method was used to check the fluctuation level, that shows the minimum changing of water table depth initially and after year-2015 and water scarcity is creating continuously. Suddenly increase in level of Shorkot, Kabirwala, Jalalpur Pirwala and Shujabad was due to flood season of 2010 and 2015. There is a significant effect of flood water on water quality and level, due to variation of salinity (Ghazavi *et al*., 2012). Figure 3, indicates the maximum fluctuation upward to zero feet after 2014. Shujabad trend is increasing upward continuously, due to perennial canals and rainfall impact on water table. Sometimes Pre-pattern decreasing but Post-pattern is increasing due to rainfall of monsoon season, but now it is decreasing due to changing of climate. But comparison of pre to pre- or post-trend shows continuously decreases from one monsoon season to another.

Table 1: Average data depth to water table in (meter) in study area for tehsil wise Pre-2005 to Pre-2019

TEHSIL	SHORKOT	KABIRWALA	KHANEWAL	MULTAN	SHUJABAD	JALALPUR PIRWALA
Average	3.249	9.266	14.046	15.112	12.728	13.163
Maximum	3.957	10.18	14.57	15.848	13.988	13.963
ST-DEV	0.388	0.387	0.406	0.655	0.632	0.51
Median	3.204	9.25	14.101	15.265	12.738	13.171
Avg. Rise/year	**0.0095**	**0.0780**	**0.0972**	**0.1567**	**0.0577**	**0.0827**

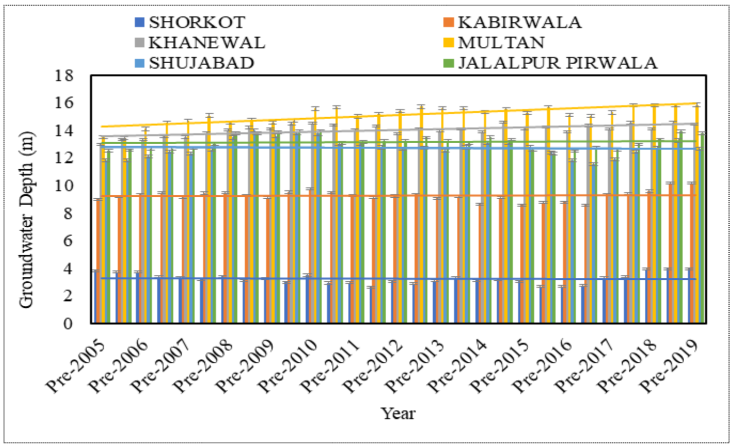

Figure 2: Groundwater level and trend pattern of different tehsils

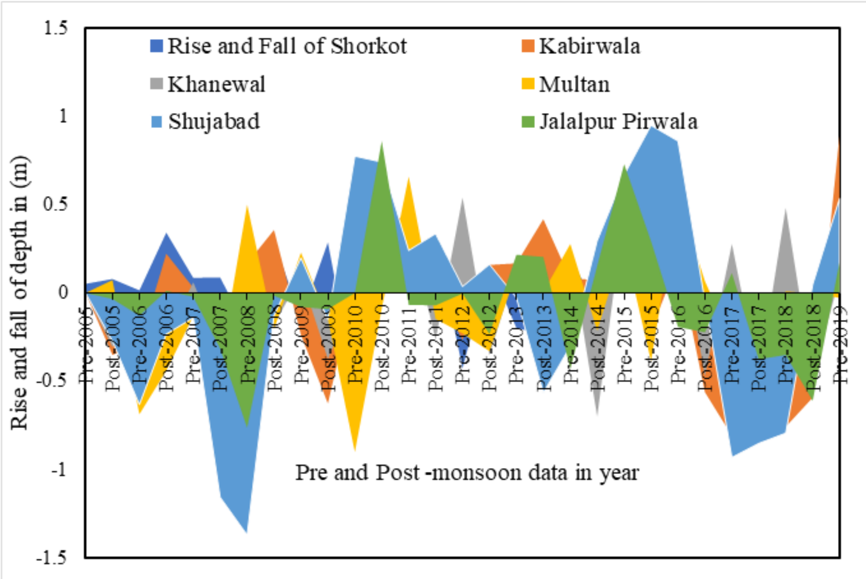

Figure 3: Fluctuation in Water table with rising and fall of water of study area, from 2005 to 2019

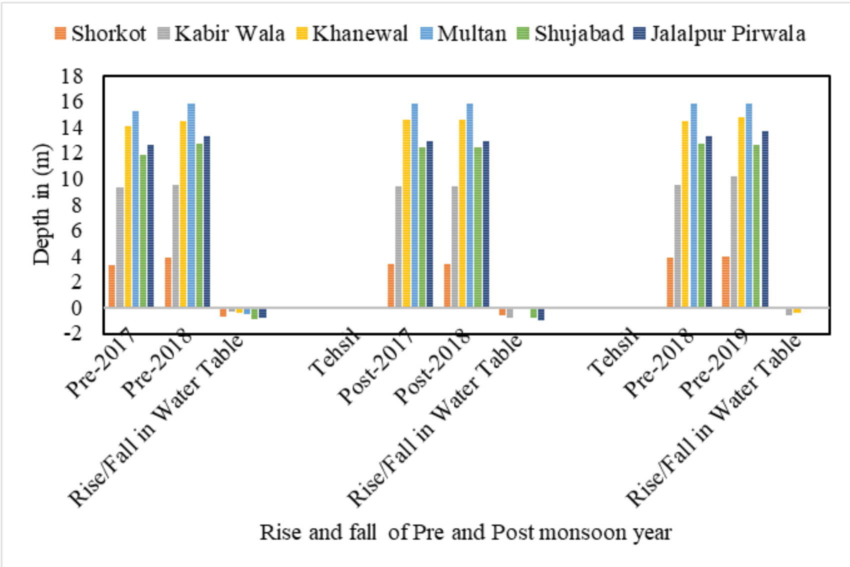

Figure 4: Last 3-year fluctuation of Water Table of study area

Figures 5 to 10 shows the groundwater table fluctuation for the years 2005 to 2019 at Shorkot, Kabir Wala, Khanewal, Multan, Shujabad and Jalalpur Pirwala. The analysis shows that the groundwater table is decreasing during the Pre-monsoon season for all the years 2005 to 2019. as well as Post-monsoon of two consecutive years also decreasing, that show Post-monsoon data also fluctuate as like Pre-monsoon that has no effect of rainfall on water table due to change of critical climate change decreasing of rainfall and increasing of temperature year to year. Figure 4 uses rise and fall pattern with indicating continuously falling pattern of groundwater level of last three year**.** Groundwater level detection is declining suddenly after 2015 of study area. Overall, every tehsil trend analysis is decreasing in Figure 11. The reason of declining water table is climate changing, decreasing discharge of canal and due to lined and non-perennials canals presence and level trend is showing to increase suddenly after 2015 of study area in Figure 11. Average decrease of water table depths in meter per year of tehsil Shorkot, Kabirwala, Khanewal, Multan, Shujabad and Jalalpur Pirwala are 0.0095, 0.0780, 0.0972, 0.1567, 0.0577 and 0.0827 meter respectively as shown in Figure 12.

The results of this research will be helpful for the policy maker, to operate water resources at proper time with standard procedure of installation of tubewells. Most of the industries store toxic pollutant and effluent to dispose of. But they adopt unscientific methodology to dispose wastewater and debris material through bore and leachate. Mostly this waste material is discharged with runoff of rainfall. Therefore, proper check and balance is necessary to control quality of water to save water and life. Below the water table, there are mostly rocky area so there involves water chemistry of different reactions that includes different minerals and metal in impure form, and this water is also extracted through tube wells with poor quality. With decreasing of water table, water and hydrological chemistry also involve that effect on water quality. When water table decreases up to critical level, then extraction of water reaches up to critical level, where water chemistry involves. In the area having lined canals and areas, so less water percolate and because of decreasing pattern of rainfall with increasing temperature, more declining is detected. But average declining of overall study area is 0.09636 meter (0.3160 feet). And main reasons for fluctuation of water table in study area are due to following reasons, such as:

Continuous pumping of ground water through the private tube wells at large scale due to shortage of canal water, less number of canals and due to presence of non-perennial canals in study area. Increase in cropping intensity such as, in given tehsils of Punjab number of crops raising per year is more in same field. Poor recharge through rivers and canals due to fluctuation in discharge of river Chenab and presence of non-perennials canal, Low rainfall, Misuse of groundwater due to unawareness and Lack of adaptation of water saving techniques/ practices in given tehsils.

In Figure 5, main reasons for fluctuation for high water table in tehsil Shorkot are high rainfalls in recently last years, perennial Irrigation system (Perennial-canal) and high-water discharge and prolong supply period of Trimmu Sidhnai Link Canal. But the policy maker should develop such policies that make water table helpful to maintain instead of declining of water table. If water table cannot be increased, then such policies should be developed that will be helpful to maintain the water table. But in Lahore water table conditions is too much critical in which no policy was given and there is no seepage rate because of its overall surface is veteranized. However, question arises how to control the decline or lowering of water table, that is decreasing day by day inappropriately due to several given reason. The clarifications and solution to control the declining of water table by giving instruction to farmer as well as by making good policies are following.

Zero tillage technique should be adopted (Desta *et al*., 2021). Areas should be cleared according to standards, for low-delta and high-delta crops accordingly. Supply of canals must be increased through increasing depth, lining, remodeling of canals, and lined water course system, so that farmer would minimize the uplifting process of under groundwater. Canals should be perennials instead of non-perennials and inundation. With the help of legislation, groundwater regulatory framework should be developed. But legislation is necessary to ban, for the installation of the Sugar & Rice Mills in cotton areas/belts and vice versa because of sugarcane and rice crop, farmer uplift more water, to complete their requirements. Attention should be given to water resources and storage bodies such as dams and water conservation, on war-footing basis instead of bewailing water scarcity. Water saving techniques and practices should be adopted such as drip and sprinkler irrigation, laser land leveling technique, bed sowing, mulching, farmyard manuring (FYM), and green manuring (Sharma *et al*., 1998; Mou *et al*., 2014).

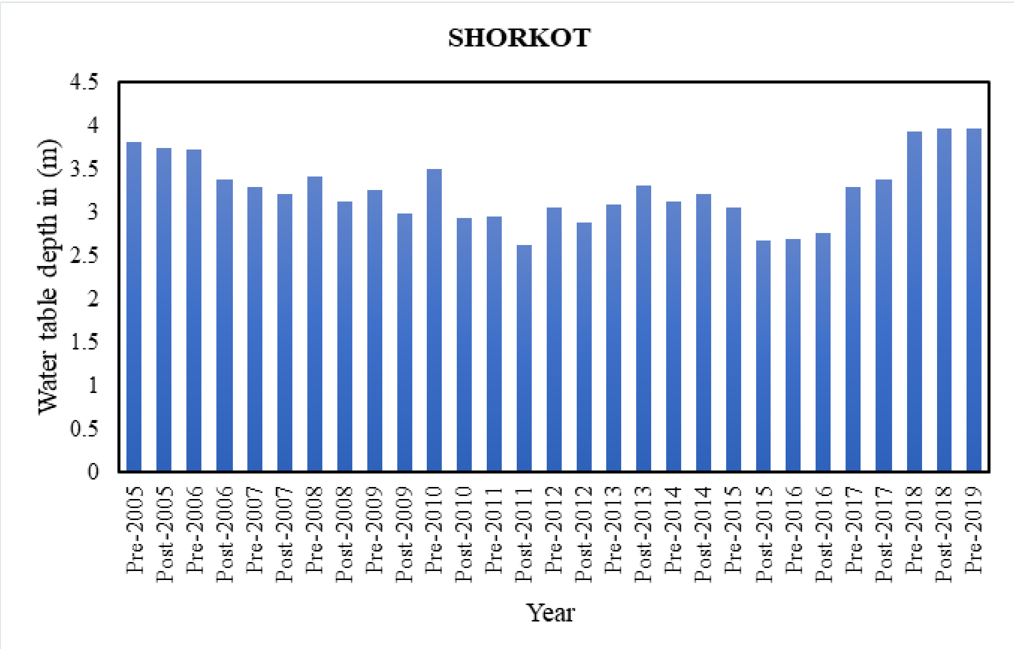

Figure 5: Average data depth to water table tehsil Shorkot from 2005 to 2019 (pre & post-monsoon)

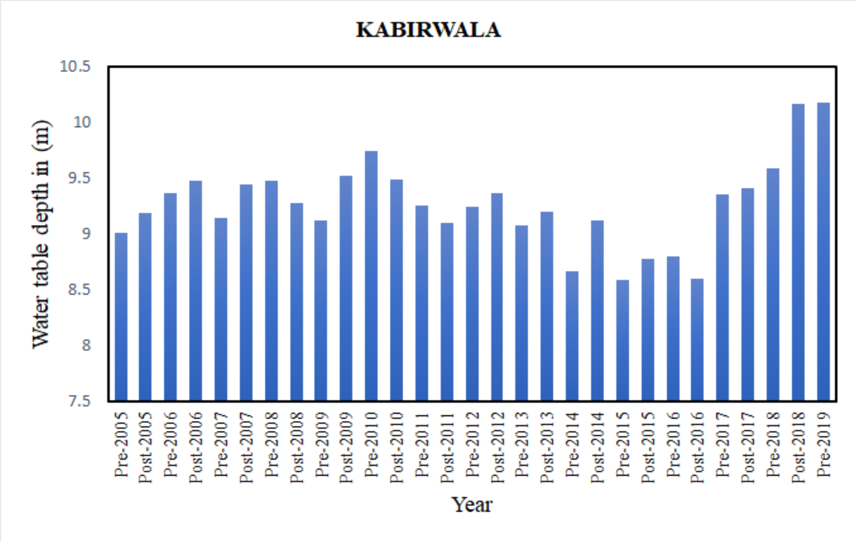

Figure 6: Average data depth to water table tehsil Kabir Wala from 2005 to 2019 (pre & post-monsoon)

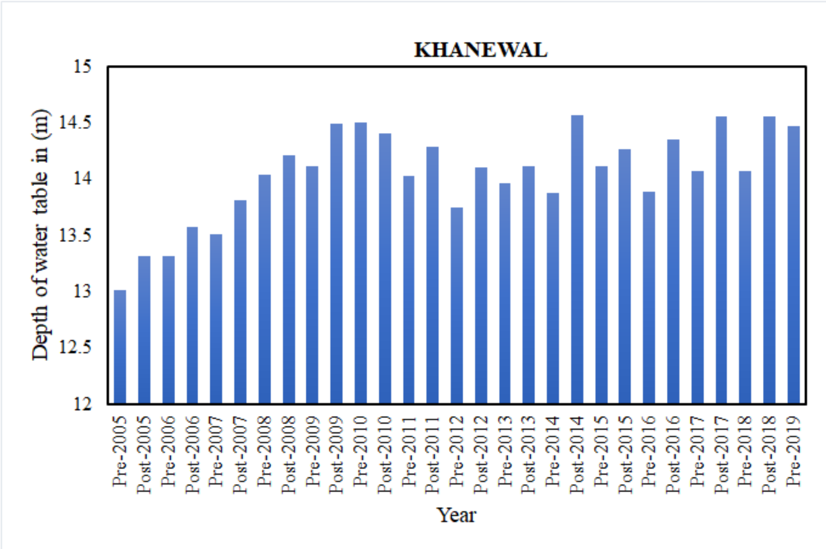

Figure 7: Average data depth to water table (m) tehsil Khanewal from 2005 to 2019 (pre and post-monsoon)

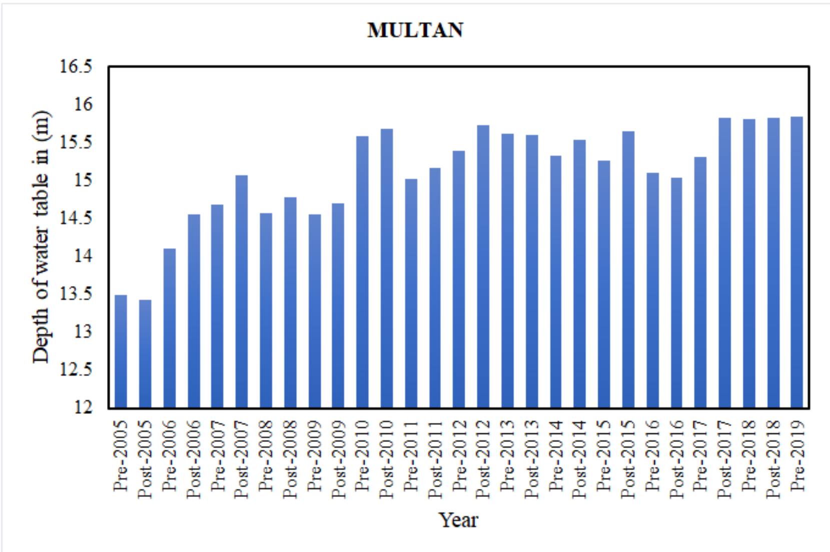

Figure 8: Average data depth to water table (m) tehsil Multan 2005 to 2019 (pre & post-monsoon)

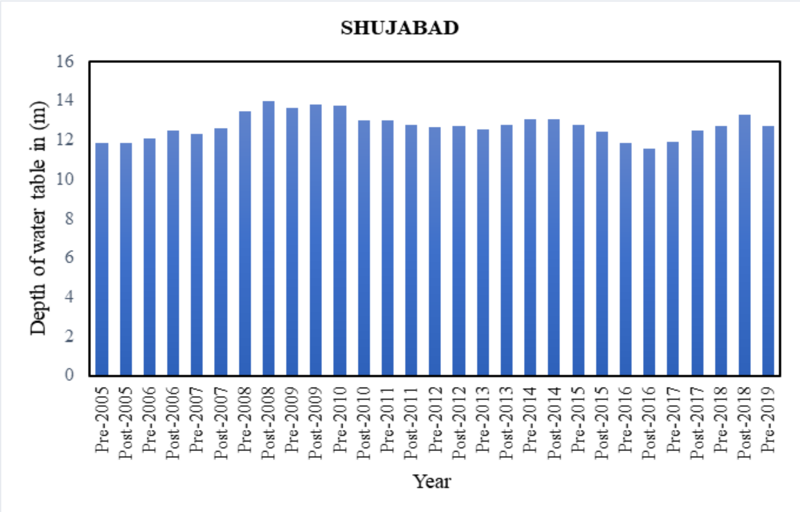

Figure 9: Average data depth to water table (m) tehsil Shujabad from 2005 to 2019 (pre & post-monsoon)

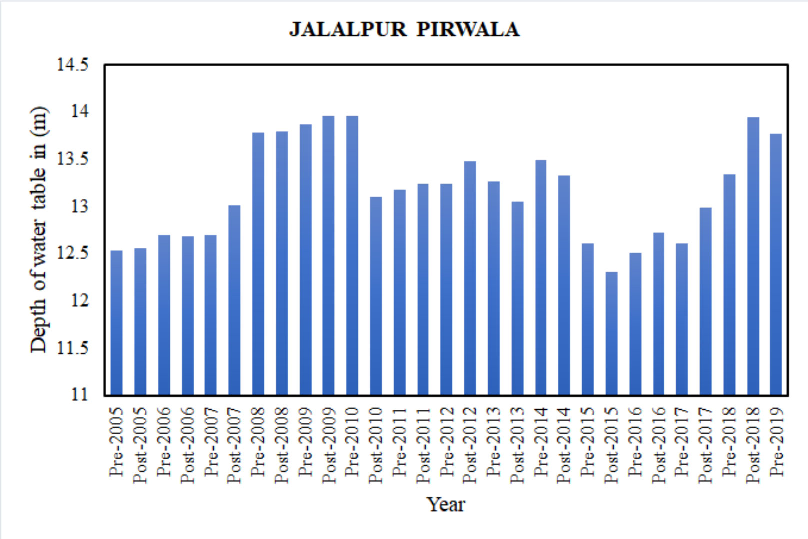

Figure 10: Average data depth to water table (m), tehsil Jalalpur Pirwala from 2005 to 2019 (pre & post-monsoon)

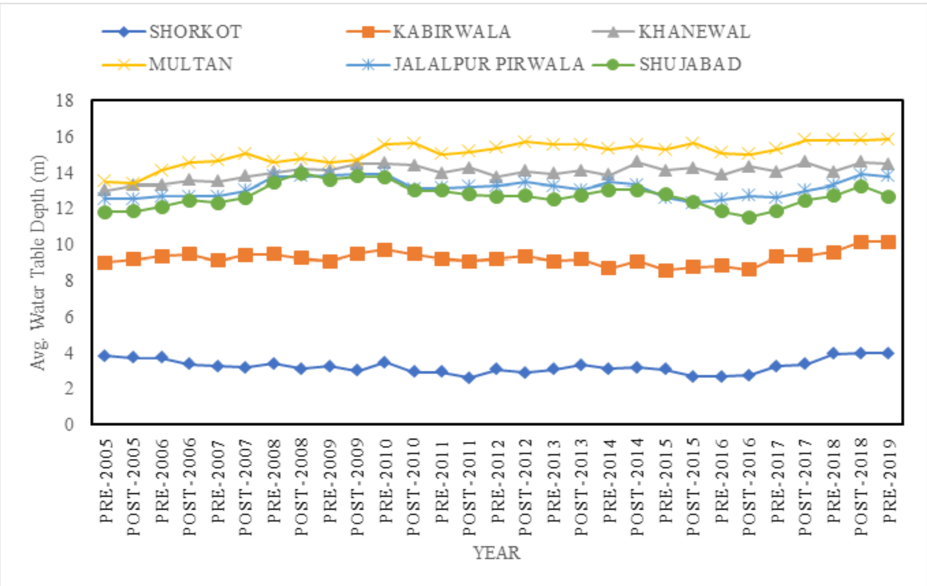

Figure 11: Last 15-year Fluctuation in ground water depth of study area

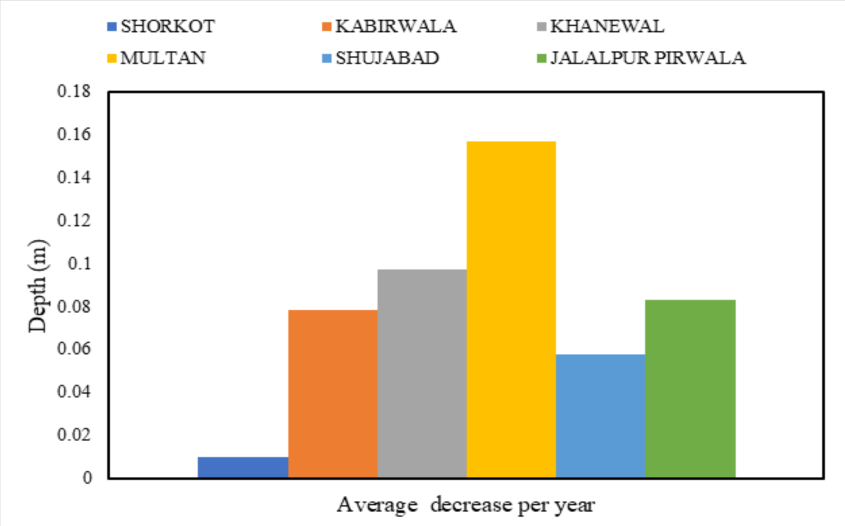

Figure 12: Average decrease of water table depth per year

3.2 Groundwater Quality Monitoring and Analysis
Trend detection and estimation with graphical analysis of groundwater quality

Table 2: Data of water quality samples for agricultural use post-2008 to post-2018 in study area

Sr. No	District	Tehsil	Total	Fit for Irrigation	% age	Unfit for Irrigation	% age	% age Fit for Irrigation	% age Unfit for Irrigation	% age Fit for Irrigation	% age Unfit for Irrigation
				2018					**2013**		**2008**
1	Jhang	Shorkot	50	28	56.00	22	44.00	66.67	33.33	70.83	29.17
2	Khanewal	Kabir Wala	135	105	77.77	30	22.23	78.57	21.43	77.55	22.45
		Khanewal	21	11	52.38	10	47.62	53.85	46.15	53.85	46.15
3	Multan	Multan	138	95	68.84	43	31.16	75.00	25.00	72.66	27.34
		Shujabad	46	23	50.00	23	50.00	58.00	41.03	64.10	35.90
		Jalal Pur Pirwala	22	18	81.81	04	18.19	66.67	33.33	80.00	20.00
4	T.T. Singh	Kamalia	09	06	66.66	03	33.34	66.67	33.33	66.66	33.34
Total =			421	286	67.93	135	**32.07**	71.75	**28.25**	72.33	**27.67**

But the area of second part is to analyze groundwater quality on same monitoring sites, to check water quality of the tube wells for irrigation purpose. The fit and unfit criteria of wells chemically analyzed by four basic indicator of irrigation such as PH, EC, SAR and RSC. From the calculation of collected data, In Table 3, percentage of unfit wells increasing gradually. Data of groundwater quality samples for agricultural use is chemically analyzed on the base of EC, SAR and RSC parameters for the last ten year. Unfit observed monitoring sites of groundwater quality parameters for irrigation are on basis of EC, SAR, RSC, (EC+SAR), (EC+RSC), (SAR+RSC) and (EC+SAR+RSC) as shown in Fig 13. Unfit wells in 2008 were 96 but in 2018 were 135. Quantity of unfit wells increased year by year about 3.9 wells per year with 0.44% wells per year. In Graphical analysis of Figure 13, unfit wells pattern of every tehsil study area is shown to increase gradually with curved edges of graphical analysis and shows 0.44 % is the number of unfit wells per year and the number of effected tubewells during 11-year interval are shown in Table 3.

$n = y_2 - y_1 / x_2 - x_1$

n = (135-96)/(2018-2008)
n = 3.9 (tubewells / year)
= (0.44 % per year)
n= No of tube wells per year.

The Figure 13 shows 0.44 % is the number of unfit wells per year. Sodium residual effect the electrical conductivity during rainfall season and at different temperatures. Water chemistry involve during underground water movement that may cause bad quality of water by affecting SAR and RSC parameters (Ali *et al*., 2020).

When water table decreases, it also effects the ground water quality. Water table reaches up to leachate and different feldspar and reactive minerals. In this aquifers place, water chemistry is involved, and different reactions take place, where water is extracted continuously through tube wells for agricultural purpose from such aquifers place and delivered to field where salt may reclaim on earth surface and surface become salty. During post monsoon season of every year, these salt leach down to ground water table and effect the ground water. Therefore, quality and quantity of surface and groundwater should be monitored on daily basis with spatio-temporal variability.

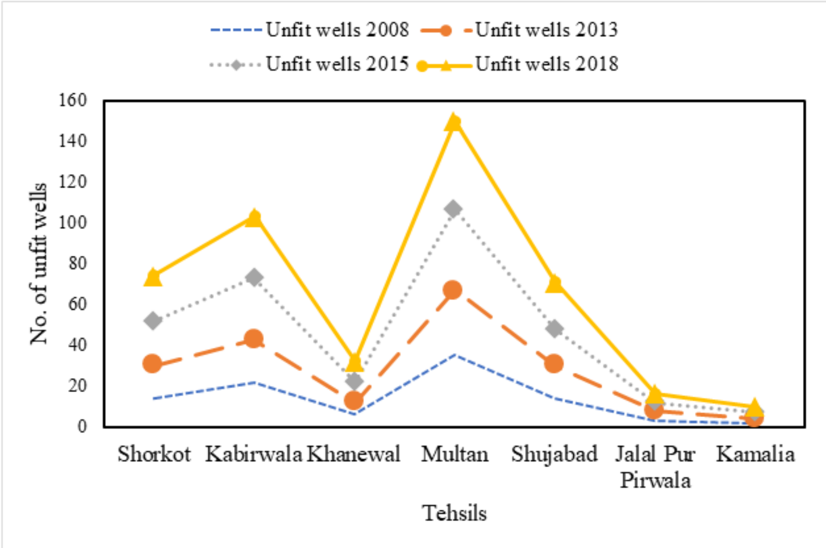

Figure 13: Unfit wells pattern from 2008 to 2018 of study area

Table 3: Unfit wells percentage from 2008 to 2018

Year	Unfit wells	%age
2008	96	27.67
2013	98	28.25
2015	127	30.17
2018	135	32.07

CONCLUSION

Rise-fall method was adopted to check the declining of water table depth. Groundwater level is decreasing continuously due to poor recharge through rainfall and decreasing canal discharge of Haveli Main Line from 2014 and 2017 are 2816.29 and 1947.71 cumecs respectively in tehsil Shorkot, as well as discharge of Sidhnai Canal and discharge of Shujaabad Canal are also decreasing year by year. Average declining of groundwater table is 0.09636 meter per year in HCC area. Declining of groundwater level effects, the groundwater quality. Water level declining in whole study area is 20% per year. Extraction of water is increasing due to more installation of private tube wells, such as eight tube wells (1.75%) per year. But four tube wells per year (0.44%) are becoming unfit according to unfit criteria of Punjab Irrigation Department (PID) and PCRWR. The ratio of unfit tube wells to number of increasing tube wells is 1:2 (50%). According to future strategy, if tube wells installation is increasing then half number of tube wells will be unfit. So strict policies should be implemented, on tube well installation that has adverse effect on both groundwater level and quality.

Author's Contribution

Asif Ali planned and conducted the study, collected data, analyzed data, wrote initial draft of this article. Mehboob Hassan, Hafiz Fiaz and Fakhar Din Khan: Supervised field work study, during under two-month Internship Program July-2019.

REFERENCES

- Ali, A. (2021). Assessment of Spatial and temporal variability of surface water quality of Irrigation Canals. A case study of Trimmu Head Canals under Chenab River area. *Pakistan Journal of Multidisciplinary Research*, *2*(1), 9-24.
- Arshad, M., Shakoor, A., Ahmad, I., & Ahmad, M. (2013). Hydraulic transmissivity determination for the groundwater exploration using vertical electric sounding method in comparison to the traditional methods. *Pakistan Journal of Agricultural Sciences*, *50*(3), 487-492.
- Abbasnia, A., Alimohammadi, M., Mahvi, A. H., Nabizadeh, R., Yousefi, M., Mohammadi, A. A., ... & Mirzabeigi, M. (2018). Assessment of groundwater quality and evaluation of scaling and corrosiveness potential of drinking water samples in villages of Chabahr city, Sistan and Baluchistan province in Iran. *Data in brief*, *16*, 182-192.

- Ali, A., Farid, H. U., & Khan, M. M. H. (2020). Divergent effect of rainfall, temperature and surface water bodies on groundwater quality in Haveli Canal Circle of Multan Irrigation Zone, Southern Punjab. *Pakistan. Journal of Environmental and Agricultural Sciences*, *22*(4), 25-36.
- Chaudhary, M. R., Bhutta, N. M., Iqbal, M., & Subhani, K. M. (2002, December). Groundwater resources: use and impact on soil and crops. In *Second South Asia Water Forum* (pp. 14-16).
- Desta, B. T., Gezahegn, A. M., & Tesema, S. E. (2021). Impacts of tillage practice on the productivity of durum wheat in Ethiopia. *Cogent Food & Agriculture*, *7*(1), 1869382.
- Fisher, R. S., & Mullican III, W. F. (1997). Hydrochemical evolution of sodium-sulfate and sodium-chloride groundwater beneath the northern Chihuahuan Desert, Trans-Pecos, Texas, USA. *Hydrogeology journal*, *5*(2), 4-16.
- Farid, H. U., Mahmood-Khan, Z., Ali, A., Mubeen, M., & Anjum, M. N. (2017). Site-Specific Aquifer Characterization and Identification of Potential Groundwater Areas in Pakistan. *Polish Journal of Environmental Studies*, *26*(1), 17–27.
- Farid, H. U., Ahmad, I., Anjum, M. N., Khan, Z. M., Iqbal, M. M., Shakoor, A., & Mubeen, M. (2019). Assessing seasonal and long-term changes in groundwater quality due to over-abstraction using geostatistical techniques. *Environmental Earth Sciences*, *78*(13), 1-12.
- Famiglietti, J. S. (2014). The global groundwater crisis. *Nature Climate Change*, *4*(11), 945-948.
- Gupta, V. S. S. R., Rao, R. S., & Divya, K. (2017). Evaluation of groundwater quality using multivariate statistical techniques and GIS–a case study. *International Journal of Civil Engineering and Technology*, *8*(8), 1165-1176.
- Ghazavi, R., Vali, A. B., & Eslamian, S. (2012). Impact of flood spreading on groundwater level variation and groundwater quality in an arid environment. *Water resources management*, *26*(6), 1651-1663.
- Annapoorna, H., & Janardhana, M. R. (2015). Assessment of groundwater quality for drinking purpose in rural areas surrounding a defunct copper mine. *Aquatic Procedia*, *4*, 685-692.
- Mou, Y. J. (2014). Current situation and development trend of agricultural water saving irrigation in China, *J Shandong Agricultural Sciences*, 124-126.
- Qureshi, A. S. (2012). Groundwater management in Pakistan: The question of balance. *Centenary Celebration (1912–2012), Paper*, (717), 207-217.
- Sharma, R. C., Govindakrishnan, P. M., Singh, R. P., & Sharma, H. C. (1988). Effects of farmyard manure and green manures on crop yields and nitrogen needs of potato-based cropping systems in Punjab. *The Journal of Agricultural Science*, *110*(3), 499-504.
- Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., Van Beek, R., Wada, Y., ... & Treidel, H. (2013). Ground water and climate change. *Nature climate change*, *3*(4), 322-329.
- Varol, S., & Davraz, A. (2015). Evaluation of the groundwater quality with WQI (Water Quality Index) and multivariate analysis: a case study of the Tefenni plain (Burdur/Turkey). *Environmental Earth Sciences*, *73*(4), 1725-1744.
- Yousefi, M., Yaseri, M., Nabizadeh, R., Hooshmand, E., Jalilzadeh, M., Mahvi, A. H., & Mohammadi, A. A. (2018). Association of hypertension, body mass index, and waist circumference with fluoride intake; water drinking in residents of fluoride endemic areas, Iran. *Biological trace element research*, *185*(2), 282-288.
- Zou, X., Cremades, R., Gao, Q., Wan, Y., & Qin, X. (2013). Cost-effectiveness analysis of water-saving irrigation technologies based on climate change response: A case study of China. *Agricultural water management*, *129*, 9-20.