# The Causes of Depletion in Groundwater in Pishin District of Balochistan

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**ABSTRACT**
The present study has been undertaken to analyses the current situation of groundwater and reason for depletion of groundwater in Pishin District of Balochistan. The study is based both on primary and secondary data. The primary data has been collected from farmers through questionnaires. A sample of one hundred and five farmers has been selected randomly through a stratified random sampling method. Secondary data in the form of published literature and reports were used in order to support the study. The main findings of the study were that the current situation of groundwater was very critical in Pishin district. The groundwater levels were declining at an alarming rate of 16 to 25 feet annually. The reason for groundwater depletion included subsidy on electric tubewells, indiscriminate installation of tubewells, violation of tubewells spacing norms and running hours of tubewells. Moreover, the results also showed that most of the farmers were not educated and they were not aware of the use of high-efficiency irrigation system which led to mismanagement of water resources in the study area of Pishin district. On the basis of the results of this study, it has been recommended that the government develop effective strategies to put a restriction on the installation of more tubewells, awareness campaigns for educating farmers about the use of high-efficiency irrigation system, and educating farmers regarding adaption of the modern techniques of production.

**Keywords:** Groundwater, depletion, subsidy, installation of tubewells, high-efficiency irrigation system, educating farmers, mismanagement.

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## 1 INTRODUCTION

Intensive use of groundwater is common in many parts of the world, particularly in the arid and semi-arid area. Groundwater is generally a reliable and good quality water source, and with modern technology for drilling, electrification, and pumping, it is widely accessible in many parts of the world [23] (Villholth, & Giordano, 2007). Groundwater constitutes critical components of water resources [19] (Russo, & Lall, 2017), and it is an important water supply for more than two billion people around the world, it also provides more than 40 percent of the irrigation supply for global agricultural production [5] (Gaily, 2018)). Groundwater is an important factor for reducing poverty and malnutrition, and improving sanitary condition; it has helped farmers to overcome the poverty thresholds in many regions [4] (Custodio, Kretsinger, & Llamas, 2004). Millions of farmers and consumers have benefited from the growth of groundwater use all around the world [22, 17] (Shah, Singh, & Mukherji, 2006; Qureshi, Gill, & Sarwar, 2008). The major stimulating factor of groundwater development has been the groundwater related policies adopted in many of the countries of South Asia and China [17] (Qureshi, Gill, & Sarwar, 2008). Groundwater is minded for irrigation use in many industrialized and developing countries including India, Pakistan, China, Yemen, and the United State [15] (Landefeld, & Sekhri, 2015).

The rapid population growth, improved living standards, and climate change resulted significantly increase the demand for water demand globally in the next few decades. With the projected increase in global population and economic growth, the demand for water increased [10] (Khair, Mushtaq, & Smith, 2014). The per capita availability of water in many countries of the world has been declining sharply, especially in countries having low rainfalls. Moreover, due to groundwater over-exploitation and mismanagement, in many arid regions, it sends a major warning to the effect on the environment, health and food security [13] (Khair, Mushtaq, Culas, & Hafeez, 2011). Additionally, due to the absence of sufficient institutional setups for resource availability, extraction and use checks in most developing countries, inter-generational, inter-temporal and inter-spatial misallocation is taking place. It is resulting in a serious overdraft and has caused several externalities [11] (Khair, & Culas, 2013). Pumping of groundwater lowers of water table creating a cone of depression around the world [18] (Rathfelder, 2016). The consequence of groundwater mismanagement seems to be disastrous in many countries of the world [20] (SAM, 2009). The declining water tables, due to over-extraction, is now a great problem in many arid and semi-arid region of the world. There is still time to learn from the experience of one another around the world provided that increased focus, awareness, and political will is exercised [23] (Villohlth, & Giordano, 2007).

Poverty alleviation programs in many developing countries have included subsidies for agricultural inputs. Such subsidies have played a significant role in the development of tubewells irrigation by reducing the cost of groundwater extraction, increasing crop yields and lowering food prices [3] (Badiani, & Jessoe, 2011). In India, electricity subsidies enable farmers to use electricity for groundwater pumping at a price below the marginal cost of supply, reducing their inputs cost [3] (Badiani, & Jessoe, 2011). Similarly, in Pakistan, the subsidy for electricity supply to agriculture tubewells is high, amounting Rs. 7 billion in 2011 for around 16,000 tubewells in Balochistan province alone [10] (Khair, Mushtaq, & Smith, 2014). Pakistan is among the most groundwater dependent countries, but it is struggling to established suitable groundwater policies and governance arrangements. Currently, the rate of abstraction of groundwater far exceeds in replenishment, causing massive resource depletion, particularly in the water-poor province such as Balochistan [12] (Khair, Mushtaq, Culas, & Hafeez, 2012).

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Balochistan is facing an unprecedented water shortage, owing to climate change and poor water management resulting in the exploitation of water at a rate faster than its replenishment. This situation worrisome as water tables are falling at the rate of more than two to five meters per annum, threatening the viability of agricultural communities [13] (Khair, Mushtaq, Culas, & Hafeez, 2011). Balochistan is characterized by tubewells as the main source of irrigation. The government's past and current groundwater development policies, such as electric tubewells subsidy to encourage farmers to use groundwater for increased agricultural production and to support farmers' incomes have resulted in a massive drawdown of water table [1] (Ahmad, 2006a). However, as a result of over-exploitation of groundwater resources and increasing water scarcity, tubewells are now drying up in many parts of Balochistan. Drying tubewells, as a result of declining in water tables, have resulted in the dispossession of a large number of tubewells owners from their source of irrigation. Groundwater availability in this region has reached a threshold limit where small and medium farmers are increasingly opting to buy water to avoid damage to high valuable fruit crops [10] (Khair, Mushaq, & Smith, 2014).

Pishin district is one of the district of Balochistan province in Pakistan. Pishin district lies in a semi-arid region in the northern part of Balochistan province. Agriculture, livestock, and fruit production are the major source of income for the majority of farmers in district Pishin. A major source of water supply for irrigation needs is fulfilled by using a different source of groundwater like karezes, springs, dug-wells, and tubewells. Pishin district is characterized by low rainfall and a frequent spell of drought, where water resources cannot meet the domestic, agriculture and livestock needs.

Historically, groundwater has been an important source of irrigation water in Pishin district. The electrification program introduced the use of tubewells for the development of groundwater resources and there has been a rapid increase in the drilling activities over the past 40 years with some major benefits but also some disadvantages, such as indiscriminate installation of tubewells and pumping of water in excess of recharge have caused lowering of water table resulting in the drying of dug-wells and a number of karezes and springs. The depletion of groundwater due to widespread of rural electrification, subsidy on electric agriculture tubewells, the illegal abstractors and lack of proper regulation for the management of groundwater. The mining of groundwater and lowering of the water table are causing serious concern regarding the sustainability of groundwater irrigated agriculture. By analyzing the history of groundwater depletion and investigating farmers' perspectives on groundwater development, this study aims to produce scientific knowledge about the depletion of groundwater resources, and the reason for depletion of groundwater in the study area of district Pishin.

### 1.2 Objectives of the Study

1.2.1 To assess the current situation of groundwater depletion in the study area of district Pishin.

1.2.2 To find out the factors causing of groundwater depletion in the study area of Pishin district.

1.2.3 To suggest measures and techniques for controlling of depletion in groundwater in the study area of Pishin district.

## 2. MATERIAL AND METHODS

This section presents the general description of the study area; provide information about data sources, a collection of data instruments, sampling techniques, and methodology.

### 2.1 The study area

Balochistan is the north western province of Pakistan that is located between latitudes 25° and 32° N, and longitudes 61° and 71° E. The geographical area of Balochistan is around 347,190 square kilometers. The provincial plateau is mostly comprised of hilly terrain. Balochistan has an annual rainfall of less than 250 mm on average. The province can be classified as a dry/arid region and thus the reliance on rainfall for crops growing is low, which intensifies the search for a more reliable water source to secure irrigation to ensure high crop yields for the Balochistan farmers.

### 2.2 Study Area: An Overview of Pishin District

The Pishin District can be classified as arid in term of rainfall, receiving an average rainfall 200 mm to 250 mm annually. Pishin district is located, 1370-1680 meter above sea level, in the north part of Balochistan. It is bordered with Afghanistan to the west, Killa Saifullah to the east, Killa Abdullah to the north, Quetta and Ziarat districts to the south. The area of Pishin district is immense importance for the examination of water scarcity as the groundwater is depleting at an alarming rate and water shortage for the economic and non-economic use is one of the major problems facing by people in the study area of Pishin [9] District (Kakar, 2017).

### 2.3 Research Methods Used

A comprehensive questionnaire was developed to collect information from farmers related to land use, crops, yields, cropping pattern, irrigation practice, the profile of groundwater irrigation, critical problems faced by groundwater economy, estimation of private tube wells and groundwater extraction. Information was collected from farmers at the village level

### 2.4 Reliability and Validity of Questionnaire

As the questionnaire contains a question on a nominal scale, and include both open-ended and closed-ended questions, it was not possible to measure the reliability and validity by using statistical tools. However, the questionnaire was distributed among the exports for their valuable suggestions to ensure the reliability and validity of the instruments. As the comments and suggestions received from the exports and their incorporation, the instrument was finalized for the survey. Moreover, for strengthening the validity of the instruments, the questionnaire was pretested in the field by interviewing ten (10) farmers in Pishin District. The instrument was revised after pretesting based on the feedback.

### 2.5 Data Collection/Sampling Methods

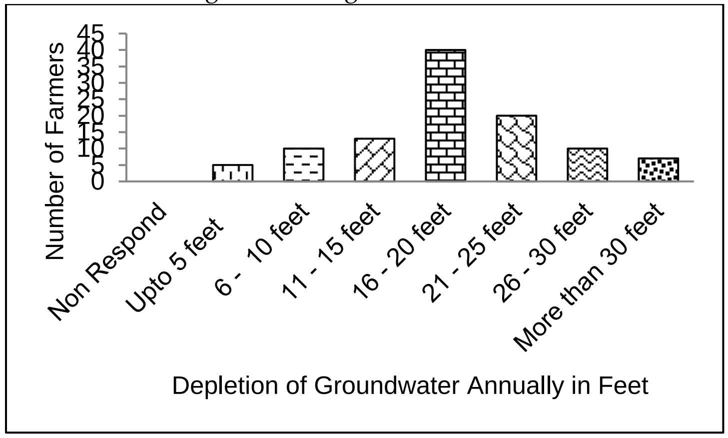
Primary and secondary data were used for this study. Primary data has been obtained through a questionnaire, interviews, and group discussion from the farmers in the study area of Pishin district. The farmers' community of the study area is taken as a target population. Pishin district consists of four Tehsil, i.e. Barshore Tehsil, Karezat Tehsil, Pishin Tehsil, and Huramzai Tehsil. A sample of 105 farmers selected randomly from all the Tehsil of Pishin District. The sample size based on stratified random sampling from each Tehsil of Pishin district according to their population proportion. Moreover, secondary data were collected from the relevant government department which included the Department of Agriculture Research and Extension, Irrigation and Power Department, Planning and Development Department, NGOs and other relevant departments.

## 3 RESULTS AND DISCUSSIONS

This section presents the results and discussions of the research; the purpose of this section is to present the farmers' perception about the depletion of groundwater and factors causing the decline of groundwater in the study area of Pishin District. The details are as follow:

### 3.1 Groundwater Depletion

Pishin District lies in an arid region characterized by low rainfall and extremely high evaporation rates. Groundwater is the major source of irrigation in the study area of Pishin District. Prior to 1980s when there was no electricity in the study area, the sources of irrigation were well, springs and karezes. After electrification, and high profit from agriculture production, replaced the traditional sources with the tubewells technology. The main purpose behind such replacement was the efficient use of groundwater resources. However, this development led to the over-exploitation of groundwater and resulted in depletion of water table. During the survey, it was noted that although the farmers were aware of the rapid decline of the water table, but they had no choice as the groundwater was the main source of irrigation. According to [14] (Khair, Culas, & Hafeez, 2010) that the groundwater levels in upland Balochistan were declining at an alarming rate of 2 to 3 meters annually. [7] (Halcrow, 2008) studied in the alluvial aquifer of Quetta valley and concluded that the decline of the groundwater table was around 18-24 feet per year. Similarly, [1] (Ahmad, 2006a) studied that the water table in the three basins-Pishin Lora basin (PLB), Nari River Basin (NRB), and Zhob River Basin (ZRB) of Balochistan are declining at the rate of more than four to five meters annually. The overall water table decline from 50-100 feet to 200-700 feet in a period of around 30 years is an excellent example of water mining. During the survey when the farmers asked for knowing the rate of annual decline in groundwater table in Pishin District. The following responses have been received from all the farmers which are showing below in figure 1.




Source: Field Survey

Fig 1: Depletion of Groundwater Annually in Feet in Pishin District

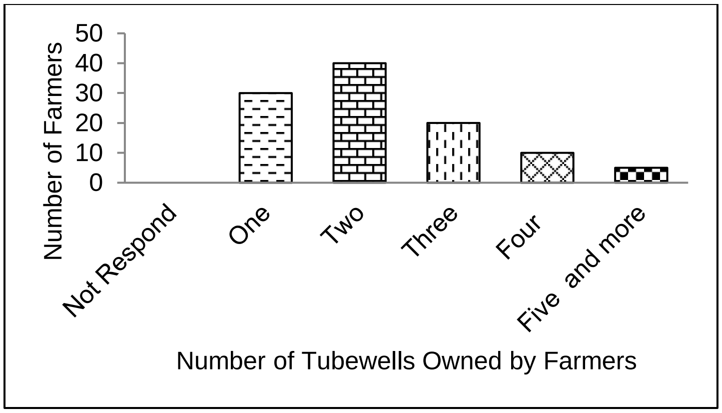
Figure 1 shows the farmers response about the annual depletion of groundwater table in the study area. It can be seen that majority of farmers i.e. 60 out of 105 farmers mentioned that groundwater is declining with an annual rate of 16 to 25 feet per year. Similarly, 10 farmers pointed out that it is declining at a rate of 26 to 30 feet annually, 13 farmers mentioned that 11 to 15 feet per year and 10 farmers stated that the rate of depletion is 6 to 10 feet annually. Overall out of 105 farmers 70 stated that the groundwater is depleting 25% annually which is a very high rate in Balochistan. It is further noted that farmers are the only source of information in the study area even providing information about the groundwater depletion to the Government Irrigation and Agriculture Department due to lack of an effective monitoring system.

### 3.2 Factors Causing for Groundwater Depletion

Followings are the causes of depletion in groundwater in the study area of Pishin District.

#### 3.2.1 Indiscriminate installation of Tubewells

During the survey, it was noted that in spite of the persistent decline of the groundwater table, the farmers were installing more and more tubewells for the irrigation water requirements. There was no mechanism for the installation of new electric tubewells. Anyone could drill the boreholes and install the tubewells anywhere, without caring for any kind of standards or regulations for the selection of site, technique for drilling, material, and design. According to [2] (Ahmad, 2006b) that the unchecked installations of tubewells are in large numbers, indiscriminate pumping of water and highly subsidized electricity was the main reasons for depletion of groundwater in Balochistan. During the survey, when the farmers asked about the number of tubewells they owned, the following response has come from farmers as shown below in figure 2.

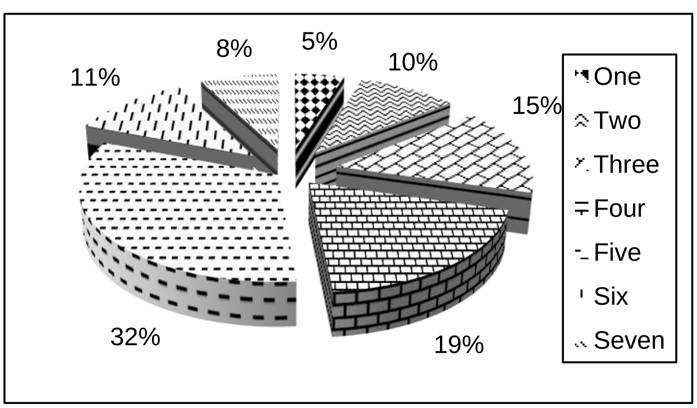



Source: Field Survey
Fig 2: Number of Tubewells Owned by Farmers in Pishin District

Figure 2 showed the responses of the farmers about the number of tubewells they owned. It can be seen that majority of farmers having more than one tubewells. Out of total 105 farmers, only 30 farmers mentioned that they have one tubewells. 40 farmers pointed out that they have two tubewells. 20 farmers stated that they have three tubewells, 10 farmers mentioned four tubewells, and 5 farmers mentioned that they have more than five tubewells. These results clearly show that on one side the majority of farmers having more tubewells, whereas on the other hand a few numbers of farmers having only one tubewells. This discrimination in the installation of tubewells caused the overexploitation of groundwater in the study area.

### 3.2.2 Violation of Tubewells Spacing Norms

There exists a clause that guides regulators about tubewell to tubewell spacing norms which are 750 feet under the Balochistan Groundwater Administration Ordinance 1978 [8] (Halcrow, 2007). Violations of these tubewells spacing norms were often observed during the survey. No one cared about such norms, and this is developing into a situation of the tragedy of commons. Therefore, it also happens to be one of a major contributing factor to the depletion of groundwater in the study area of Pishin District. When the farmers asked about the number of tubewells in per 1000 feet, the following response received from the farmers as shown in the figure below.

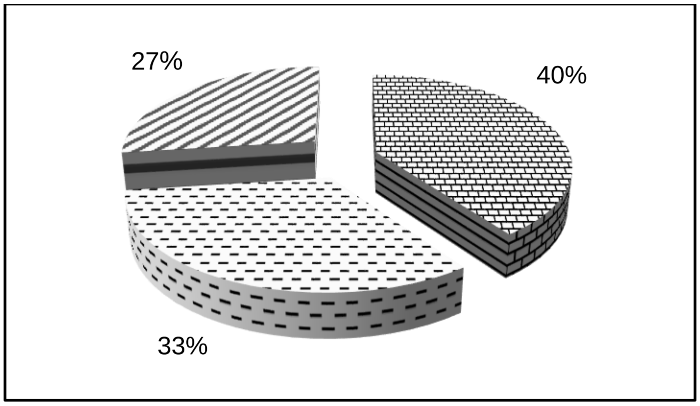



Source: Field Survey
Fig 3: Percentage of T/W Installation within 1000 Square Feet

Figure 3 shows that 8% farmers that there are 7 tubewells within 1000 square feet, 11% pointed that 6 tubewells, 20% responded that 5 tubewells within 1000 square feet, 19% mentioned 4 tubewells within 1000 square feet. These results clearly show that the number of the tubewells per 1000 square feet is very high. It has also been noted that no permission is required for the installation of tubewells, because of the lack of proper regular system from the government.

### 3.2.3 Subsidy on Electric Tubewells

The agriculture sector in Balochistan has been receiving a subsidy on electric tube wells. The government has been giving subsidies on tariffs to electric tubewells since the 1980s in Balochistan. The tariff payment has changed from time to time. Since 2001 the government of Pakistan approved a flat rate Rs. 4,000 per month for agriculture tubewells in Balochistan. Farmers pay only10% of the total electricity bill while the remaining 90% is being subsidized and paid for by the government. The total bill amounts to more than Rs. 7 billion every year. The overall burden of subsidies was shared by the Federal Government, Water and Power Development Authority (WAPDA) and the Provincial Government in a ratio of 40:30:30 [13] (Khair, Mushtaq, Culas, & Hafeez, 2011). The subsidy helped farmers in the installation of deep tubewells and also resulted in lowering of water table and the mining of groundwater. The indiscriminate and unplanned development of deep tubewells in the last three decades, with no control over their operation, has resulted in a rapid decline in groundwater table in the study area of Pishin District. According to [3] (Ahmad, 2005) subsidized electricity to agriculture tubewells encouraged farmers to use groundwater indiscriminately for increasing agriculture production. [21] (Shah, Roy, Qureshi, & Wang, 2003) mentioned that in order to boost production in some regions of South Asia, subsidy on electricity have been provided in many years and such subsidies caused the over-exploitation of groundwater. Similarly, [14] (Khair, Mushtaq, & Smith, 2010) studied that in Balochistan, province of Pakistan the government policies of groundwater development and electricity subsidies have resulted in an enormous growth of electric tubewells and rapid depletion of water table. During the survey when the farmers asked about the running hours electric tubewells per day the hollowing responses have been received.

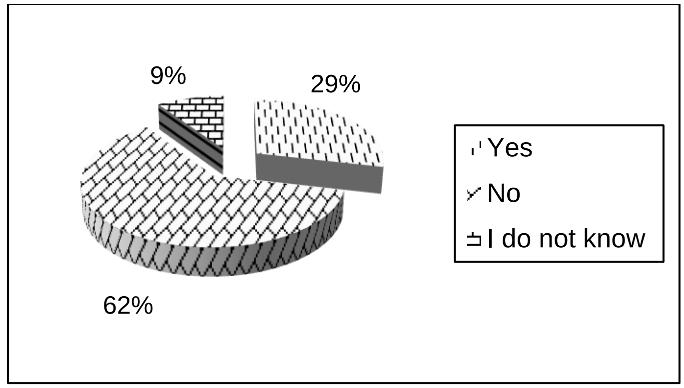



Source: Field Survey
Fig 4: Running Hours of Electric Tubewells per Day

Figure 4 shows the responses of the farmers about the per day running hours of electric tubewells. About 40 % of the respondent that they run the electric tubewells for 12 hours a day, 33% responded that 10 hours per day and 27% mentioned 8 hours per day. On average, the responses of the farmers showed that they run the tubewells the tubewells for 10 hours per day. The farmers pointed that until electricity available they run the tubewells. The main reason for that is the lack of regulation, there is no meter on the tubewells because of the subsidy provided by the government. When the farmers were asked how would they react if the government withdraws subsidy on electricity, their responses was that they had no choice, but to agitate against the government' policy, and would block the main road until the concerned authorities accept our demands for subsidized electricity.

### 3.2.4 Inefficient Irrigation System

The irrigation system in Balochistan operates at 45% efficiency due to poor maintenance of water courses and channels, use of inefficient and traditional methods of irrigation (mainly flooding). For the betterment; the strategy for sustainable agriculture should include a measure to improve water management practices, reorienting and improving service delivery at the community level [14] (khair, Culas, & Hafeez, 2010). [16] (Lashari, McKey, & Villoholth, 2007) reported that in western Australia irrigation efficiency was very much high 90% using high-efficiency pressurized irrigation techniques, whereas in Pakistan the irrigation efficiency is very low not more than 60% due to use of the traditional irrigation methods (flooding irrigation methods). During the survey, it has been observed that most of the farmers not receiving any education and training about the use of a high-efficiency irrigation system. Moreover, they are not receiving any information about the innovation and techniques of methods for irrigation and cropping pattern. When the farmers were asked whether they have any awareness about the application of high-efficiency irrigation system i.e. a trickle irrigation system, bubbler irrigation system etc. the farmers responded in the following way:




Source: Field Survey
Fig 5: Farmers Perception about High-Efficiency Irrigation System

Figure 5 shows the information about the usage of a high-efficiency irrigation system in the study area of Pishin District. Due to lack of awareness about the high-efficiency irrigation system, the majority of the farmers responded that the system does not help in the increase of output with the less amount of water. Out of 105 farmers, 62% responded that they think high-efficiency irrigation system put no impact on their output production. Whereas, 29% of the farmers stated that they are in a fever of the usage of a high-efficiency irrigation system. Hence the lack of awareness about the high-efficiency irrigation system is one of the major factors causing water depletion in the area.

### 3.3 Regression analysis of factors responsible for water decline in Pishin district of Balochistan

For this analysis using OLS, five independent variables were regressed on water table decline. The five predictor variables are a total number of tubewells, water table depletion rate, running hours of tubewells, farmers' education and load shedding as shown in table 1.

TABLE 1
REGRESSION ANALYSIS OF FACTORS RESPONSIBLE FOR DECLINE IN WATER TABLE

| Variables | Coefficients | Standard Error | t-Statistic | P-Values |
|---|---|---|---|---|
| NTW | -0.14** | 0.11 | 1.272 | 0.012 |
| WTB | -9.364** | 3.125 | 3.000 | 0.048 |
| RTW | -0.612** | 0.084 | 7.247 | 0.027 |
| FED | 0.312*** | 0.011 | 28.069 | 0.000 |
| LSH | -0.554 | 0.048 | 11.374 | 0.423 |
| C | 0.541 | 0.013 | 40.375 | 0.349 |
| $R^2$ | 0.87 | | | |
| Adj $R^2$ | 0.85 | | | |
| Durbin Watson Statistic | 2.16 | | | |
| F-statistic | 199.12 | | | |
| Prob(F-statistic) | 0.0000 | | | |

Asterisks "*", "**", "***" stand for 10%, 5%, and 1% significance level

Table 1 present the results of a regression analysis. In modal (GWA) is the total groundwater available for the agriculture sector in a cubic meter. The GWA is the dependent variable, and the variables, total number of tubewells (NTW), water table depletion rate (WTB), running hours of tubewells (RTW), farmers' education (FED) and load shedding (LSH) are independent variables. The result shows that all the independent variables are significant at a different confidence level. The result shows that (NTW) is not only significant at 5% level of significance but also has a negative relation with the (GWA). That means an increase in the number of tubewells, it will bring decline the groundwater level, which will decrease groundwater availability for the irrigation of agriculture in the study area. Similarly, variable (WTB) is also significant at 5% level of significance, i.e. increase in the water table depletion rate results in decline of the groundwater level, ultimately leading to decrease in the availability of water in the study area. The variable running hours of tubewells (RTW) is significant with negative correlation with the (GWA) at 5% level of significance, indicating an increase in daily running hours of farmers' tubewells which will increase the discharge of groundwater and consequently decline water table, this will decrease the availability of groundwater. The coefficient of farmers' education (FED) is significant with positive correlation at 1% level of significance. The positive correlation with GWA shows that increase in the farmers' education efficiency put a positive effect on the availability of groundwater. One justification for this result might be that educated farmers improve their irrigation efficiency which results in efficient use of groundwater, and ultimately water availability will be increase. The coefficient of last variable, i.e. load shedding (LHD) is insignificant with negative correlation, showing that with the increase in load shedding in the area brings a decrease in water availability. This shows that when the per day load shedding hours increase in the area, the number of tubewells for irrigation increase by the farmers, which results ultimately decline of groundwater level and decrease in the availability of groundwater in the area.

The $R^2$ value is i.e. 0.87 showing that most of the variation in the dependent variable has explained by the explanatory variables in the model. The DW value is 2.16 which indicate that there is no problem of the autocorrelation in residuals.

## 4 CONCLUSIONS

The main findings of the study are that the current situation of groundwater is very critical in the study area of Pishin District. The groundwater is depleting at an alarming rate. When the farmers asked about the current rate of groundwater depletion, majority of the farmers mentioned that the groundwater depletion rate was 16 to 25 feet annually, the reason for groundwater depletion is indiscriminate installation of tubewells, subsidy to electric tubewells, violation of tubewells spacing norms, over-exploitation of groundwater and running hours of tubewells in the study area. Similarly, most of the farmers are having more than one heavy electric tubewells operating on average for around 10 hours a day. Moreover, the results also showed that most of the farmers were not aware about the modern high efficiency irrigation system led to the mismanagement of water resources in the study area of Pishin District.

## 5. RECOMMENDATIONS

On the basis of the study finding the following recommendations have been suggested for the controlling of groundwater depletion.

5.1 The use of high-efficiency irrigation system can be a very effective option to conserve water. It is recommended that the high-efficiency irrigation system should be introduced in the study area of Pishin district for tackling the issue of groundwater depletion.

5.2 On the basis of the results of this study, it has been recommended that the government should develop effective strategies to put a restriction on installation of more tubewells in the study area of Pishin district.

5.3 The result showed that load shedding and low voltage of electricity are also the major factors resulting in the increase of tubewells in Pishin district. Arrangements have to be made through Quetta Electricity Supply Company to provide reliable supply to the farmers.

5.4 It is also recommended that mass awareness campaign must be launched through print and electric media. In this regards, the government and NGOs should start awareness campaigns in the area for training the farmers about getting higher production with limited water resources.

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