Estimation of Potential Rainfall Recharge in the Pothwar Area

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***Abstract*-**Groundwater recharge is a complex phenomenon to understand and describe because it cannot be seen with open eyes. We have to depend on some theoretical assumptions to understand this complicated hidden natural underground water movement process. There are many factors affecting and controlling the water movement in soil profile. Groundwater use in district Chakwal is of a fundamental importance to meet the rapidly expanding drinking and agricultural water requirements. The main factors contributing to groundwater recharge in Chakwal are rainfall, evapotranspiration and geology. Due to the semi-arid climatic conditions of the area, this resource is almost the only key to economic development. There are a number of dug wells in the area where water is getting stored during rainy season. Sources and processes of recharge in humid areas are different compared with semi-arid areas. Due to the main source of available water in the area, the potential groundwater recharge estimation could be good exercise to visualize the amount of rainwater entering the ground. For groundwater recharge estimation there are a number of simple and advanced techniques available. In the present study simple methods were used to estimate potential recharge due to available limited resources. Rainfall runoff, gravimetric and water table fluctuation methods were used to quantify rainfall recharge during the monsoon season. The average potential recharge estimated was 60% of the rainfall of 148 mm. Rainfall runoff and gravimetric methods were found to be comparable for short period potential recharge estimation while water table fluctuation method gives actual recharge and require longer period data. Potential recharge values were higher for area having grassland type vegetation and low for area covering shrubs and thick vegetation.

***Keywords*-**Semi Arid, Plateau, Gravimetric, Rainfall Runoff, Water Table Fluctuation

I. INTRODUCTION

The Pothwar Upland commonly called the Pothwar Plateau, lies on the South of Northern Mountains. It is bounded by river Jhelum on the East, Indus on the West, Kalla Chitta Range and Margalla Hills on the North and Salt Range on the South. District Chakwal is surrounded by Mianwali, Rawalpindi, Attock, Jhelum and Khushab districts as shown in Fig. 1. The area is full of diverse wildlife and pictorial scenes. At present, the area is under water stress conditions due to low rainfall and extensive deforestation. There are a number of famous lakes like Kallar Kahar, Uchali, Khabeki and Jhallar having problems of water quality and storage area. Chakwal is a rural barani district with hilly terrain having a very small industrial sector. Due to high spatial and temporal variation of rainfall in arid region great difficulties arise in raising crops/plants due to uncertain water-supplies [i]. The total runoff potential of Pothwar Plateau is about 3.50 million-acre-feet (MAF) and only 0.10 MAF is being harvested [ii]. However, a large amount of water (about 3.40 MAF) is being lost as surface runoff annually. This is not only the loss of precious resource, but also causes erosion of fertile top-soil which results in decreased soil fertility and productivity, siltation of water storage reservoirs and conveyance system as well as floods in the downstream areas [iii]. Most of the soils in District Chakwal range from silt loam to loam with pH ranging from 7 to 9. Chakwal lies within the monsoon range. There are two rainy seasons in this area, The first caused by the monsoon winds originating from the Bay of Bengal, begins from 15th July and continues up to around the 15th September. The second season caused by the Mediterranean winds (Western disturbances) begins from December and continues upto the monsoon season. Occasionally Western Disturbances coincide with monsoon causing prolonged large areas. The average rainfall is 558-635 mm and Choa Saidan Shah Subdivision has the maximum rainfall in the district.

Due to undulating features of Chakwal the rainfall runoff takes place quickly causing soil erosion. The farmers were unhappy with this phenomenon. To control these problems, the Government of Punjab established an institution named Soil and Water Conservation Research Institute (SAWCRI) and Barani Agriculture Research Institute (BARI) based

at Chakwal with SAWCRI substations at Rawalpindi, Jhelum, and Hafizabad districts. SAWCRI is working well with the co-operation of farmers to reduce the soil loss by placing stone structures in the way of runoff. These hurdles divert the direction of runoff and reduce its speed causing minimum soil erosion. SAWCRI is also working on rainwater harvesting and BARI is endeavoring to enhance agricultural production under barani conditions.

II. Review

Groundwater recharge can be defined as the quantity of rainfall reaching the water table. Groundwater recharge can be quantified either by change in the soil moisture status or water table fluctuations. For this purpose accurate measurement of seepage, net pumping leakage from nearby aquifer, water content and pressure variations on the water table is required. [iv-vi] used water table elevations to describe the recharge. However, only a few investigations attempted to describe recharge by soil moisture data [vii]. [viii] showed that the two quantities might differ, due to either the influence of the unsaturated zone or non-acceptance by the aquifer of the potential value. Losses from irrigation systems frequently provide contribution, which exceeds that from rainfall. [ix] presented a water balance model to estimate groundwater recharge in Rechna Doab. [x] presented a method for calculation of groundwater recharge from rainfall in the Indus Plains of Pakistan. [xi] while working on development of ground water model for SCARP-1, considered contribution of rainfall to ground water recharge in the surface water balance of field. A certain fraction of the seasonal rainfall was assumed to drain out as surface run off and rest either recharge the aquifer or increase the moisture content of soil profile and ultimately evaporate. What remained on surface was assumed to have evaporated. Subtraction of evaporation and evapotranspiration losses from effective precipitation resulted in the quantity of rainfall contribution to ground water recharge. It has been estimated and prepared by various agencies (WAPDA, 1980) that 10 percent of the total rainfall over an area contributes towards the ground water reservoir. An exercise on the same line was carried out by WAPDA (1982) for 52.5 percent cropping intensity (actual for 1980-81) for SCARP-1 and losses for rainfall was estimated to be about 35 percent.

There is no wide spread irrigation system in Chakwal. The only major rivulets and seasonal channels that run through Chakwal are the Soan and the Soj Nullah. A number of small dams have been constructed in the district through which some irrigation takes place. There are large numbers of storm channels which are mostly active during rainy season. Chakwal area is a barani area, so there is a need to develop groundwater resources to fulfill the irrigation and domestic water requirements. Due to this reason it is necessary to see the ground water storage pattern after the monsoon season and to quantify the rainfall recharge occurring actively in every monsoon season. The objective of the present study was to estimate potential rainfall recharge using different methods.

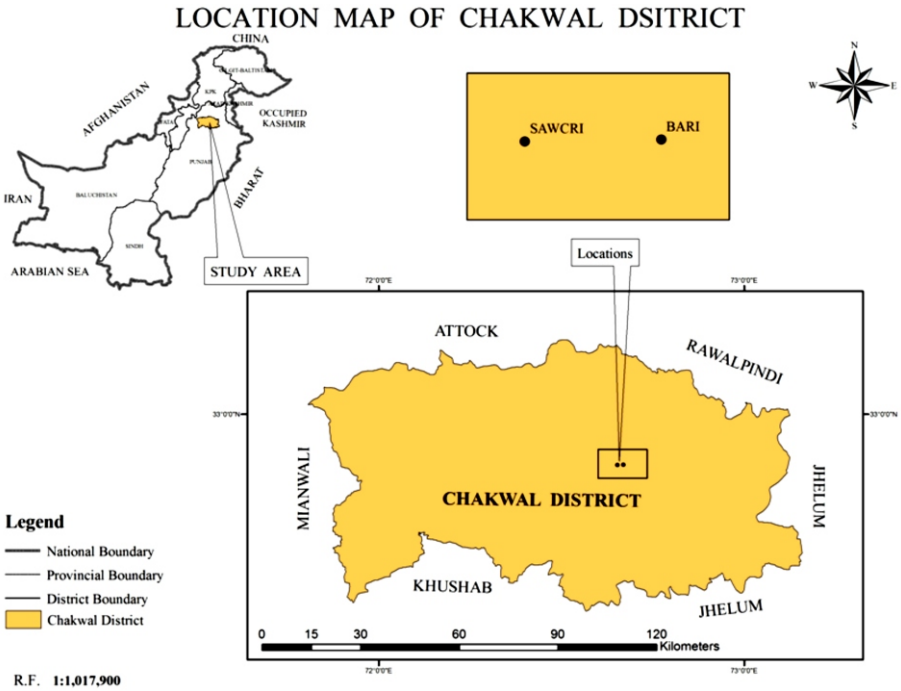

Fig.1. Map of study area

III. Materials and Methods

The study was conducted during the monsoon season (June to July, 2006) over an area of 65 hectares at the Barani Agricultural Research Institute (BARI) Chakwal to carry out the different field activities. Rainfall and the water table variation in the area are from 400 mm to 750 mm and 35feet to 90 feet respectively (BARI). The data required (Soil Texture, rainfall data, runoff data) for this study was taken from the meteorological station of Soil and Water Conservation Research Institute (SAWCRI) Chakwal. The following methods were used for the estimation of rainfall recharge:

1. Gravimetric Method
2. Rainfall Runoff Method (Also called Water Balance Method)
3. Water Table Fluctuation Method

A. Data Collection

1) Hydraulic Conductivity

To determine the hydraulic conductivity of the selected field, the soil samples were collected at different locations and constant head permeater apparatus was used for analysis.

2) Soil Moisture Data

Soil moisture data was used in gravimetric method. For soil moisture data, the soil samples were collected for forty days on daily basis at the depth difference of 0.5 to 5 feet and the samples were analyzed in the SAWCRI lab.

3) Specific Yield

Specific yield data was used in water table fluctuation method. Pumping test analysis was performed to determine the specific yield of the wells. For this purpose two open wells in the study area were selected and draw down was noted during the pumping test. Water table fluctuation was also noted by considering an open well as observation well. To calculate the rainfall recharge, the change in water table depth before and after rainfall was multiplied with specific yield of the well as given below;

$$R = \Delta H * S_Y \quad (1)$$

Whereas

R	Rainfall recharge (mm)
ΔH	Change in water table depth (mm)
S_Y	Specific yield of the well

To quantify the soil erosion and rainfall runoff in district Chakwal, SAWCRI has laid a network of runoff plots. There are twenty plots with each of size 10 m^2. .The study was divided in five field slopes ranging from 1% to 5% with four field conditions as;

T_1	Control	T_2	Ground nut
T_3	Moong	T_4	Millet

When rainfall occurred the runoff of different quantities was generated in each plot, due to different slope and vegetative cover. This runoff was collected in collection drums buried at the plots outlets. The recharge was calculated by using the following relationship,

$$\text{Recharge} = \text{Precipitation} - \text{Runoff} - \text{Evaporation} \quad (2)$$

IV. Results and Discussion

During the study period there were three rainfall events as shown in Fig. 2. Water table fluctuation during the study is shown in Fig.3. The soil texture up to the depth of 0-15 cm was loam and 15-90 cm the soil texture was clay loam so the soil under consideration was clay loam. The average bulk density of the soil was 1.35 g/cm^3 and the saturated hydraulic conductivity was 0.01 cm/min. It is clear from the Fig. 4 that the maximum recharge occurred by rainfall of 60 mm. The maximum recharge was estimated by rainfall runoff method. The recharge estimated by the water table fluctuation is the actual recharge which is very less as compared to potential recharge. The results of gravimetric method and rainfall runoff method are comparable whereas the results of water table fluctuation method are not comparable because the water table data taking period was very short and there is always a lag between rainfall event and actual recharge.

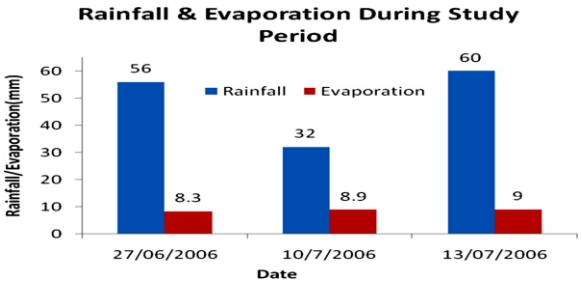

Fig.2. Rainfall during the study period

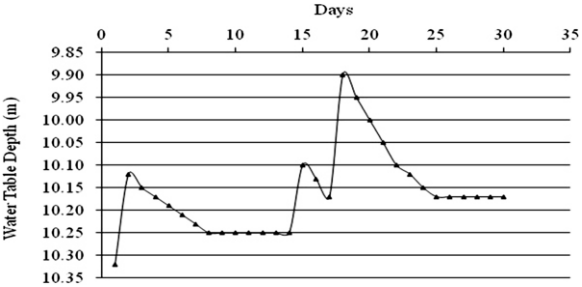

Fig.3. Water table fluctuation in dug well during the study period

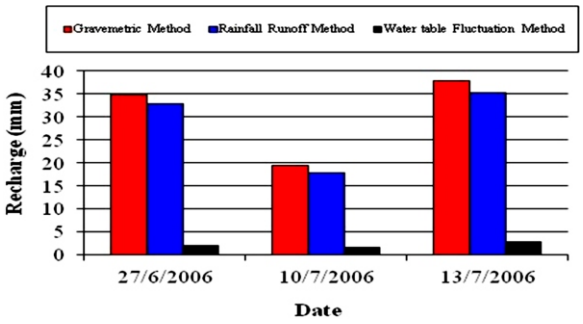

Fig. 4. Recharge comparison of three methods

V. CONCLUSIONS AND RECCOMENDATIONS

There were three rainfall events during the study period with a total rainfall of 148 mm.

The soil texture was clay loam. The bulk density and hydraulic conductivity determined were 1.35 gm/cm^3 and 16.6 cm/day respectively.

The Rainfall-runoff method and Gravimetric method are the best approaches for Potential recharge estimation while water table fluctuation method is good for actual recharge estimation.

Potential recharge values were higher for area having grassland type vegetation and low for area covering shrubs and thick vegetation.

Study should be conducted for longer period covering multiple rainfall events and the results for shorter period data should be used carefully.

Remote sensing and GIS data used with detailed water balance models may give better results of recharge estimation.

REFERENCES

[i] M. Shafiq, M. Z. Ikram, S. Ahmad, A. Nasir, (1996). Surface runoff and soil loss under cropped fields of medium rainfall zone of Pothwar Plateau, *J. Eng. Appl. Sci.*, Vol. 15, No. 2, July-Dec.

[ii] M. N. Bhutta, M.R. Chaudhry, M. Sindhu, (2002). Rainwater harvesting impact on agriculture in Pakistan, In Proceedings of *the National symposium on drought and water resources in Pakistan*, 18th March 2002, CEWRE, Lahore, Pakistan.

[iii] M. Shafiq, (2001). Rainwater harvesting for sustained agriculture production, *J. of Sci., Tech. and Dev.*, Vol. 20 (1), March , Islamabad.

[iv] E. Eriksson, (1970). Groundwater time-series, an exercise in stochastic hydrology, Journal of Nord. Hydrol, 1(3), 181-205.

[v] C. Venetis, (1971). Estimating infiltration and/or the parameters of unconfined aquifers from ground water level observations. J.Hydrol. 12, 161-169.

[vi] L. W. Gelhar, (1974). Stochastic analysis of phreatic aquifers, water resource Res.,10(3), 539- 545.

[vii] H. I. Chiew, (1972). A stochastic model for the occurrence of moisture in vadose media, Ph.D, dissertation, Clemson Univ., Clemson, S. C.

[viii] K. R. Rushton, S.C.TAWARI, (1988). Mathematical modeling of a multi layered alluvial aquifer. Instin. Engineers, India.

[ix] G. Z, Hasan, M. N. Bhutta, (1996). A water balance model to estimate ground water recharge in Rachna Doab, Pakistan. Irrigation and Drainage Systems vol. 10, 296-317pp.

[x] M. Maasland, J.E. Priest, M.S. Malik, (1963). Development of Ground Water of Indus Plains. Lahore Pakistan Engineering congress, symposium on water logging and salinity, proceeding vol .7 paper 56, p123-161.

[xi] N. M Awan, (1988). Ground Water Development Model of SCARP-1. Pakistan Council of Research in Water Resources Islamabad. Research Publication No.5 PCRWR / Publication / 32.