Hydraulic and Civil Engineering Technology VIII
M. Yang et al. (Eds.)

doi:10.3233/ATDE230803

Groundwater Level Forecast for Muktsar District of Punjab: A Matlab Based Approach

Saikat KARMAKAR [a,1], Ritesh Kumar JAIN [a] and Sunil GARG [b]
[a] *Department of Civil Engineering, PAU Ludhiana*
[b] *Department of Soil and Water Engineering, PAU Ludhiana*

Abstract. Groundwater is one of the most important natural resources in to sustain the human habitat on earth. It serves us as the major source of drinking water as well as the fresh water resource to be utilized in agriculture and industries. Over the decades the groundwater pumping has been increased few fold and that is raising serious concern about the depth of groundwater level at different parts of earth. The south western Punjab is facing the problem of fluctuating groundwater table due to the heavy agricultural practices in this state. Our study focuses on the observation of change and prediction of groundwater table the in the Muktsar district of south west Punjab, based on the village wise collected well data. Curve fitting technique though MATLAB software has been taken into account for this purpose and it showed a increase in depth to groundwater table for all the four blocks of Muktsar district by 2025. The study highlights the need of raising awareness and establish new laws to ensure sustainable groundwater management in the study area to avoid the scarcity of groundwater in the near future.

Keywords. Groundwater, groundwater level forecast, MATLAB

1. Introduction

Groundwater is the important part of global water resource and it covers around 1.69% of total water on earth. It serves as a great source of freshwater and is heavily getting used for drinking, irrigation and industrial purposes. Around 30.1 per cent of world's total fresh water is sourced from groundwater [1]. Global groundwater storage refers to the entire amount of water stored beneath the earth, including snow, ice packs, and glaciers at the poles. When there is a draught, this store is the sole natural supply of water available to fulfill the demand for surface water. Aquifers are under enormous stress and are vulnerable to depletion, specifically in semiarid and arid regions where natural recharge fails to meet the sufficient rate to balance withdrawals [2].

The irregular and uneven rainfall patterns worsen the situation, which cause agriculture to rely too much on groundwater supplies. Groundwater variations are caused mostly by pumping from bore wells, less recharge than discharge, water absorption by vegetation, and periodic moisture differential [3]. Due to the decreasing trend of groundwater levels, several groundwater-related concerns such as groundwater

[1] Saikat KARMAKAR, Corresponding author, Department of Civil Engineering, PAU Ludhiana; E-mail: ritesh5@pau.edu.

depletion [4], groundwater quality deterioration [5], land subsidence, and hydrological droughts arise [6]. As a result of rising climate uncertainties, groundwater level measurement and trend forecast might be critical for sustainable water management. Despite the critical need to study the impact of groundwater exploitation under changing climatic conditions, there are relatively few studies owing to a lack of significant geographical and temporal datasets.

During India's green revolution, Punjab was a pioneer in embracing sophisticated agricultural methods. The green revolution came to success on the basis of groundwater irrigation [7]. The economical backbone of the Punjab state is mostly agricultural, and a large portion of groundwater is used for irrigation. A widespread resource depletion happened due to this over-reliance on groundwater. Rainfall has an impact on groundwater levels in addition to irrigation. In India, there are two rainfall seasons: summer monsoon (June to September) and winter monsoon (October to December), Punjab is heavily influenced by the monsoon rainfall [8].

A thorough study of trend analysis of groundwater level change and their possible reasons along with the remedies is required to ensure the sustainability of the environment. Although numerous studies overviewed water quality and quantity, little concerted efforts were made for the qualitative and quantitative analysis of groundwater in the most affected southern regions in Punjab. Muktsar is one of the most flooded districts in southern Punjab, has been chosen for the study. This study employed the curve fitting technique in MATLAB R2022b software for analysing the water-level data from wells to observe the change in groundwater level over a long duration in the study area and to predict the groundwater level for the year 2025.

2. Review of Literature

Dash et al. (2010) [9] sought to build a Hybrid neural model (ANN-GA) for groundwater level prediction in the lower Mahanadi River basin in Orissa by combining an artificial neural network (ANN) model with genetic algorithms (GA). They compared the power of the suggested hybrid model in the effective prediction of groundwater fluctuations using three types of functionally diverse algorithm-based ANN models (namely back-propagation (GDX), Levenberg-Marquardt (LM), and Bayesian regularisation (BR). They carried out the ANN-GA hybrid modelling with a one-week advance time and primarily concentrated on the November and January months of the year. They discovered that the Bayesian regularisation model was the most effective of the ANN models evaluated throughout the research period. They discovered a high link between observed and anticipated groundwater levels for all models. They also discovered that the hybrid GA-based ANN algorithm outperformed standard ANN approaches such as the Bayesian regularisation model in terms of accuracy and performance in medium and high groundwater level forecasts. After all, they found that hybrid neural models can have a major impact on groundwater management and water supply planning in semi-arid locations where aquifer information is unavailable.

Kochhar et al. (2021) [10] used the deep learning and statistical modelling to estimate and forecast premonsoon and postmonsoon groundwater levels for the entire state of Punjab. To model, predict, and forecast groundwater levels, they used two deep learning models namely Multi-Layer Perceptron (MLP) and Long Short-Term Memory (LSTM) and combined them with Seasonal Autoregressive Integrated Moving Average

(SARIMA). To assess the models, they examined pre-monsoon, post-monsoon, and combined annual groundwater level data from three different wells in Punjab during the last 20 years. They compared the model outcomes in terms of inaccuracy, correlation, and efficiency. They discovered that deep learning models outperformed regression models. They also discovered that MLP produces the best variability representation for pre-monsoon data while LSTM produces the best variability representation for post-monsoon data. After all, they determined that the model works better when tested for pre- or post-monsoon data rather than combined yearly data.

Yousefi et al. (2019) [11] used MODFLOW2005-NWT in MATLAB to estimate groundwater levels in the Karaj plain (Iran) over 10 years. They used the MATLAB interface to anticipate groundwater levels in the Karaj study region until the water year of 2023-2024 by considering three scenarios: optimistic, pessimistic, and continuous current. They measured 12.834, 19.089, and 4.906 m for each of these three circumstances.

3. Study Area

Muktsar district (figure 1) encompasses an area of approximately 2,630 km2 and is located between latitudes 29°54'20" to 30°40'20" N and longitudes 74°15' to 74°16' E. The district is located on the main Indus basin and the Satluj sub-basin, and there are no river flows through it. It is mostly fed by the Sirhind feeder canal network. The landscape slopes northeast to southwest, with an average elevation ranging from 230 to 256 meters above mean sea level (AMSL) [12].

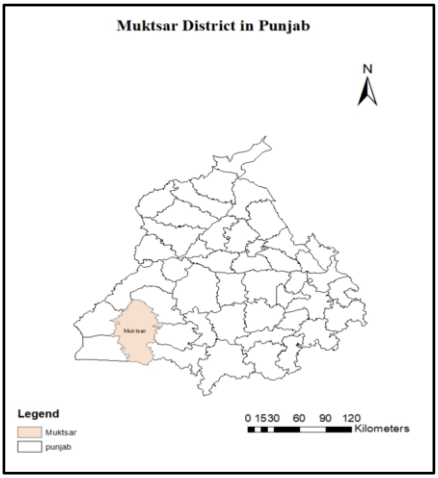

Figure 1. Location of Muktsar District in Punjab.

It has a dry sub-humid environment with an annual average rainfall of 431 mm; 79% of its rainfall is caused by the southwest monsoon, while 21% is caused by western disturbances and thunderstorms.

According to geomorphology, the district is divided into two groups: (1) historic and present quaternary alluvial plains modified by orogenesis, and (2) sand dune complexes [13]. The district's alluvial plain is divided into three sections: (1) upper alluvial plain with coarse-grained sand and a vast bed of yellow clay known as pandoo; (2) alluvial plain with good moisture or flooded; and (3) alluvial plain with salt encrustation. The district has two soil types: sierozem and desert [14]. Because the soil is nitrogen-phosphorus-potassium (NPK) deficient, it requires more fertiliser for optimal agriculture. Waterlogging affects 70% of the district, with a rise in water level of 0.008-0.322 m/year and a decrease in water level of 0.031-0.21 m/year in the remaining 30% [15].

4. Materials and Method

The district Muktsar is encompassing four blocks namely Sri Muktsar Sahib, Malout, Lambi and Kot Bhai. The blocks are consisting of 88, 52, 49 and 44 villages respectively. Pre and post monsoon (June and October) groundwater table data of 111 villages of these four blocks has been collected from Water Resource Department, Govt. of Punjab for the span of 23 years (1998 to 2020). The annual average groundwater table data for each village has been obtained by averaging the two data of two seasons. Then the village wise annual average data was averaged to obtain the annual average groundwater table data for each of the four blocks. The water table depth (Y axis values) and year (X axis values) data was incorporated in MATLAB and the block wise graphs were plotted for the span of 22 years (1998 to 2019).

To predict the water table depth, the Basic Fitting tool of MATLAB R2022b software has been used in this study. Then each block wise water table depth graph has been interpolated using the cubic equations. To check the accuracy of prediction, the Y value has been interpolated inputing the X value for the year 2020 (X = 23) in MATLAB and the value has been compared with the known Y value for the year 2020. Finally the unknown Y value has been interpolated for the year 2025 (X = 28).

5. Results and Discussion

The depth versus years graph of the blocks showed tremensous variation in groundwater level in past 22 years as in figures 2 (a, b, c, d). The graph of Kot Bhai block showed a continuous decreasing trend of depth to groundwater level upto the year 2011 and then it went almost parallel to X axis upto 2018 but showed a sudden decline in the year 2019. Lambi showed the continuous decreasing trend upto the year 2013 and then the depth to groundwater table went on increasing upto the year 2019.

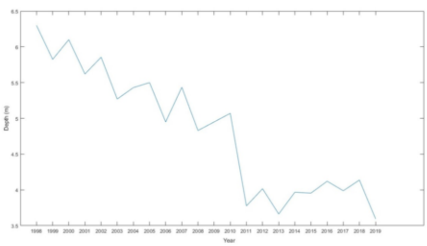

Figure 2(a). Change in depth of water table of Kot Bhai block.

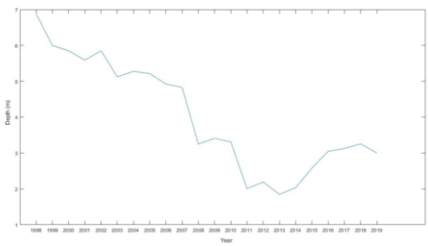

Figure 2(b). Change in depth of water table of Lambi block.

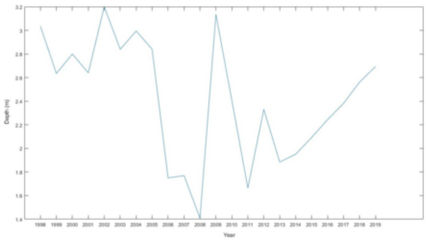

Figure 2(c). Change in depth of water table of Malout block

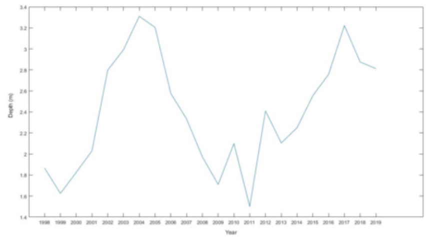

Figure 2(d). Change in depth of water table of Muktsar block.

A huge unusual variation in groundwater table was seen in Malout block, where there was sharph decrease in groundwater table in the year 2006 and sudden rise in 2008 followed by another sudden decrease in 2009. In Muktsar, the gradual decrease in depth to groundwater was seen between 2004 to 2011 and then the gradual increase was seen between 2011to 2017 with further decline in 2018 and 2019.

Using Basic Fitting tool, the generated curves have been fitted in cubic equations, taking 10 significant digits and then the interpolation has been done for the X value equals 23 (i.e., for the year 2020) as show in figures 3 (a, b, c, d). The interpolated water table depth values of the year 2020 has been compared with the actual observed values in table 1.

Table 1. Comparison between observed and interpolated depth values for the year 2020.

Blocks	Observed Depth (m)	Interpolated Depth (m)
Kot Bhai	3.973	3.96
Lambi	3.104	4.2
Malout	2.267	3.02
Muktsar	1.88	3.89

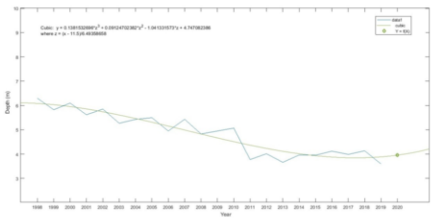

Figure 3(a). Interpolated water table depth curve for Kot Bhai block

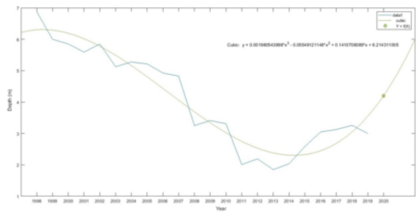

Figure 3(b). Interpolated water table depth curve for Lambi block.

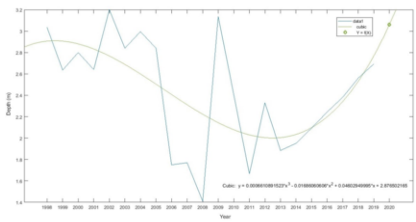

Figure 3(c). Interpolated water table depth curve for Malout block

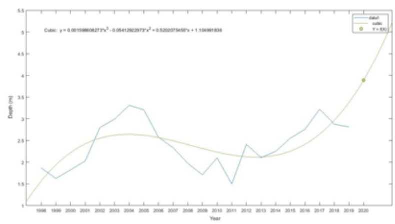

Figure 3(d). Interpolated water table depth curve for Muktsar block.

Similarly, the water table depth value has been interpolated for the year 2025 by inputting X value. The blockwise predicted water table depth data is shown in table 2.

Table 2. Groundwater level prediction for 2025.

Blocks	Predicted Groundwater Depth (m)
Kot Bhai	4.96
Lambi	10.1
Malout	5.46
Muktsar	8.33

6. Conclusion

The interpolated depth of Kot Bhai block nearly matched the observed depth value. Whereas the interpolated depth values of Lambi, Malout and Muktsar showed 35.3, 33.21 and 106.91 percent deviation from the observed value. In the predicted value for the year 2025 it showed the overall trend of increase in depth to water table in 4 blocks. In Kot Bhai, Lambi, Malout and Muktsar the increase in depth has been observed at the percentage of 25.25, 140.48, 80.79 and 114.14 respectively over the interpolated depth of the year 2020.

According to Sahoo et al. (2021) [16] the major cause of this significant groundwater level reduction is over-exploitation of groundwater for irrigation, mostly for rice farming, not withstanding monsoonal rainfall and a well set up of canal irrigation infrastructure. Furthermore, in this location, inconsistent rainfall, reduced recharge, and over-reliance on groundwater supplies produce a significant reduction in groundwater levels. Crop diversification and enhancement of modern irrigation techniques, as well as the installation of new recharge structures, are required to address the declining groundwater level circumstances in this water-stressed region. As a result, the need of the hour is for the government to establish new acts and push new principles for improved groundwater resource management.

References

[1] Gleick PH. Water in Crisis. Oxford University Press, New York; 1993; 100, pp.13.

[2] Vörösmarty CJ and Sahagian D. Anthropogenic disturbance of the terrestrial water cycle. BioSci. 2000; 50: 753–765.

[3] Rajaveni SP, Brindha K, Rajesh R and Elango L. Spatial and temporal variation of groundwater level and its relation to drainage and intrusive rocks in a part of Nalgonda District, Andhra Pradesh, India. J Indian Soc. Remote. 2014; 42: 765–776.

[4] Dhillon MS, Kaur S and Aggarwal R. Delineation of critical regions for mitigation of carbon emissions due to groundwater pumping in central Punjab. Groundwater for Sustainable Development. 2019; 8: 302–308.

[5] Singh DD, Thind PS, Sharma M, Sahoo S and John S. Environmentally sensitive elements in groundwater of an industrial town in India: Spatial distribution and human health risk. Water. 2019;; 11(11): 2350.

[6] Anand B, Karunanidhi D, Subramani T, Srinivasamoorthy K, Suresh M. Long-term trend detection and spatiotemporal analysis of groundwater levels using GIS techniques in Lower Bhavani River basin, Tamil Nadu, India. Environment, Development and Sustainability. 2020; 22: 2779–2800.

[7] Khara DS. Carbon concerns of groundwater irrigation in India: Insights from green revolution states of Punjab and Haryana. IASSI-Quarterly. 2022; 41(1,2): 5-18.
[8] Gosal G. Physical geography of the Punjab. JPS. 2004; 11(1):20
[9] Dash NB, Panda SN, Remesan R & Sahoo N. Hybrid neural modeling for groundwater level prediction. Neural Computing and Applications. 2010; 19(8): 1251-1263.
[10] Kochhar A, Singh H, Sahoo S, Litoria PK and Pateriya B. Prediction and forecast of pre-monsoon and post-monsoon groundwater level: using deep learning and statistical modelling. Model Earth Syst. Environ. 2022; 8(2): 2317-2329.
[11] Yousefi H. Ten-year prediction of groundwater level in Karaj plain (Iran) using MODFLOW2005-NWT in MATLAB. Environ. Earth Sci. 2019; 78:343.
[12] Kumar M, Kumari K Ramanathan AL and Saxena R. A comparative evaluation of groundwater suitability for irrigation and drinking purposes in two intensively cultivated districts of Punjab, India. Environ. Geol. 2007; 53: 553-574.
[13] Pant D, Keesari T, Rishi M, Jaryal A, Sharma DA, Thakur N, Singh G, Kamble SN, Sagwan P, Sinha UK and Tripathi RM. Quality and quantity of groundwater in highly exploited aquifers of Northwest India. J. Hazard Toxic Radioact. Waste. 2020; 24(2): 501-9009.
[14] Kumar M, Kumari K, Singh UK and Ramanathan AL. Hydrogeochemical processes in the groundwater environment of Muktsar, Punjab: Conventional graphical and multivariate statistical approach. Environ. Geol. 2009; 57 (4): 873–884.
[15] Singh S. Waterlogging and its effect on cropping pattern and crop productivity in South-West Punjab: A case study of Muktsar district. J. Econ. Soc. Dev. 2013; 9 (1): 71–80.
[16] Sahoo S, Swain S, Goswami A, Sharma R and Pateriya B. Assessment of trends and multi-decadal changes in groundwater level in parts of the Malwa region, Punjab, India. Groundw. Sustain. Dev. 2021; 14: 100-644.