29

ASSESSMENT OF TRENDS AND MULTI-DECADAL CHANGES IN GROUNDWATER LEVEL IN PUNJAB: A REVIEW

Ritesh Jain[1], A.K. Nanda[2], Jaspal Singh[3] and B.S. Walia[4]

[1,3]Civil Engineering Department, PAU, Ludhiana, Punjab, India

[2]Civil Engineering Department, RIMT, Gobindgarh, Punjab, India

[4]Civil Engineering Department, Maharishi Markandeshwar (Deemed to be University), Mullana, Haryana, India

*Corresponding Author: ritesh5@pau.edu

Abstract: *With an approximate annual usage of 230 km^3, India is the world's greatest user of groundwater. Over the past three decades, Punjab, which makes up only 1.57% of the overall geographical area, has contributed 27–40% rice, 55–65% wheat, and 18–25% cotton to the central pool. The use of groundwater for irrigation that is not sustainable is primarily to blame for the declining water levels. This essay explores the possible and detrimental effects of climate change on Punjab's groundwater resources while providing an overview of the state of groundwater issues at the moment. Therefore, in this study an attempt has been made to assess the problem of dwindling groundwater supplies and the variables accountable for this and recommend viable measures for arresting over-exploitation and for sustainable agriculture in Punjab. It is found that Groundwater potential can be increased by construction of ponds, wells and canals. Some policies were already made to prevent the over-use of groundwater such as, training and subsidies of drip, sprinkler irrigation; promoting of low water required crops and delayed paddy transplanting.*

Keywords: *Punjab, Groundwater, Monitoring, Depletion*

1. INTRODUCTION

With an estimation of 251 km^3 year^{-1} usage of groundwater, India is the largest groundwater consumer in the world. As per the reports of Ministry of Water Resources, by the year 2050, requirement for irrigation will increase by 56%. Although, demand of drinking water will twofold and for industries, water supplies will increase to fivefold and for energy water requirement will increase 16 times more increases. With the increasing demand of water, supplies have been decreased. Surface water availability per person has already declined from 2309 m^3 in 1991 to 1902 m^3 in 2001, and it is anticipated that it would further decline to 1401 m^3 by 2025 and 1191 m^3 by 2050 (Baweja *et al* 2017). The trend of reducing groundwater level by various issues such as groundwater quality deterioration, groundwater depletion, hydrological droughts and land subsidence, respectively.

Punjab state, with just 1.54 % of the total geographical area having semi-arid climate zone and highly monsoon precipitation, contributes 55–65% wheat, 18–25% cotton and 27–40 % rice in the past few decades. Through last 4 decades, farmers shift a cropping pattern from Sugarcane-Maize-Wheat to Wheat-Rice crops, it increased the need for irrigation water and further stressed the groundwater, causing a decline in the water table and a reduction in water quality (Krishan *et al* 2016).

With the above background, the study presents an overview of current groundwater issues in the state of Punjab.

2. STUDY AREA

The Punjab State is situated between longitudes 73′ and 77′ in the east and latitudes 29′ and 32′ in the north. It is spread across a land area of 50,362 km^2. Punjab is one of the nation's wealthiest states despite having an agricultural economy. Three separate physiographic zones may be identified in the state based on soil type, elevation, rainfall, and climate. Table 1 summarizes the main aspects of each zone. Figure 1 shows a map of the study region with various zones and contour lines.

Table 1: Characteristics of different zones of Punjab

Regions	Districts	Area (000 hectare)	Climate	Rainfall (mm)	Soil type
Sub-Mountain Zone	Gurdaspur, SBS Nagar, SAS Nagar, Pathankot, Rupnagar, Hoshiarpur	1063	Sub-humid	1150	Clay, clay loam
Central Zone	Amritsar, Barnala, Moga, Fatehgarh Sahib, Jalandhar, Kapurthala, Patiala, Sangrur Tarntaran, Ludhiana,	2481	Semi-arid	650	Loam
South-Western Zone	Bathinda, Ferozpur, Fazilka, Faridkot, Muktsar, Mansa	1492	Arid	375	Sandy loam, loamy sand

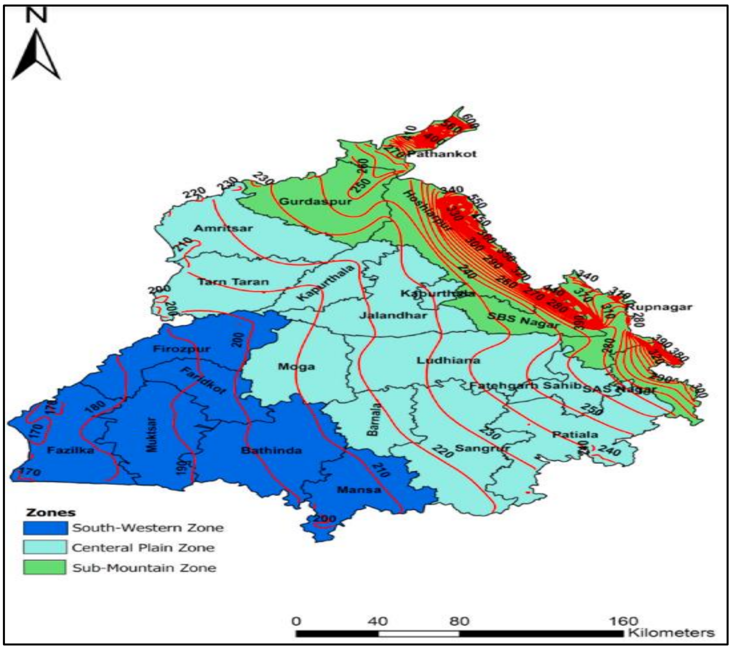

Figure 1: Map of the study area showing different zones and contour lines.

3. REVIEW RELATED RESEARCH

Various researches have been conducted regarding the depletion of groundwater in Punjab. Many researchers have done the monitoring of groundwater in Punjab state.

Singh et al. (2013) used geographical information system (GIS) and remote sensing techniques to locate artificial groundwater recharge zones in the Bist Doab basin of Indian Punjab. The goal of this endeavor was to alleviate the acute problems with water scarcity that the region's intensive agricultural practices were causing. The study took into account a number of thematic layers, such as geology, geomorphology, drainage density, slope, soil texture, aquifer transmissivity, and specific yield. Based on each theme layer's proportional contribution to groundwater recharge, weights were assigned, and Saaty's analytic hierarchy approach was used to normalize these weights.

ArcGIS was used to integrate thematic layers in order to draw artificial groundwater recharge zones. Based on their impact on groundwater recharge, the area was divided into four zones on the resultant recharge map: poor, moderate, good, and very good. According to the study, these groups comprised 15%, 18%, 37%, and 30% of the study region.

The areas with the highest potential for recharge were located in the western and parts of the middle region, characterized by high infiltration rates due to the presence of flood plains, alluvial plains, and agricultural land. Conversely, the eastern and middle parts of the study area were identified as having the least effective recharge potential due to low infiltration rates.

Overall, the study provided valuable insights into the spatial distribution of artificial groundwater recharge potential in the Bist Doab basin, which can inform future water management strategies in the region to mitigate water scarcity issues.

The study conducted by Krishan et al. (2016) focused on monitoring groundwater levels in four blocks – Ajnala, Majitha, Rayya, and Tarsika – located in Amritsar over a period of seven years, from January 2006 to December 2013. The investigation aimed to assess the groundwater levels in these areas.

The groundwater in these blocks was found to occur under phreatic conditions, with varying depths to groundwater across the blocks. Specifically, the depth to groundwater ranged from 6 to 11 meters below ground level (m bgl) in Ajnala, 5 to 11 m bgl in Majitha, 14 to 19 m bgl in Rayya, and 9 to 14 m bgl in Tarsika. It's noteworthy that an increase in depth was observed during the study period, with a 6-meter increase observed in Majitha and a 5-meter increase observed in the other three blocks.

Analysis of monthly groundwater level data revealed a declining trend in groundwater levels across all four blocks, albeit at varying rates. This suggests a concerning situation regarding groundwater depletion in the region over the study period.

The findings of this investigation underscore the importance of continuous monitoring and management of groundwater resources in the studied blocks to address the declining groundwater levels and mitigate potential water scarcity issues in the future.

Sahoo et al. study from 2021 was primarily concerned with calculating spatiotemporal variability and multi-decadal trends of changes in groundwater level (GWL) in the Malwa region. With the use of geo-statistics and the standardized depth to water level index (SDWLI) approach, the researchers examined oscillations in groundwater. The study investigated GWL data from 90 observation wells/piezometers over a 21-year period (1997-2018).

Hierarchical cluster analysis was used to group the wells into various clusters according to how much they fluctuated. Sen's slope and the Modified Mann-Kendall (MMK) test were used to perform the trend analysis for each well's GWL variations.

For the majority of the wells in the Malwa region, the trend analysis's results showed a marked decline in GWL between 1997 and 2018. More than 30% of tube wells in the eastern portion of the research region showed an average depletion rate of roughly 40 cm/year during the pre- and post-monsoon seasons, according to spatiotemporal variation maps.

In contrast, throughout the past 20 years, there has been a discernible increase in the GWL in the southwest of the Malwa region. During the monsoon season, serious water logging problems were caused by this rise in water level. According to the study, nearly 20% of wells in the Malwa region's southwest had higher GWL over a 21-year period.

Overall, the findings highlight the complex spatio-temporal variations in GWL changes across the Malwa region, with significant declines observed in most areas but contrasting trends observed in specific regions, particularly in the southwestern part where rising GWL poses challenges related to water logging. These results underscore the importance of continuous monitoring and sustainable management practices to address groundwater depletion and water logging issues in the region.

The study by Singh et al. (2011) focused on qualitatively assessing groundwater quality in the Rupnagar district. The researchers utilized a groundwater quality index criterion to evaluate the suitability of groundwater for both irrigation and drinking purposes in the study area. This assessment involved a GIS-based multicriteria analysis, where different weights were assigned to various water quality parameters.

The water quality was classified into six classes ranging from very good to unfit for drinking. The study revealed that in most parts of the Rupnagar district, the groundwater quality varied from moderate to good. However, there were certain areas where the quality was poor to unfit for consumption.

Additionally, the researchers conducted an assessment of changes in land use and land cover (LULC) from 1989 to 2006 using Landsat and LISS III satellite data, respectively. They correlated these changes with the groundwater quality data and found that areas experiencing rapid urbanization and industrialization showed poor to unfit groundwater quality.

This correlation between land use changes and groundwater quality highlights the potential impacts of human activities, such as urbanization and industrialization, on groundwater quality in the study area. The findings underscore the importance of monitoring and managing land use practices to mitigate adverse effects on groundwater quality and ensure the sustainability of water resources for both agricultural and drinking purposes.

Gautam and Rai (2023) study used a multi-criteria decision analysis approach to identify groundwater zones in Punjab, India's Bist-Doab region. The groundwater table, groundwater quality factors for both residential and agricultural usage, and land-use/cover patterns served as the foundation for the investigation.

The region under study was predominantly characterized by agricultural activities, with approximately 71% of the land dedicated to agriculture. Other land-use categories included built-up areas (12%), forest cover (7%), tree plantations (5%), water bodies (3%), and open areas (2%).

About 8% of the land, primarily in and around the urban regions of Jalandhar, was discovered to have a groundwater table that was lower than 30 meters. Qualitatively, the groundwater was found to be unsuitable for residential usage in some areas surrounding the Jaijjon, Taunsa, Jalandhar metropolitan agglomeration, Shahkot, and Nakodar blocks. Additionally, it was discovered that 10% of the groundwater in Sultanpur Lodhi, Shahkot, Nakodar, Phagwara, and Bhulath was unsuitable for irrigation.

The integration of these thematic layers resulted in a groundwater zoning that showed that about 20% of the region had poor groundwater quality. These areas were primarily connected to urban agglomerations like Jalandhar, Phagwara, and Hoshiarpur, as well as portions of Sultanpur Lodhi, Mahilpur, and Balachaur blocks. High levels of industrialization and urbanization, in particular the untreated discharge of industrial wastes from pharmaceutical businesses in the Balachaur block, were factors contributing to the poor quality of groundwater in these areas.

The groundwater quality in the remaining 80% of the area, however, was comparatively better. However, a number of human-caused causes, including as over-extraction of groundwater, extensive application of chemical fertilizers in agricultural fields, and prevalent cropping patterns, continued to make this groundwater susceptible to degradation.

Overall, the study underscores the importance of comprehensive assessment and management strategies to address groundwater quality issues in the Bist-Doab region, particularly in areas experiencing rapid urbanization and industrialization. Effective measures are needed to mitigate anthropogenic factors contributing to groundwater deterioration and ensure sustainable water resource management in the region.

Sidhu et al. (2021) study sought to evaluate the effects of different policies on Punjab's groundwater depletion from 2000 to 2019. According to the report, Punjab saw an average

8.91-meter decline in groundwater throughout this time. Remarkably, the depletion in the Barnala district was the highest, measuring almost 20.38 meters.

The study found that the area of the state where the depth to the water table surpassed 10 meters significantly increased through the analysis of depth to the water table maps. In particular, this area increased from about 30% in 2000 to more than 75% in 2019. This suggests that during the study period, groundwater levels significantly decreased throughout Punjab.

Furthermore, the study utilized water table elevation maps to identify the development of groundwater depression cones in areas characterized by excessive groundwater over-exploitation. These depression cones signify a likely reversal in the direction of groundwater flow, indicating the severity of groundwater depletion in these regions.

Overall, the findings of the study highlight the alarming rate of groundwater depletion in Punjab over the examined period. The expansion of areas with significant depths to the water table and the development of groundwater depression cones underscore the urgent need for effective measures to address groundwater over-exploitation and ensure sustainable management of groundwater resources in the region.

By examining past climate data spanning almost two decades, Singla et al. (2022) looked into trends in precipitation, temperature, groundwater levels, and potential evapotranspiration (PET) in Central Punjab. The goal of the study was to identify the variables influencing the decrease in groundwater depth between 1998 and 2017.

The researchers' data revealed that the drop in groundwater depth was less pronounced in years with above-average rainfall, such 2008 and 2011. This implies that the amount of rainfall in the area has a big impact on groundwater levels.

Regarding potential evapotranspiration (PET), the study observed both maximum (2026 mm) and minimum (1566 mm) values in 2009 and 2004, respectively. In terms of rainfall, the minimum observed was 422.6 mm in 2000, while the maximum was 1012 mm in 2011.

Furthermore, the study identified a significant positive association between groundwater depth and factors such as paddy area and tubewell density. This indicates that areas with larger paddy cultivation and higher tubewell density tend to have shallower groundwater depths.

Overall, the findings suggest that variations in precipitation, temperature, and land use practices such as paddy cultivation and tubewell density are important factors influencing groundwater depth in Central Punjab. Understanding these trends is crucial for effective groundwater management and sustainable water resource utilization in the region.

Singh et al. study from 2021 sought to assess the groundwater quality in the Kapurthala district. During the pre-monsoon season, 200 samples were taken from each of the district's five blocks, and their hydro-chemical behavior was examined.

According to the study, the water samples had mean pH and electrical conductivity (EC) values of 7.16 and 825.7 μmhos/cm, respectively. $Na^+ < Ca^{2+} < Mg^{2+}$ was found to be the dominant order among the various cations, and their respective average amounts were 4.43, 2.46, and 1.71 meq/l.

Regarding the sodium adsorption ratio (SAR), every sample in the area was determined to be appropriate. On the other hand, 2.5% of the samples' salinity hazard (EC) made them unsuitable for irrigation. Furthermore, because of excessive residual sodium carbonate (RSC) values, 17.7% of the water samples were deemed unfit for irrigation.

By considering both EC and RSC criteria, the study classified 75.5% of the samples as fit and 24.5% as marginal for irrigation purposes in Kapurthala district.

Overall, the findings of the study provide valuable insights into the hydro-chemical characteristics of groundwater in Kapurthala district, highlighting both its suitability and limitations for irrigation purposes based on various parameters such as pH, EC, cation, and anion concentrations. Such assessments are essential for informed decision-making regarding groundwater usage and management in agricultural practices.

The study conducted by Kumar et al. (2007) examined the temporal variations of groundwater quality in Patiala and Muktsar districts, with a focus on comparing its suitability for irrigation and drinking purposes.

Only a few sites in the Patiala area appear to be at risk of future degradation, according to an analysis comparing chemical contents with WHO drinking water guidelines. Overall, the existing groundwater quality in the district is deemed suitable for drinking and irrigation. However, given the possibility of more adjustments, prudence was advised. Higher levels of total hardness (TH) and total dissolved solids (TDS) were found in the study in several Patiala locations, suggesting that those particular regions are not suitable for irrigation or drinking.

On the other hand, the Muktsar district's groundwater was found to have elevated levels of total hardness and total dissolved solids, making it unfit for human consumption. This suggested that Muktsar's water quality was inadequate for both irrigation and drinking.

Regarding the impact of the monsoon, the study observed that groundwater in Patiala district exhibited dilution and flushing effects during the monsoon season, which could potentially improve water quality. On the other hand, groundwater samples from Muktsar district showed excessive leaching of different chemical components, resulting in the enrichment of various anions and cations. This enrichment indicated pollution from external sources, highlighting potential contamination issues in Muktsar.

Overall, the study highlighted variations in water quality and possible future trends while offering crucial baseline data on the utility of groundwater in the two regions. It emphasized how crucial routine management and monitoring procedures are to guarantee the sustainable use of groundwater resources in the districts of Patiala and Muktsar, especially when it comes to resolving possible contamination issues in Muktsar.

Yadav and Kumar's (2020) study sought to determine whether groundwater in Punjab's Bathinda and Mansa districts was suitable for drinking and irrigation.

The average pH of groundwater in Bathinda district was found to be 8.2, although it was somewhat higher at 8.4 in Mansa district. Indicators of salinity, such as maximum mean electrical conductivity (EC), were recorded in Sardulgarh tehsil in Mansa district and Talwandi-Sabo tehsil in Bathinda district. This indicates that these particular places have higher saline levels than other areas in their respective districts.

The mean concentration of sodium (Na) was reported as 155 mg/L in Bathinda district and 21.2 mg/L in Mansa district. Higher sodium concentrations can indicate potential salinity issues in the groundwater.

The research also revealed that the highest recorded fluoride (F^-) content was discovered in the Mansa tehsil in the Mansa district, with a value of 2.3 mg/L, and Talwandi Sabo tehsil in the Bathinda district. These results suggest that there may be elevated fluoride levels in these particular sites, making the groundwater unfit for human consumption.

Overall, the study shows how different the groundwater quality is in the Bathinda and Mansa districts, with some places showing greater salinity and fluoride levels that could be problematic for drinking and irrigation. The findings highlight how crucial it is to regularly monitor and manage groundwater resources in order to guarantee their sustainable usage and mitigate any potential health hazards related to low water quality.

4. CONCLUSION

The decline of groundwater levels in Punjab has indeed become a significant concern, driven primarily by the over-exploitation of groundwater resources, especially for irrigation purposes. Irrigation is the major factor responsible for this depletion in the state.

To address this issue, various measures have been proposed and implemented. One approach is to increase groundwater potential through the construction of ponds, wells, and canals, which can help in replenishing groundwater levels by capturing and storing rainwater.

Furthermore, policies have been formulated to prevent the overuse of groundwater. These include providing training and subsidies for adopting more efficient irrigation techniques such as drip and sprinkler irrigation. Promoting the cultivation of low-water-required crops and encouraging delayed paddy transplanting are also strategies aimed at reducing water consumption in agriculture.

Additionally, creating public awareness regarding the depletion of groundwater levels and the importance of its sustainable management is crucial. Education campaigns can help inform farmers and the general public about the consequences of over-extraction and the need for conservation measures.

Overall, addressing the issue of groundwater depletion in Punjab requires a multi-faceted approach involving policy interventions, technological solutions, and public awareness campaigns to ensure the sustainable management of this vital resource for future generations.

REFERENCES

1. Baweja, S., Aggarwal, R., Brar, M., & Lal, R. (2017). Groundwater depletion in Punjab, India. *Encyclopedia of Soil Science*, 2017, 1-5.

2. Gautam, A., & Rai, S. C. (2023). Groundwater zoning and sustainable management strategies for groundwater resources in the Bist-Doab region of Punjab, India. Environment, *Development and Sustainability*, 1-22.

3. Krishan, G., Lohani, A. K., Rao, M. S., Kumar, C. P., & Takshi, K. S. (2016). Groundwater fluctuation and trend in Amritsar, Punjab, India. In Geostatistical and Geospatial Approaches for the Characterization of Natural Resources in the

Environment: Challenges, Processes and Strategies (pp. 183-187). Springer International Publishing.

4. Sahoo, S., Swain, S., Goswami, A., Sharma, R., & Pateriya, B. (2021). Assessment of trends and multi-decadal changes in groundwater level in parts of the Malwa region, Punjab, India. *Groundwater for Sustainable Development*, 14, 100644.
5. Sidhu, B. S., Sharda, R., & Singh, S. (2021). Spatio-temporal assessment of groundwater depletion in Punjab, India. *Groundwater for Sustainable Development*, 12, 100498.
6. Singh, A., Panda, S. N., Kumar, K. S., & Sharma, C. S. (2013). Artificial groundwater recharge zones mapping using remote sensing and GIS: a case study in Indian Punjab. *Environmental Management*, 52, 61-71.
7. Singh, C. K., Shashtri, S., & Mukherjee, S. (2011). Integrating multivariate statistical analysis with GIS for geochemical assessment of groundwater quality in Shiwaliks of Punjab, India. *Environmental Earth Sciences*, 62, 1387-1405.
8. Singh, G., Batra, N., Salaria, A., Wani, O. A., & Singh, J. (2021). Groundwater quality assessment in Kapurthala district of central plain zone of Punjab using hydro-chemical characteristics. *Journal of Soil and Water Conservation*, 20 (1), 43-51.
9. Singla, C., Aggarwal, R., & Kaur, S. (2022). Groundwater decline in Central Punjab- Is it a warning? *Groundwater for Sustainable Development*, 16, 100718.