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A QUANTITATIVE ANALYSIS OF INTERACTIONS BETWEEN GROUNDWATER AND SURFACE WATER IN THE HAILIUTU RIVER BASIN, ERDOS PLATEAU, CHINA.

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ABSTRACT

This study describes the exchange processes, seasonal variability, as well implications for basin water management in the Hailiutu River Basin on the Erdos Plateau, China. It uses numerical water-balance and groundwater-flow models, field observations, hydrochemical and isotopic tracing, and the results of this investigation to provide a quantitative assessment of the interactions between surface water and groundwater in this basin. Over the course of many weeks, scientists in several sub catchments monitored the flow of water via various channels, the amounts of groundwater being pumped, the speeds of groundwater pumping, and the effects of the weather. By simulating actual hydrographs and groundwater levels using a set of calibrated coupled surface-subsurface models. The researcher were able to estimate baseflow fractions, exchange fluxes at the river-aquifer interface, and the effects of human abstraction in both real-world and hypothetical situations. A spatially heterogeneous connection is shown by the results. The upstream headwater reaches are mostly supported by precipitation and have intermittent shallow groundwater, whereas the middle and lower reaches show sustained gaining circumstances driven by shallow unconfined aquifers. Analyses of isotope and hydrograph separation show that groundwater acts as a buffer, contributing significantly to mean yearly streamflow, especially during dry seasons. The main constraints on exchange magnitudes are recharge variability and riverbed hydraulic conductivity. In order to preserve natural flows and ensure long-term water security in the Hailiutu Basin, the research found that coordinated management of surface and groundwater resources was crucial.

Keywords: Groundwater-Surface Water Interaction, Hailiutu River Basin, Water Resource Management, Erdos Plateau.

INTRODUCTION

Maintaining hydrological equilibrium, preserving ecosystems, and assuring water supply in semi-arid locations are all greatly influenced by the interplay between groundwater and surface water. Due to growing human water needs, significant evaporation, and limited precipitation, it is particularly crucial to understand these dynamics in regions like the Hailiutu River Basin on the Erdos Plateau, China. Groundwater and surface water do not exist in a vacuum; rather, they are interdependent resources that are affected by one another via exchange mechanisms, which in turn affect streamflow, recharging of groundwater, and water quality. Despite the significance of this information, there is a lack of quantitative understanding of the river-aquifer interactions in this basin, which makes it difficult to manage the resources effectively (Ariken et al., 2020). Groundwater is an important source for human, agricultural, and commercial needs in the Hailiutu River Basin, which is representative of typical semi-arid regions where surface water supplies are limited and unpredictable. While upstream portions see intermittent flows due to seasonal precipitation and snowmelt, perennial flow in the lower and middle reaches is sustained by baseflow contributions from aquifers. However, water levels have dropped and biological flows have been endangered due to over-extraction of groundwater, which might eventually degrade river ecosystems. While some research has evaluated groundwater-surface water interactions using numerical modelling, isotopic tracing, and hydrochemical analysis, very little has offered a thorough quantitative framework specific to the Erdos Plateau's peculiarities. In order to fill this knowledge vacuum, this work uses a combination of field monitoring, chemical and isotopic markers, and calibrated groundwater-surface water models to measure exchange fluxes, compare variability across time and space, and determine the effects of human activities like pumping. Understanding linked water systems in semi-arid environments and providing scientific data to support sustainable water management are the goals of this project, which focusses on the Hailiutu River Basin. The results should help with environmental preservation, improve groundwater extraction regulations, and guide future water management in delicate plateau ecosystems (Duan et al., 2021).

BACKGROUND OF THE STUDY

The critical importance of surface and groundwater to the maintenance of ecosystems and human lives, water scarcity is a major problem in semi-arid and dry countries. The Hailiutu River Basin in China's Erdos Plateau is a prime example of a delicate hydrological setting defined by little precipitation, considerable evapotranspiration, and mounting human interference. Groundwater often maintains river flow during dry seasons and recharges aquifers during rainy times, making the connectivity between surface water and groundwater vital in these areas. These exchange mechanisms, however, are multifaceted, regionally varied, and subject to both natural and anthropogenic influences. Because of its strong hydraulic link to shallow aquifers, the Hailiutu River is one of the few rivers on the Erdos Plateau that flows continuously throughout the year. As a result of this connection, water is provided to local residents, agricultural irrigation is supported, and ecological balance is maintained (Ermida et al., 2020). However, the equilibrium between aquifer and river systems is becoming more and more endangered due to the rising extraction of groundwater for agricultural and industrial expansion. Environmental sustainability and long-term water security are being called into question due to declining groundwater levels, decreasing baseflow contributions, and changing river discharge patterns. Few hydrological studies have quantitatively examined the dynamic interactions between surface water and groundwater, despite the fact that they have offered insights on water supplies in the basin. Incomplete knowledge of the linked behaviour of these systems was a common result of traditional water resource evaluations that handled them independently. Researchers can now analyse the consequences of human activities under various hydrological conditions, track water sources, and quantify exchange flows thanks to advances in hydrochemical and isotopic methods coupled with numerical modelling. Using these methods as a foundation, this research analyses the Hailiutu Basin's river-aquifer interactions quantitatively. The study provides crucial information for sustainable water management in semi-arid plateau ecosystems by elucidating the methods and magnitudes of exchange (Firozjaei et al., 2021).

PURPOSE OF THE STUDY

The purpose of this research is to quantify the interactions between surface water and groundwater in the Hailiutu River Basin. It aims to fill information gaps while offering insights for effective water management on the Erdos Plateau along with additional semi-arid environments by merging field data, chemical and isotopic methods, and modelling methodologies. Because of both growing human demand and dwindling natural supplies, water resources in semi-arid and dry areas are under severe stress. An important water supply for agriculture, household usage, and ecological systems, the Hailiutu River Basin is located on China's Erdos Plateau. Due in significant part to its robust hydraulic connection with shallow groundwater aquifers, the Hailiutu River is one of the few rivers in the area that continues to flow year-round. In order to sustain river discharge, maintain ecological balance, and provide water security, this interplay between surface water and groundwater is crucial. But the basin is encountering more and more problems. More groundwater is being drawn out of the earth as a result of fast population growth, agricultural expansion, and industrial development. When rivers and aquifers are over-pumped, it changes the normal flow of water from the rivers and lowers the levels of groundwater. Climate change, which is characterised by low precipitation and excessive evapotranspiration, adds more strain on water systems that are already delicate. The long-term viability of the groundwater and surface water supplies is jeopardised under these circumstances. Groundwater and surface water have often been considered as distinct entities in China's water resource assessments in the past. These methods failed to take into account the hydrological cycle's interconnectedness and dynamic character. There are new ways to measure the interplay between groundwater systems and river flows thanks to developments in numerical modelling, isotopic tracking, and hydrochemical analysis. Using these instruments, scientists can determine the strength, direction, and unpredictability of exchanges, shedding light on the ways in which both natural and anthropogenic influences affect water availability.

LITERATURE REVIEW

As a consequence of how important they are in maintaining biological systems, supplying water, and controlling river flow, groundwater-surface water interactions have been the centre of hydrological study for decades. Research in more recent years has shown the significant hydraulic relationship between rivers and aquifers, which was previously overlooked. This is especially true in dry and semi-arid locations, where baseflow is essential for the maintenance of perennial streams. The interconnections between China's groundwater and surface water have been more acknowledged in the last few decades. Groundwater inputs are crucial to the biological flow of several rivers in the western and northern parts of the country. The hydraulic relationship between rivers and aquifers in the Erdos Plateau, a region with little precipitation and high evapotranspiration, is becoming more and more important. According to earlier studies conducted in the Hailiutu River Basin, this river is unique among the region's perennial streams, being supported by shallow aquifers (Huang et al., 2021).

While hydrochemical tracers and isotope studies have shown that groundwater affects river flow, the majority of these investigations have been qualitative, hence there is a lack of quantitative evaluations. More accurate source and exchange process identification of water has been made possible by recent developments in hydrochemical and isotopic methods. When used in conjunction with numerical and hydrological models, these methods provide accurate predictions of fluxes as well as their geographical and temporal variability. Simulated groundwater flow in the Hailiutu Basin has been achieved using numerical modelling; however, there is a lack of comprehensive studies that include field data, isotopic analysis, and model calibration. In addition, several studies in other semi-arid basins have shown that baseflow decreases and river quality declines due to human factors like groundwater pumping. In the Hailiutu Basin, where water stress has been worsened by agricultural and industrial development, these results imply comparable dangers. Regardless, there is a lack of research that thoroughly assesses the effects of pumping on the interconnections between the basin's rivers and aquifers. Accordingly, quantitative, integrated methods are crucial for comprehending groundwater-surface water interactions, as stated in the literature. This researcher fills important gaps in overall understanding of the dynamics of river-aquifer systems on the Erdos Plateau by integrating hydrochemical, isotopic, and modelling approaches; the results help with sustainable water management (Kamara et al., 2020).

RESEARCH QUESTION

What is the relevance of groundwater extraction rate on hailiutu river basin, erdos plateau, China?

RESEACH METHODOLOGY

Research Design: The SPSS version 25 was used for the quantitative data analysis. A 95% confidence interval and odds ratio were used by the researchers to assess the direction and strength of the statistical association. A statistically significant criteria was established by the researchers at $p < 0.05$. The data's basic features were revealed via a thorough investigation. Data examined using computer tools for statistical assessment and data gathered via surveys, questionnaires, and other methods are often subject to quantitative techniques of evaluation.

Sampling: Participants were requested to complete questionnaires to participate to the research. Researchers distributed 800 questionnaires after identifying a research population of

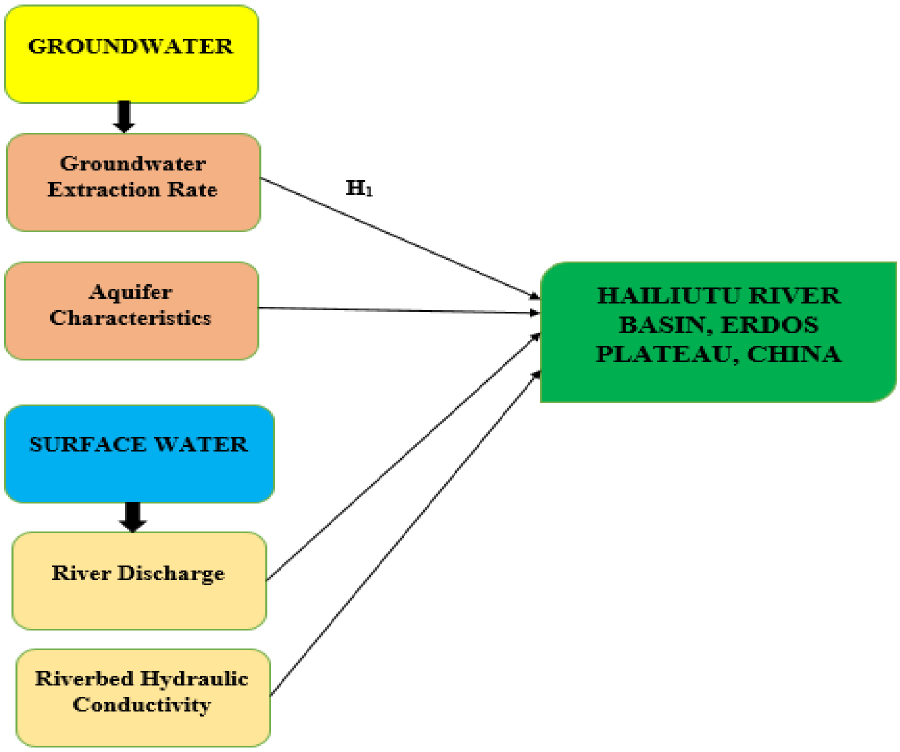
670 individuals utilising the Rao-soft method. Following the collection of 768 replies, the researchers eliminated 68 due to incompleteness, yielding a final sample size of 700.

Data and Measurement: The study mostly utilised data acquired from a questionnaire survey. The participant's essential demographic information was requested first. Participants were subsequently given a 5-point Likert scale to evaluate the online and offline channels. The researchers rigorously analysed several resources, especially internet databases, for this secondary data acquisition.

Statistical Software: Statistical analysis was conducted using MS-Excel and SPSS 25.

Statistical Tools: The primary characteristics of the data were understood via the use of descriptive analysis. Using ANOVA, the researcher must examine the data.

CONCEPTUAL FRAMEWORK



RESULT

Factor Analysis: Factor Analysis (FA) is often used to find hidden variables in observable data. Regression coefficients are often used to provide evaluations in the absence of discernible visual or diagnostic indicators. Success in financial analysis is significantly reliant on models. The goals of modelling are to identify errors, intrusions, and apparent linkages. The Kaiser-Meyer-Olkin (KMO) Test is one tool for evaluating datasets that have been generated by numerous regression analyses. The representativeness of the model and the variables in the sample are checked by them. There seems to be data duplication based on the numbers. Data is more easily comprehensible when proportions are smaller. The output of KMO is an integer from 0 to 1. A sufficient sample size is defined as a KMO value between 0.8 and 1. According to Kaiser, these are the acceptable limits: According to Kaiser, the following are the requirements for admission:

The usual range is 0.60 to 0.69, however this range is much lower at 0.050 to 0.059. A range of 0.70 to 0.79 is considered average for middle grades. Ranging from an 80 to an 89 on the quality point scale. They discover awe between 0.90 and 1.00. The Kaiser-Meyer-Olkin .943 scale.

The findings of Bartlett's sphericity test are as follows: Chi-square, significance = .000, about 190 degrees of freedom this substantiates the legitimacy of the assertions made on sampling. The researchers used Bartlett's Test of Sphericity to ascertain the relevance of the correlation matrices. A Kaiser-Meyer-Olkin value of 0.943 indicates that the sample is deemed adequate. Bartlett's sphericity test yields a p-value of 0.00. A researcher may ascertain that the correlation matrix is not an identity matrix if Bartlett's sphericity test yields a significant result.

Table 1. Testing for Bartlett's Sampling Adequacy and KMO.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.943
Bartlett's Test of Sphericity	Approx. Chi-Square	4550.968
	df	190
	Sig.	.000

Moreover, the Bartlett Test of Sphericity confirmed the broad applicability of correlation matrices. The Kaiser-Meyer-Olkin metric of sample adequacy is 0.943. The researchers obtained a p-value of 0.00 via Bartlett's sphericity test. The correlation matrix did not pass Bartlett's sphericity test, indicating a significant outcome.

INDEPENDENT VARIABLE

Groundwater: To maintain river flow and meet human and biological demands in this semi-arid environment, groundwater in the Hailiutu River Basin is crucial. In dry seasons, when precipitation is scarce, the shallow aquifers on the Erdos Plateau, which are linked to surface water systems, play a major role in baseflow. Despite considerable evapotranspiration and unpredictable rainfall, the Hailiutu River is able to stay perennial because to its hydraulic link. Nevertheless, the over-depletion of groundwater supplies for agricultural use, household usage, and industrial expansion is becoming more problematic. Groundwater levels are reduced, recharge-discharge cycles are disrupted, and the ecological balance of the basin is threatened by intensive pumping. This highlights the critical need of knowing how groundwater works, including recharge rates, aquifer properties, and seasonal changes. To assess the function of groundwater in river-aquifer interactions and sustainable water resource management, this work employs hydrochemical analysis, isotope tracking, and modelling to provide a quantitative foundation (Luo et al., 2021).

FACTOR

Groundwater Extraction Rate: The rate of groundwater extraction is the amount of water pulled from aquifers for various uses, including agriculture, industry, and households. An increase in demand has prompted heavy pumping in the Hailiutu River Basin, which has an effect on groundwater levels. Lower baseflow contributions, weaker hydraulic links to the river, and less aquifer storage are all results of high extraction rates. The basin's long-term viability is in jeopardy since this process changes the water balance naturally and speeds up ecological deterioration. Human activities exacerbate stress on the surface and groundwater interactions, which are highlighted in the research by analysing extraction rate as a factor (Yang et al., 2021).

DEPENDENT VARIABLE

Hailiutu River Basin, Erdos Plateau, China: The Hailiutu River Basin, situated on the semi-arid Erdos Plateau, is unique among areas where groundwater plays a significant role in maintaining perennial river flow. The stability of agriculture, ecology, and local populations in this basin is largely reliant on the groundwater-surface water ratio. But this equilibrium has been upset by rising groundwater removal, leading to falling baseflow, less water available, and environmental hazards. Thus, groundwater management has a direct impact on the hydrological stability of the basin (Li et al., 2022).

Relationship Between Groundwater Extraction Rate and Hailiutu River Basin, Erdos Plateau, China: There is an exact relationship between human water consumption and natural hydrological processes, as shown by the connection between the rate of groundwater extraction and the Hailiutus River Basin. Lower river discharge and greater susceptibility to droughts are consequences of excessive pumping, which diminishes groundwater storage and baseflow. The health of ecosystems, community water supplies, and agricultural output are all jeopardised by this. On the other hand, sustainable extraction techniques are key to preserving river flows, aquifer levels, and long-term water security. By investigating this connection, researcher may learn more about the ways in which the Erdos Plateau and other semi-arid areas are affected by human activities on the hydrological cycle (Zhou et al., 2022). On the basis of the above discussion, the researcher formulated the following hypothesis, which was analyse the relationship between Groundwater Extraction Rate and Hailiutu River Basin, Erdos Plateau, China.

“H_{01}: There is no significant relationship between Groundwater Extraction Rate and Hailiutu River Basin, Erdos Plateau, China` .”

"H_1: There is a significant relationship between Groundwater Extraction Rate and Hailiutu River Basin, Erdos Plateau, China."

Table 2. H1 ANOVA Test.

ANOVA					
Sum					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	44828.643	345	5655.437	1289.429	.000
Within Groups	573.788	354	4.386		
Total	45402.431	699			

The outcome is substantial in this research. Statistical significance is achieved with a p-value of .000 (below the .05 alpha level), and the F value is 1289.429. This suggests that researchers might support the alternative view, "H_1: There is a significant relationship between Groundwater Extraction Rate and Hailiutu River Basin, Erdos Plateau, China" is accepted and the null hypothesis is rejected.

DISCUSSION

The discussion of the study of groundwater-surface water interactions in maintaining hydrological in addition to ecological stability in the Hailiutu River Basin is emphasised by the findings of this research. The findings corroborate the significance of baseflow as a stabilising element in semi-arid settings and show that groundwater significantly contributes to river discharge, especially during dry seasons. What this means is that aquifers act as natural buffers, keeping rivers flowing even when precipitation varies with the seasons, according to research conducted all across the world. Because of the basin's complicated geological and hydrological circumstances, there is noticeable geographical variation across the upstream, midstream, and downstream portions. While groundwater inflows have a far stronger impact on flows in the middle and lower parts, precipitation and snowmelt have a more significant impact on flows upstream. These exchanges are vulnerable to both natural and anthropogenic fluctuation, according to isotopic data and models. Evidence suggests that ecological hazards like river drying and habitat damage might result from excessive groundwater pumping, which lowers aquifer levels and reduces baseflow. Sustainable water management in the Hailiutu Basin must take into account both surface and groundwater as a connected system, according to the results. Striking a balance between human needs and ecological requirements is crucial for the long-term sustainability of water resources on the Erdos Plateau. This can only be achieved by integrated monitoring, regulated abstraction, and model-based planning.

CONCLUSION

In the Hailiutu River Basin, a semi-arid area of the Erdos Plateau where water resources are becoming scarcer, this research offers a thorough quantitative evaluation of the interactions between surface water and groundwater. Studies demonstrate the critical significance of groundwater in maintaining river discharge, especially during dry spells when baseflow keeps perennial flows going. The geographical and temporal diversity of river-aquifer exchanges was proven by isotopic and hydrochemical data in conjunction with numerical modelling. This evidence highlighted unique upstream, midstream, and downstream dynamics. Excessive groundwater abstraction, which decreases aquifer storage and baseflow contributions, endangers this fragile equilibrium, which is a key finding. River flow is compromised, ecological stability is endangered, and long-term water security is jeopardised by such repercussions. The need of adaptive management solutions is further highlighted by the fact that exchange mechanisms are very susceptible to recharge variability and riverbed hydraulic conditions. Therefore, for the Hailiutu Basin's water administration to be sustainable, surface water and groundwater must be considered as one interdependent resource. It is suggested that basin planning include linked hydrological models, that monitoring networks be strengthened, and that pumping be regulated according to recharge. By the end of the day, the research provides useful information for policymakers who are trying to balance human requirements with biological functions in delicate plateau ecosystems.

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