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Characterization of the Surface Lake and Evaluation of Its Benefits on Unconfined Aquifer Interaction—A Study on Coastal Karnataka Lake, India

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Abstract and Figures

Groundwater recharge is pivotal in addressing diverse water needs in rural India, like water supply, irrigation, and domestic requirements. A significant amount of recharge happens through lakes. However, minimal research has been conducted to evaluate the status of extinct lakes and their potential contributions to nearby unconfined aquifers. This study aims to bridge this gap by assessing critical aspects of groundwater recharge and investigating the role of an extinct lake in this process. Sixteen strategically positioned monitoring wells facilitated data collection, enabling a comprehensive analysis of the groundwater dynamics. The study revealed a substantial increase in built-up areas from 25.66 to 37.59% between 2004 and 2021. The rainfall-runoff relationship was found to be strong, with runoff levels varying from 703.8 to 3426 mm. Using the Korkmaz method, it was determined that around 48% of precipitation naturally replenishes unconfined aquifers. Soil samples near the monitoring wells have varying hydraulic conductivity values of 77.76 to 570.24 m/day, indicating their suitability for water storage. Lake restoration and bund construction emerge as a transformative intervention, positively influencing consistent water levels in wells, redirecting water flow, and enhancing 16.38% increased crop productivity. This emphasizes the lake's significance in replenishing nearby wells, establishing its crucial role in groundwater recharge. These insights are vital for informed water resource management, particularly in sustaining the region's water and agricultural needs. Understanding and harnessing the potential of extinct lakes emerge as imperative measures for ensuring long-term water security in rural India.

Study area | Schematic diagram of… | Location of wells in the lake… | Representation study procedur… | Land use land cover maps of t…

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RESEARCH

Characterization of the Surface Lake and Evaluation of Its Benefits on Unconfined Aquifer Interaction—A Study on Coastal Karnataka Lake, India

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Abstract

Groundwater recharge is pivotal in addressing diverse water needs in rural India, like water supply, irrigation, and domesti requirements. A significant amount of recharge happens through lakes. However, minimal research has been conducted t evaluate the status of extinct lakes and their potential contributions to nearby unconfined aquifers. This study aims to bridg this gap by assessing critical aspects of groundwater recharge and investigating the role of an extinct lake in this proces Sixteen strategically positioned monitoring wells facilitated data collection, enabling a comprehensive analysis of the ground water dynamics. The study revealed a substantial increase in built-up areas from 25.66 to 37.59% between 2004 and 2021. Th rainfall-runoff relationship was found to be strong, with runoff levels varying from 703.8 to 3426 mm. Using the Korkma method, it was determined that around 48% of precipitation naturally replenishes unconfined aquifers. Soil samples near th monitoring wells have varying hydraulic conductivity values of 77.76 to 570.24 m/day, indicating their suitability for wate storage. Lake restoration and bund construction emerge as a transformative intervention, positively influencing consister water levels in wells, redirecting water flow, and enhancing 16.38% increased crop productivity. This emphasizes the lake' significance in replenishing nearby wells, establishing its crucial role in groundwater recharge. These insights are vital fo informed water resource management, particularly in sustaining the region's water and agricultural needs. Understanding an harnessing the potential of extinct lakes emerge as imperative measures for ensuring long-term water security in rural India

Keywords Groundwater recharge · Unconfined aquifers · Surface water storage · Runoff · SCS-CN · Hydraulic conductivity · Lake aquifer interaction

Introduction

Lakes and reservoirs cover less than 2% of the Earth's lan surface. Despite this relatively small area, they signifi

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approximately 90% of the Earth's unfrozen surface fresh water. It also plays a crucial role in global hydrological an biogeochemical processes and is essential for maintainin a reliable source of fresh water for various ecological an human needs. Lakes and reservoirs are often biodiversit hotspots, hosting a wide range of species. The groundwate and surface water, such as lakes, are interconnected withi the global water cycle [1, 2]. This means a dynamic wate exchange exists between underground aquifers and surfac water bodies. Understanding groundwater flow in and out o lakes is crucial for the sustainable management of surfac water resources like lakes [3, 4]. This knowledge is essentia

for protecting, developing, and effectively managing water bodies. While it is relatively easy to characterize the inflow of surface water into lakes, understanding how interactions with aquifers affect the quantity and quality of lake water is challenging [5]. Quantitative approaches are necessary to understand the influence of changes in groundwater levels on the flow patterns and hydraulic relationships between lakes and aquifers. These approaches involve measuring and quantifying various parameters and variables [6].

The Indian government has considered lake restoration to solve the country's water scarcity issues. Prioritizing scientific research and lake restoration measures is necessary to address water resources [7, 8]. Arid regions have a more significant number of lakes, but semi-arid areas and humid regions have a greater need to improve their lakes in the Indian context [9, 10]. Water harvesting structure improvement has been practiced in Karnataka for a long time [11]. As per the archaeological and historical records, lake restoration was implemented during the Chandra Gupta Maurya [392–297 BC] period. Karnataka has only 5% of its water harvesting structures installed throughout the state. Despite the abundance of lakes, one-third of Karnataka's total irrigation depends on Lakes (6th Minor Irrigation Census). Due to reduced rainfall, the coastal Karnataka region has faced water scarcity for agricultural production, which has led to a few crop rotations in the past year. Heavy groundwater pumping in the region has significantly influenced the freshwater gradient toward the sea. This gradient has sometimes reversed, causing saltwater intrusion from the sea into the freshwater aquifers [12]. This intrusion can contaminate and damage the internal freshwater resources [13]. The damage caused by saltwater intrusion can have long-lasting implications for the affected aquifers. For instance, the paddy crop is typically rotated three times per year, but due to water scarcity, the yield has been reduced to one crop in recent years [14].

Previous studies have examined groundwater (GW) and surface water (SW) systems as interconnected components of a larger hydrological cycle [5, 15]. The amount of water generated from the catchment to the lake is the primary concern in hydrological studies. The amount of groundwater recharging an aquifer is determined by precipitation distribu-

to evaluate the total runoff generated in the catchment an lake storage and its overall benefit for unconfined aquifer to improve the groundwater table. The study assess the gen eral runoff generated from the catchment to the lake, quan tify the total storage of the lake using the Korkmaz metho and evaluate the lake benefits for unconfined aquifers. T achieve this objective, lake-level and open well data are use to understand the benefits of lakes near unconfined aquifers

Materials

Study Area

Kavoor Lake, located in Mangalore taluk of Dakshin Kan nada district and adjacent to the old Mahalingeshwara Tem ple in Kavoor, holds historical importance as the water fror the lake has been traditionally used for temple rituals. Th study area is located to the north of the city, between lati tudes 12°54′00″ N to 12°55′30″ N and longitudes 74°51′00 E to 74°52′30″. The lake, irregular in shape and extending t 300 m, covered an area of 0.0338 km^2 (8.37 Acres) in 200(diminishing to 0.0142 km^2 (3.51 Acres) by 2022. With fou inlets and an outlet channel directing water to the Kuloc River, the lake's hydrological connectivity is crucial to it ecosystem. However, rapid urbanization in the vicinity ha led to siltation, encroachment by builders, and sewage dis posal, resulting in the lake's deterioration. This degradation attributed to escalating urbanization, has adversely affecte the lake's health and significantly reduced its size. Due t its ecological and cultural significance, preserving and reju venating Kavoor Lake has become imperative to protect it environmental integrity, restore its historical and cultura value, and maintain its role as a valuable resource for th local community. Details of the study area are given in Fig. 1

Data Sets

This study employed various data sets obtained from sit

recharge challenging to examine in all water resource evaluations[16, 17]. Limited research has been conducted to investigate the status of the extinct lake and how it could impact nearby groundwater levels in the coastal Karnataka context. Selecting potential lakes in coastal Karnataka and conducting studies of unconfined aquifers are critical. The Kavoor lake has deteriorated over the last decade due to sewage discharge, encroachment, siltation, and weed infestation. The restoration of these aquifers is a complex and time-consuming process that could take several years. The present study aims

soil. A 2.5-m resolution image from the Google Earth Pr satellite imagery database for 2004, 2014, and 2021 was use for land use land cover (LULC) classification. The years wer chosen based on satellite images with less cloud cover avail ability and with a focus on photos taken during Novembe and December in the years 2004, 2014, and 2021 to minimiz the drying out of natural landscapes, such as lakes or vegeta tion, which can occur during the summer months. The LULC data provides a comprehensive perspective on the endurin dynamics of land utilization. The study utilizes the FA

Fig. 1 Study area

world ESRI soil shapefile and the SWAT 2012 database to determine the hydrologic soil group (HSG) of the soil in the study area. Temporal daily rainfall data for one rain gauge station from 2019 to 2021 located in the study area was collected from the Coastal Karnataka Minor Irrigation Department . It serves as the primary source for obtaining accurate and reliable precipitation measurements for the study period.

Methodology

catchment area. The survey focused on community member living near the lake for 30 to 40 years and engaged numerou households, predominantly targeting respondents aged 40 t 60 who have resided in the region for an extended period The summary of questions discussed during questionnair survey is listed in Table 1.

SCS-CN Method

The SCS-CN method was used to estimate runoff throug the watershed. It is based on the Soil Conservation Servic Curve Number approach, as documented in studies b

age capacity using specific methods (SCS-CN approach and the Korkmaz method). Figure 2 illustrates the overall methodology employed in the study.

Questionnaire Survey

The questions are designed to gather information about crop productivity improvement after the bund construction in the

Service (SCS) in 1969. It is a widely used metho for calculating the amount of direct surface runoff i hydrological studies. The CN, a critical parameter i the SCS-CN method, represents the runoff potential of particular area. CN values range from 0 to 100. A CN valu of 100 represents impervious conditions. Conversely, value of 0 denotes indefinitely abstracting conditions, wher the surface allows maximum infiltration, preventing runoff

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