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Geomorphic Imprints and Land-Use Footprints in Groundwater Potential Zonation of Karha River Catchment

Dr. Pravin Pannalal Gaikwad

Abstract

Groundwater scarcity continues to be a major challenge in areas where local communities have limited technical understanding of groundwater systems and their management. The present study examines the geomorphological features and land use/land cover patterns of the Karha River basin to identify and map groundwater potential zones. Based on origin and morphological characteristics, the basin's landforms are categorized into structural, denudational, and depositional types. Structural landforms, mainly found in the northern, northeastern, and marginal parts of the basin, including Askarwadi, Chimbali, and Jejuri, are associated with poor groundwater prospects. In contrast, Denudational landforms such as pediments and pediplains, located in the central part of the basin around Garade, Saswad, and Morgaon, exhibit moderate groundwater potential. The highest groundwater potential is observed in depositional landforms situated in the southeastern sector near the confluence of the Karha and Nira rivers, particularly in areas such as Songaon, Doralwadi, Karhavagaj, and Male Wadi. These results emphasize the importance of geomorphological analysis as a key tool for identifying suitable zones for sustainable groundwater exploration, planning, and management in hard rock river basins.

Keywords: Groundwater potential, Geomorphology, Landforms, Hard rock aquifer

Introduction

Water is essential for the existence of all living organisms and plays a vital role in maintaining the sustainability of the biosphere. Without water, life on Earth would not be possible. The Earth is unique among planets because of the abundant presence of water on its surface, as well as within its crust and atmosphere. Groundwater is a crucial natural resource that sustains human life, supports agriculture, and plays an important role in ensuring food security and sustainable development. However, it is not an unlimited resource and is facing increasing pressure due to growing demand and overuse. The situation is particularly serious in India, where more than 17 percent of the world's population depends on only about 4 percent of the global renewable freshwater resources. This creates a significant gap between water availability and the needs of the population, highlighting the importance of its proper management and conservation. Furthermore, the usable portion of water resources is restricted due to their uneven spatial and temporal distribution. Inequality in access, along with the absence of an integrated approach to water resource planning and management, has further complicated the situation (National Water Policy, 2012).

From the viewpoint of geomorphology, landforms offer important clues about the behavior of water both on the surface and beneath the ground. Hence, a detailed and organized classification of terrain is essential for understanding hydrological properties and evaluating the potential occurrence and availability of groundwater. Geomorphological mapping helps in identifying landforms and understanding their influence on groundwater occurrence. The integration of geomorphological, geological, and hydrological information helps to narrow down areas requiring detailed investigation through advanced techniques. Landforms represent distinct surface features shaped by natural processes such as deposition, erosion and weathering (Strahler and Strahler, 1996).

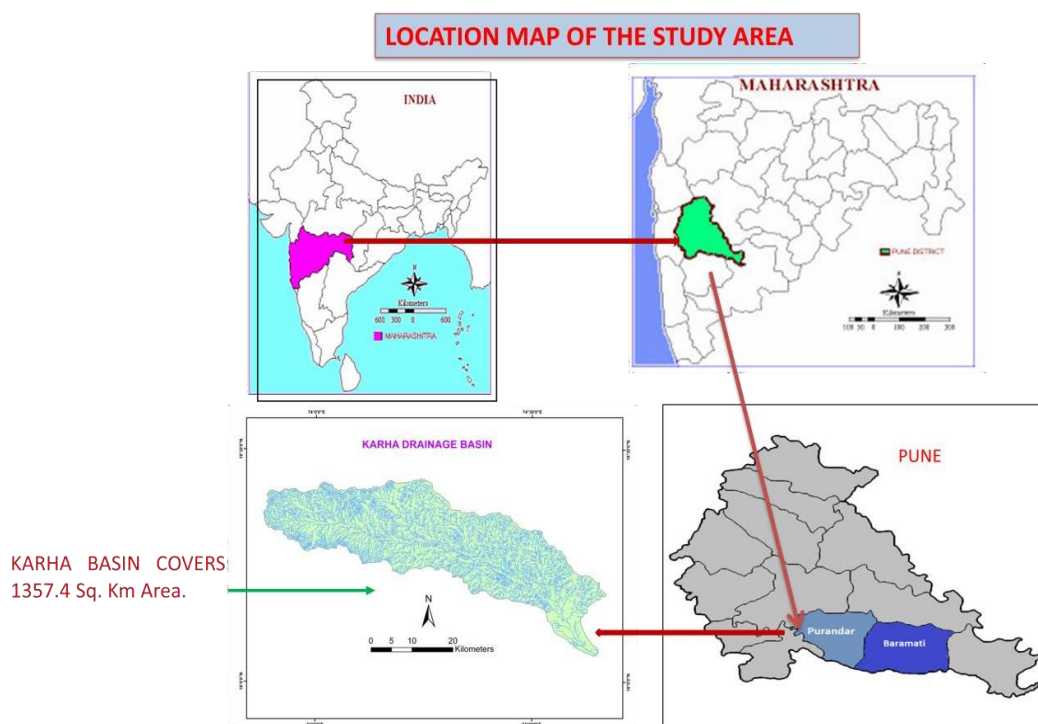
Examining landforms in a drainage basin, especially from hydrological and geomorphological viewpoints, has become increasingly important for interpreting how water is distributed and how recharge processes take place within the basin. Geomorphology has a strong relationship with both surface runoff and groundwater occurrence (Verstappen, 1983). The nature of terrain influences rainfall distribution, infiltration capacity, runoff generation, and groundwater recharge potential. The use of modern remote sensing and geospatial techniques enables accurate identification and mapping of landforms that are favourable for groundwater recharge. Factors such as geology, geomorphology, geological structures, and climatic conditions play a significant role in controlling groundwater occurrence, storage, and movement, especially in hard rock regions.

Although these features may not be directly visible on the ground, they can be effectively interpreted using satellite imagery. The integration of hydrogeological data with spatial analysis improves the accuracy and reliability of groundwater potential assessment.

Study Area

The Karha River watershed has been selected as the focus of the present investigation. This drainage basin is situated in the southwest part of the Sahyadri range within geographical boundaries of Pune district of Maharashtra State. The Karha River forms a significant feeder stream of the Nira River, contributing to its flow and overall drainage system. It originates near Askarwadi and flows southeastward before joining the Nira River in the vicinity of Sonagaon. The Malharsagar Dam has been constructed on the upper course of the Karha River, serving as a significant water storage structure in the basin.

In geographical terms, the Karha River basin spreads over the Purandar and Baramati talukas in Pune district. The basin is located between latitudes 18°24'20" N and 18°06'10" N, and longitudes 73°48'20" E and 74°40'10" E. The basin covers a total area of approximately 1357.4 square kilometres, and the river itself has a length of about 89 kilometres. The region selected for the study falls within the extent of the Survey of India topographical maps bearing sheet numbers 47J/3, 47J/4, 47J/7, 47J/8, 47J/11, 47J/12 and 47F/15. The Karha River serves as a vital source of water for agriculture and domestic use in the region. The basin exhibits considerable variation in elevation. The overall elevation of the area reaches up to 1117 meters above mean sea level, while the highest point, located at Purandar Fort, rises to 1403 meters. In contrast, the lowest elevation, approximately 400 meters above mean sea level, occurs in the southeastern sector of the basin. Such differences in elevation play a crucial role in shaping the drainage network, controlling geomorphological features, and determining the groundwater prospects of the area.



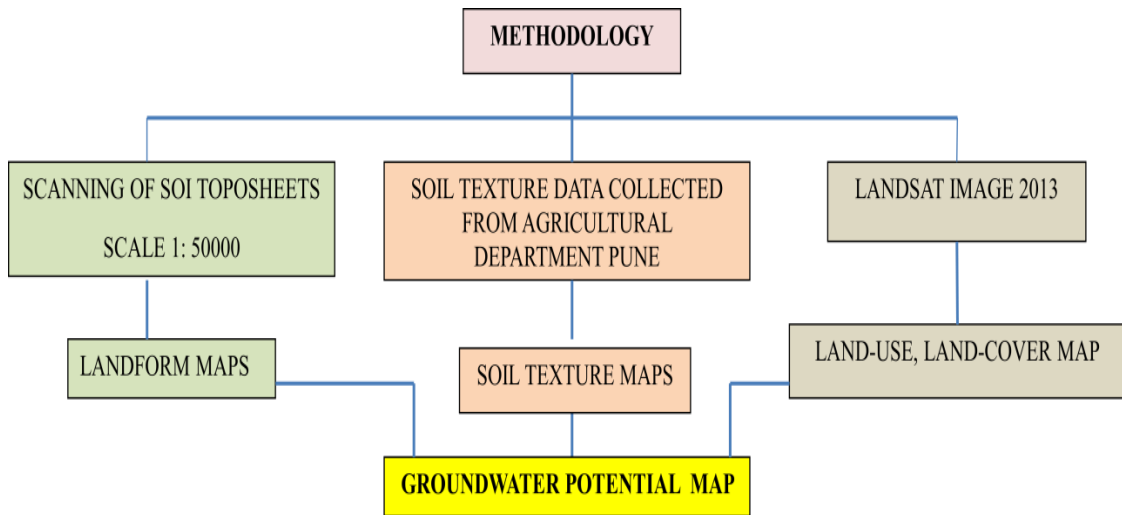
Objectives

1. To analyze how geomorphological landform features influence the occurrence and potential of groundwater in the study region.
2. To delineate and categorize groundwater potential areas into classes such as low, moderate, and high through the combined assessment of landforms, land use/land cover, and soil texture data.

Methodology

A systematic approach was adopted to analyze groundwater potential in relation to physical characteristics of the Karha River basin. Topographical maps from the Survey of India were employed to develop the landform map, whereas satellite images were used to create the land use and land cover map of the study area.

In addition, soil samples were collected directly from the field and analyzed at the Agricultural Laboratory in Pune. Supplementary soil data were also obtained from the Department of Agriculture, Pune. Based on these datasets, a soil texture map was prepared. This map plays an important role in understanding the relationship between soil characteristics and groundwater potential. Areas with coarse-textured soils generally allow higher infiltration and percolation rates, which enhance groundwater recharge and increase the likelihood of groundwater availability.



Methodology Flow – chart

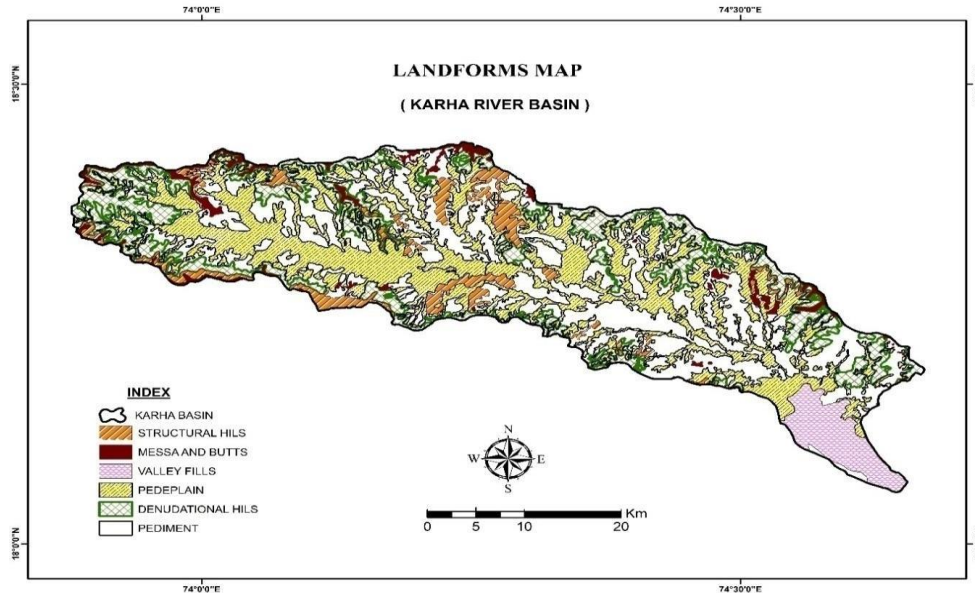
Landforms and Groundwater Potential

As mentioned previously, geomorphological conditions are a key factor in influencing groundwater potential. Evaluating groundwater resources requires proper knowledge of how groundwater originates, where it occurs, and how it moves, which are all closely linked to the nature of landforms. Various landform types, especially structural, denudational, and depositional features, play an important role in controlling groundwater availability and the processes of recharge. In the Karha River basin, several important fluvial landforms have been identified, and their characteristics and associated groundwater potential are described in the following sections.

Types of Landforms	Geomorphic Feature	Surface Material
Structural	Structural Hills	Thin soil and bare rock surface with sparse grass cover.
	Messa Buttes	Gentle slope, Flat surface, bare rock, layer of thin soil.
Denudational	Denudational Hills	Rugged Viewtop and sparse grass layer
	Pediment	Medium thick soil, sparse shrubs with Grass cover
	Pedeplain	Thick soil, fractured and weathered basalt, thick vegetation
Depositional	Valley Fills	Colluvial deposits with Alluvial

Landforms and there characteristics in Karha basin
(Source - Field Investigations)

Area covered under each landform category in Karha River Basin			
Sr.No	Landform Types	Area in (Sq.km)	Area in (%)
1	Denudational Hills	222.86	16.41815235
2	Structural Hills	87.19221	6.423472079
3	Mesa and Butts	39.8395	2.934986003
4	Pedeplain	473.9769	34.91799764
5	Pediment	472.14339	34.7829225
6	Valley Fills	61.388	4.522469427
Total		1357.4	100



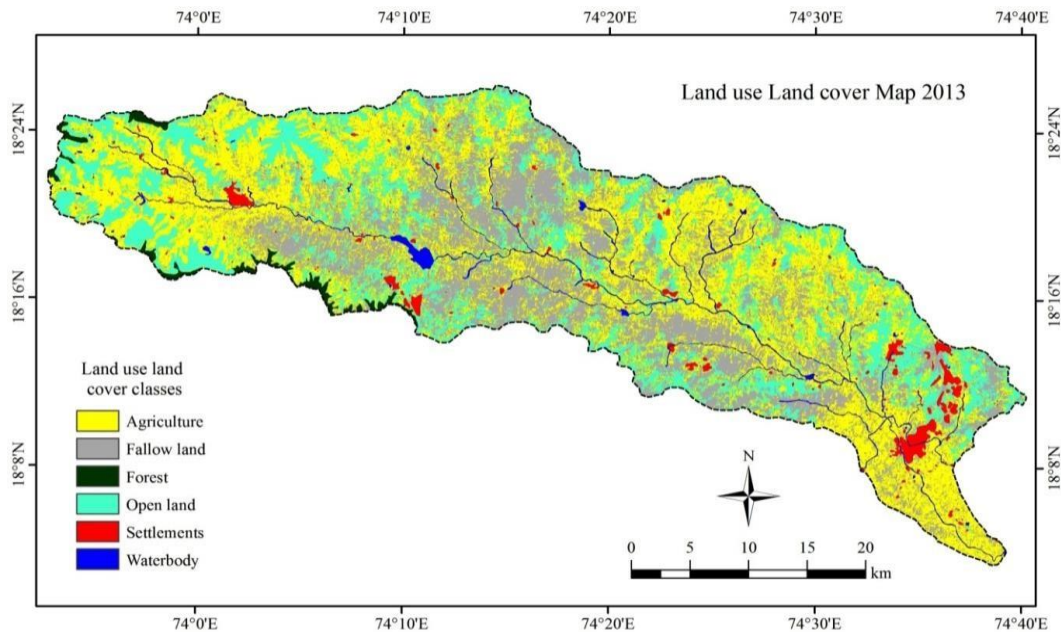
Landforms Delineated in Karha Basin

Land Use Classification

Data on land use and land cover is very important for evaluating groundwater potential, as the nature of the land surface directly affects groundwater recharge and its storage capacity. In this study, Landsat satellite images were used to develop the land use and land cover map, covering the whole Karha River basin. A exhaustive understanding of LU and LC patterns helps in evaluating groundwater availability, since different surface conditions influence infiltration, runoff, and recharge processes. Previous studies have also emphasized the strong connection between land use/land cover and groundwater occurrence (El-Koury et al., 2022).

Sr. No.	Lu/LC	Area in (Sq.km)	Area in (%)
1	Area under Agriculture	515.99	38.01
2	Area under Fallow land	448.52	33.04
3	Area as Open land	316.79	23.34
4	Area under Settlements	30.96	2.28
5	Water body	29.1	2.14
6	Area under Forest Cover	16.04	1.18

Actual Land use in Karha basin
(Source – Compiled by Author)



Land use- Land Cover Map of Karha Basin

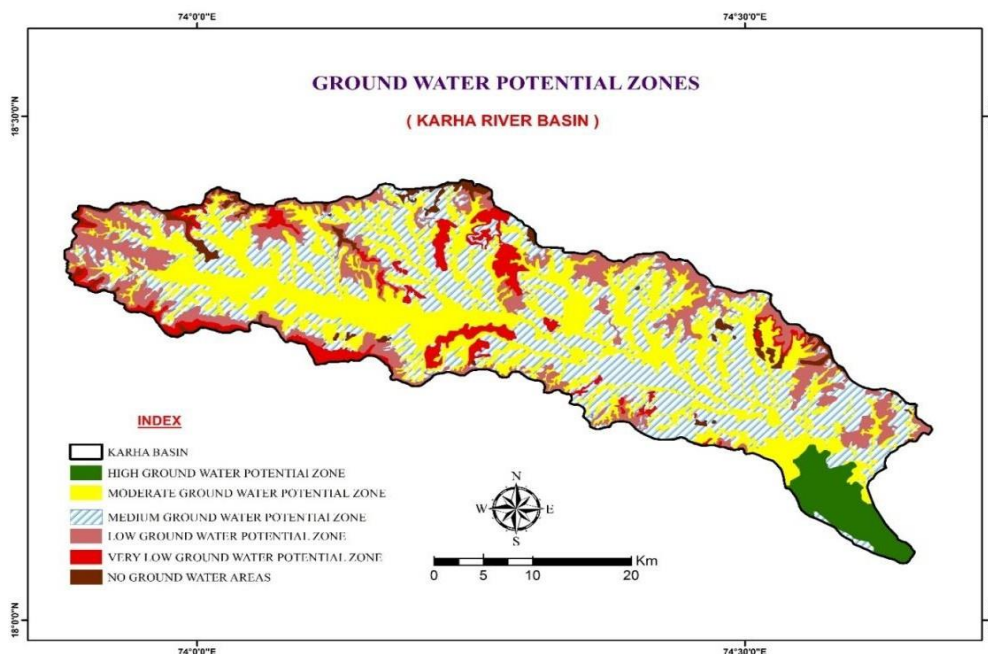
In the Karha River basin, forest cover occupies approximately 16.04 sq. km, accounting for about 1.18 percent of the total geographical area. Forested regions play an important role in conserving soil, reducing the impact of rainfall erosion, and enhancing water infiltration, which supports groundwater recharge. Water bodies extend over 29.10 sq. km, representing around 2.14 percent of the basin area, and they serve as significant sources of surface water for nearly six months of the year.

Agricultural land constitutes the largest proportion of the basin, covering about 515.99 sq. km (38.01 percent). These areas generally allow moderate infiltration, thereby contributing moderately to groundwater recharge. Fallow land covers approximately 448.52 sq. km (33.04 percent) of the study area. Such areas typically experience higher surface runoff and comparatively lower infiltration rates, resulting in limited groundwater recharge. Open land occupies about 316.79 sq. km (23.34 percent) and is also characterized by low infiltration capacity, making it less favorable for groundwater recharge. Built-up areas account for around 30.96 sq. km (2.28 percent) these are known as impermeable zones, where groundwater recharge is minimal due to the presence of constructed firm surfaces.

Groundwater Potential Zones of the Karha Basin

Zones of Groundwater potential in the Karha River basin were identified using the weighted overlay method in a GIS environment through raster overlay analysis. GIS is powerful and advanced spatial technology, provides a variety of tools for performing raster-based calculations and spatial analysis across geographic areas. In this study, different thematic layers related to groundwater potential were prepared individually using GIS methods.

These thematic layers were then integrated using the weighted overlay index method to identify groundwater potential zones. The assessment considered key parameters including land use/land cover, soil texture, and geomorphological characteristics, as these factors play a crucial role in controlling groundwater availability and recharge processes. Suitable weights were allocated to each thematic layer according to its level of influence, and their integration enabled the categorization of the study area into various groundwater potential zones.



Potential Zones of Groundwater

Conclusion

The weighted overlay index approach classified the Karha River basin into six distinct groundwater potential classes, namely High, Moderately High, Moderate, Low, Very Low, and No Potential zones. The analysis reveals that zones with high groundwater potential occupy only a small portion of the basin and are predominantly concentrated in the downstream region, particularly around the confluence of the Karha with Nira rivers. This is primarily due to the presence of valley fill deposits, which favor groundwater storage and recharge. Valley fill landforms cover about 61.38 sq. km, accounting for approximately 4.52 percent of the total basin area, and are associated with good groundwater prospects.

A significant portion of the basin falls under Moderate and Medium groundwater potential categories. These zones are largely associated with denudational landforms such as pediments and pediplains, which cover 472.14 sq. km (34.78 percent) and 473.97 sq. km (34.91 percent) of the total study area, respectively. These landforms allow moderate infiltration and groundwater storage.

In contrast, the source region and basin margins, particularly areas with minimal erosion and structurally controlled hills, show very low to negligible groundwater potential. This is mainly due to the presence of hard rock terrain, which restricts water infiltration and storage. Structural landforms such as mesas and buttes also exhibit poor groundwater prospects, covering about 87.19 sq. km (6.42 percent) and 39.84 sq. km (2.93 percent) of the basin area, respectively. Overall, the study highlights the strong influence of geomorphological characteristics on the distribution and availability of groundwater in the Karha River basin.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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