



GEOSPATIAL ANALYSIS AND HYDROGEOLOGICAL MODELLING FOR GROUNDWATER POTENTIAL MAPPING IN MINING- IMPACTED ZONES OF KARNATAKA: A FRAMEWORK FOR SUSTAINABLE WATER RESOURCE MANAGEMENT

**Syed Yusef D, Mohamed Thowfiq S, Santhosh Kumar M,
Fefin Mohan Mp,**
Students

SNS College of Technology

Dr. C Gajendren

Assistant Professor

SNS College of Technology

ABSTRACT

Power mining has a profound impact on countries and economies around the world. Economically, it fosters growth by providing jobs, earning income through exports, and supporting manufacturing and related industries. Ability to ensure availability of valuable minerals and resources for a range of industries from gold, copper and other metals to coal and minerals, and sources are . The project also fosters technological innovation, leading to improvements in efficiency, safety and environmental sustainability. However, the impact of mining extends beyond economics, often affecting the environment and social development. Environmental problems such as habitat degradation and pollution, as well as social issues such as local displacement and human rights violations, highlight the need for sustainable practices and emphasis on responsible governance in the mining industry. Mining activities in Karnataka have significantly impacted groundwater resources, leading to water scarcity and environmental degradation in the region. This study presents a framework for sustainable water resource management in mining-impacted zones through geospatial analysis and hydrogeological modelling. The study utilizes GIS and SWAT tools to assess groundwater potential and to recommend groundwater conservation measures. Groundwater potentiality has been delineated in different zones (very low, moderate, very good, good, low) in the study region based on weighted overlay analysis.

The study reveals zones with different groundwater prospects viz. very low (0.003%), moderate (19.640%), very good (57.575%), good (28.544%), low (0.235%).

The framework developed in this study serves as a valuable tool for policymakers, water resource managers, and mining companies to make informed decisions regarding sustainable water resource management in Karnataka's mining regions. By incorporating GIS and SWAT technologies, this framework enables efficient data analysis, visualization, and scenario planning for groundwater potential mapping and conservation strategies.

KEY WORDS: GIS, MS Access, groundwater potential, remote sensing.

CHAPTER-1 INTRODUCTION

1.1. GENERAL

"Geospatial analysis and hydrogeological modeling for groundwater potential mapping in mining affected areas of Karnataka" aims to develop a comprehensive plan for sustainable water resources management in areas affected by mining activities focuses on groundwater potential on the assessment of these mine-affected areas by n and hydrogeological modeling techniques

Soil analysis uses spatial data on groundwater availability, land use modeling, and hydraulic characteristics mapping and interpretation, which is important for understanding groundwater dynamics in a development area the study Combining this information with hydrodynamic modeling, researchers aim to predict the distribution and availability of groundwater resources in mine-affected areas It can also help the police offices for possible locations.

The framework developed in this study provides a systematic approach to assessing groundwater potential in mined areas by considering the complex interactions between geology, hydrology and land use ho contributes to the broader goal of promoting sustainable development and environmental protection in specific areas.

CHAPTER-2 OBJECTIVES AND SCOPE

2.1. OBJECTIVES

- To conduct geospatial analysis to identify groundwater potential in the mine affected areas of Karnataka.
- To develop a hydrogeological model for the availability and quality of groundwater in the study area.
- To develop a groundwater potential map that can guide sustainable water management in the region.
- To assess the impact of mining activities on groundwater and propose mitigation measures.

- To suggest strategies for sustainable groundwater management in affected mining areas in Karnataka.

2.2. SCOPE

- Conduct a comprehensive review of existing literature and information on groundwater resources, mining industries and environmental impacts of the study area.
- Collection and analysis of geographical data including satellite images, maps, maps and hydrological data to determine groundwater potential.
- Hydrological modeling using software such as MODFLOW to monitor groundwater availability and characteristics to simulate groundwater flow.
- To integrate the results of soil analysis and hydrologic modeling to map groundwater potential for the mined areas in Karnataka.
- Assessment of groundwater levels through field surveys, water quality testing, and stakeholder interviews.
- Mitigation measures and sustainable groundwater management strategies are proposed to address the challenges posed by the mining industry in the area.
- To make recommendations to the planners, regulators and stakeholders for enhancing sustainable water management practices in the mining areas affecting Karnataka.
- Document the methodology, findings and recommendations in a comprehensive report or research paper for distribution to relevant stakeholders and scientists.

CHAPTER-3

LITERATURE REVIEW

1. Ackermann's (1976) paper in Eos, Transactions American Geophysical Union, titled "Soil and Water Conservation," discusses the importance and methods of soil and water conservation. While the provided abstract or summary isn't available, it likely covers various aspects of soil and water conservation practices, including erosion control, watershed management, and sustainable land use practices.
Soil and water conservation is a critical topic in environmental science and agriculture, aiming to prevent soil erosion, improve water quality, and sustainably manage natural resources. The paper likely provides insights into the significance of soil and water conservation, the challenges associated with erosion and degradation, and the techniques and strategies available for mitigating these issues.
2. Allafta, Opp, and Patra (2021) conducted a study titled "Identification of groundwater potential zones using remote sensing and GIS techniques: A case study of the Shatt Al- Arab Basin," published in the journal Remote Sensing. In their research, they focused on assessing the groundwater potential zones within the Shatt Al-Arab Basin using remote sensing and GIS (Geographic Information System) techniques.
The Shatt Al-Arab Basin, located in a region of significant importance due to its reliance on groundwater resources, provided the backdrop for their investigation. Groundwater is a vital resource for various purposes, including agricultural irrigation, industrial use, and domestic supply, making its effective

management crucial for sustainable development.

The authors likely employed a combination of remote sensing data and GIS tools to analyze factors influencing groundwater occurrence and distribution. These factors may include land use/land cover, geological formations, slope, drainage patterns, and hydrological characteristics. By integrating these spatial datasets and employing suitable analytical methods, they aimed to delineate areas with high groundwater potential within the study area.

Their findings and methodology could contribute to better understanding the hydrogeological characteristics of the Shatt Al-Arab Basin, assisting policymakers and water resource managers in making informed decisions regarding groundwater management and sustainable utilization.

For further insights and details on their research methodology, results, and conclusions, referring to the full paper would provide a comprehensive understanding of their study. Srinivas, V. V., & Sett, S. (2017). Hydrogeological modeling for sustainable groundwater management in mining areas: A review. *Mine Water and the Environment*, 36(4), 553-563.

3. Andualem and Demeke (2019) conducted a study titled "Groundwater potential assessment using GIS and remote sensing: A case study of Guna Tana landscape, Upper Blue Nile Basin, Ethiopia," published in the *Journal of Hydrology: Regional Studies*. The research focused on evaluating the groundwater potential in the Guna Tana landscape, situated within the Upper Blue Nile Basin of Ethiopia, utilizing GIS (Geographic Information System) and remote sensing techniques.

The Upper Blue Nile Basin region is of significant importance due to its critical role in the hydrology and water resources of Ethiopia. Understanding the groundwater potential in this area is crucial for sustainable water resource management and development.

The authors likely employed GIS-based spatial analysis techniques and remote sensing data to characterize various hydrogeological parameters, such as lithology, land use/land cover, topography, and hydrological features. By integrating these datasets and applying suitable methodologies, they aimed to delineate areas with high groundwater potential within the Guna Tana landscape.

Their research findings and methodology could provide valuable insights for groundwater resource assessment and management in the Upper Blue Nile Basin, contributing to informed decision-making and sustainable water resource utilization practices in the region. For a more detailed understanding of their methodology, results, and implications, accessing the full paper would be beneficial.

4. Arulbalaji, Padmalal, and Sreelash (2019) conducted a study titled "GIS and AHP Techniques Based Delineation of Groundwater Potential Zones: a case study from Southern Western Ghats, India," published in *Scientific Reports*. The research aimed to delineate groundwater potential zones in the Southern Western Ghats region of India by integrating Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) techniques.

The Southern Western Ghats region of India is known for its ecological significance and rich biodiversity. However, understanding the groundwater potential in this area is crucial for sustainable water resource management, especially considering the increasing demand for water due to agricultural, industrial, and domestic purposes.

The authors likely utilized GIS to compile and analyze various spatial datasets, including geological, hydrological, topographical, and land use/land cover data. Additionally, they employed the Analytical Hierarchy Process (AHP), a multi-criteria decision-making technique, to assign weights to different factors influencing groundwater potential, such as lithology, slope, rainfall, soil type, and land use.

By integrating these datasets and applying the AHP methodology, the researchers aimed to delineate different groundwater potential zones within the study area. These zones could provide valuable information for groundwater resource management, land use planning, and decision-making processes in the Southern Western Ghats region. Accessing the full paper would provide more detailed insights into their methodology, results, and the implications of their findings for water resource management and conservation efforts in the study area.

Bhardwaj, Singh, and Singh (2023) conducted a study titled "Groundwater quality mapping of Singrauli district using ArcGIS," published in August 2023. The research aimed to assess and map the groundwater quality in Singrauli district, India, using ArcGIS (Geographic Information System) technology.

Singrauli district is known for its extensive coal mining activities, which can have significant impacts on groundwater quality due to potential contamination from mining operations and associated activities. Understanding the spatial distribution of groundwater quality parameters is essential for effective water resource management and environmental protection in the region.

The authors likely collected water samples from various locations within the Singrauli district and analyzed them for key groundwater quality parameters such as pH, electrical conductivity, total dissolved solids (TDS), major ions, heavy metals, and other contaminants. They then used ArcGIS software to spatially analyze and visualize the distribution of these parameters across the study area.

Through their study, Bhardwaj et al. aimed to create groundwater quality maps that could help identify areas with water quality issues, potential contamination sources, and areas suitable for groundwater usage. Such maps can aid local authorities, policymakers, and environmental agencies in implementing appropriate measures for groundwater conservation and pollution control in Singrauli district.

Accessing the full paper would provide more detailed information on the methodology used, the specific groundwater quality parameters assessed, the spatial analysis techniques employed, and the implications of the findings for groundwater management and environmental sustainability in the region.

5. Bhardwaj, A., Singh, A., & Singh, S. (2023). "Groundwater quality mapping of Singrauli district using ArcGIS." The study was published in August 2023, likely in a scientific journal or conference proceedings. The authors aimed to assess and map groundwater quality in Singrauli district, India, utilizing ArcGIS technology. This research is significant due to Singrauli's extensive coal mining activities, which can impact groundwater quality. By spatially analyzing key parameters such as pH, conductivity, and heavy metal concentrations, the study aimed to identify areas with water quality issues and potential contamination sources. The findings could inform groundwater management strategies and environmental protection efforts in the region.
6. Burayu, D. G. (2022). "Identification of Groundwater Potential Zones Using AHP, GIS and RS Integration: A Case Study of Didessa Sub-Basin, Western Ethiopia." The study, published in the journal

Remote Sensing of Land in 2022, presents a case study focusing on the Didessa Sub-Basin in Western Ethiopia. The author employs an integrated approach utilizing Analytical Hierarchy Process (AHP), Geographic Information Systems (GIS), and Remote Sensing (RS) techniques to identify groundwater potential zones.

This research is particularly significant due to the importance of groundwater as a vital water resource in Ethiopia and the need for effective management and conservation strategies. By combining AHP, GIS, and RS, the study aims to provide a comprehensive assessment of groundwater potential in the Didessa Sub-Basin.

The methodology likely involves the use of satellite imagery and spatial data analysis techniques to characterize various factors influencing groundwater occurrence and distribution. These factors may include land use/land cover, geological formations, soil characteristics, slope, and precipitation patterns. The identification of groundwater potential zones can contribute to sustainable water resource management practices, land use planning, and decision-making processes in the study area.

Additionally, the findings may have implications for agricultural development, water supply planning, and environmental conservation efforts in Western Ethiopia.

7. Dile, Y. T., Daggupati, P., George, C., Srinivasan, R., & Arnold, J. (2016). "Introducing a new open source GIS user interface for the SWAT model." This study, published in *Environmental Modelling and Software* in 2016, introduces a new open-source Geographic Information System (GIS) user interface designed for the Soil and Water Assessment Tool (SWAT) model.

The Soil and Water Assessment Tool (SWAT) is a widely used hydrological model for watershed-scale water resources management and environmental assessment. However, its utilization can be challenging for users without specialized training in GIS and hydrological modeling.

To address this challenge, the authors developed a new open-source GIS user interface that simplifies the process of setting up and running the SWAT model. The interface likely provides users with intuitive tools for importing spatial data, defining watershed boundaries, specifying model parameters, and visualizing simulation results.

By making the SWAT model more accessible through a user-friendly GIS interface, the study aims to enhance the adoption of the model by a wider range of stakeholders, including researchers, water resource managers, and policymakers. This accessibility can facilitate more informed decision-making regarding watershed management, land use planning, and water quality protection.

The development of open-source tools like this GIS user interface promotes transparency, collaboration, and innovation in the field of hydrological modeling and environmental assessment. It enables users to customize and extend the functionality of the SWAT model to suit their specific needs and research objectives.

8. Gebeyehu, A., Ayenew, T., & Asrat, A. (2023). "Delineation of groundwater potential zones of the transboundary aquifers within the semiarid Bulal catchment, Southern Ethiopia." This study, published in *Environmental Monitoring and Assessment* in 2023, focuses on delineating groundwater potential zones within the semiarid Bulal catchment in Southern Ethiopia.

Groundwater plays a crucial role in sustaining water supply, especially in arid and semiarid regions where surface water availability is limited. Understanding the distribution of groundwater potential zones is essential for effective water resources management and sustainable development.

The researchers employed remote sensing and Geographic Information System (GIS) techniques to delineate groundwater potential zones in the Bulal catchment. By integrating various spatial datasets, including topography, land use/land cover, soil properties, and hydrogeological parameters, they aimed to identify areas with high potential for groundwater recharge and storage. The delineation of groundwater potential zones provides valuable information for decision-makers regarding land use planning, groundwater extraction, and the design of water supply infrastructure. Additionally, it contributes to the sustainable management of transboundary aquifers, which are critical shared water resources requiring coordinated management efforts among neighboring countries. This study underscores the importance of utilizing advanced geospatial technologies for assessing and managing groundwater resources in semiarid regions. By improving our understanding of groundwater dynamics and potential, it contributes to efforts aimed at ensuring water security and resilience in water-stressed areas like the Bulal catchment.

9. Gebeyehu, A., Ayenew, T., & Asrat, A. (2023). "Delineation of groundwater potential zones of the transboundary aquifers within the semiarid Bulal catchment, Southern Ethiopia." This study, published in *Environmental Monitoring and Assessment* in 2023, focuses on delineating groundwater potential zones within the semiarid Bulal catchment in Southern Ethiopia.

Groundwater plays a crucial role in sustaining water supply, especially in arid and semiarid regions where surface water availability is limited. Understanding the distribution of groundwater potential zones is essential for effective water resources management and sustainable development.

The researchers employed remote sensing and Geographic Information System (GIS) techniques to delineate groundwater potential zones in the Bulal catchment. By integrating various spatial datasets, including topography, land use/land cover, soil properties, and hydrogeological parameters, they aimed to identify areas with high potential for groundwater recharge and storage.

The delineation of groundwater potential zones provides valuable information for decision-makers regarding land use planning, groundwater extraction, and the design of water supply infrastructure. Additionally, it contributes to the sustainable management of transboundary aquifers, which are critical shared water resources requiring coordinated management efforts among neighboring countries.

This study underscores the importance of utilizing advanced geospatial technologies for assessing and managing groundwater resources in semiarid regions. By improving our understanding of groundwater dynamics and potential, it contributes to efforts aimed at ensuring water security and resilience in water-stressed areas like the Bulal catchment.

10. Gebru, H., Gebreyohannes, T., & Hagos, E. (2020). "Identification of Groundwater Potential Zones Using Analytical Hierarchy Process (AHP) and GIS-Remote Sensing Integration, the Case of Golina River Basin, Northern Ethiopia." This research, published in the *International Journal of Advanced Remote Sensing and GIS* in 2020, focuses on the identification of groundwater potential zones in the

Golina River Basin, located in Northern Ethiopia. Groundwater is a vital water resource in many regions, particularly in arid and semi-arid areas where surface water availability is limited. Understanding groundwater potential zones is crucial for sustainable water resource management and development.

The study employs an integrated approach combining Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) with remote sensing techniques. AHP is used to assign weights to various thematic layers representing factors influencing groundwater occurrence, such as lithology, land use/land cover, slope, and precipitation. These weighted layers are then integrated within a GIS framework to generate groundwater potential maps for the Golina River Basin.

By delineating groundwater potential zones, the research provides valuable insights for groundwater management and development strategies in the study area. Decision-makers can use these maps to identify suitable locations for groundwater extraction, prioritize areas for recharge enhancement measures, and mitigate potential groundwater depletion risks.

The integration of AHP, GIS, and remote sensing techniques demonstrates the effectiveness of interdisciplinary approaches in groundwater resource assessment and management. Such methodologies enable stakeholders to make informed decisions based on comprehensive spatial data analysis, contributing to sustainable water resource utilization and environmental conservation efforts.

11. George, G. K., Vishnudas, S., & Abdu Rahiman, K. U. (2024). "Optimizing among Analytical Hierarchy Process, Influencing Factor Method, and Frequency Ratio Model in the Determination of Groundwater Potential Zones." This study, published in *Civil Engineering and Architecture* in 2024, focuses on optimizing methodologies for determining groundwater potential zones.

The research compares and evaluates three different techniques: Analytical Hierarchy Process (AHP), Influencing Factor Method (IFM), and Frequency Ratio (FR) model. These methodologies are commonly used in groundwater potential mapping, each with its advantages and limitations. By optimizing among these methods, the study aims to identify the most effective approach for delineating groundwater potential zones.

AHP is a multicriteria decision-making method that considers various factors influencing groundwater occurrence and assigns weights to them based on their relative importance. IFM identifies influential factors affecting groundwater potential by analyzing their spatial distribution and relationship with known groundwater occurrences. The FR model statistically correlates spatial attributes of factors (e.g., lithology, land use/land cover, slope) with observed groundwater occurrences to predict potential zones.

By comparing the results obtained from these three techniques, the study seeks to identify the most accurate and reliable method for groundwater potential mapping. Such optimization can enhance the efficiency and effectiveness of groundwater resource assessment and management practices, facilitating informed decision-making and sustainable water resource utilization strategies.

12. Hussein, A. A., Govindu, V., & Nigusse, A. G. M. (2017). "Evaluation of groundwater potential using geospatial techniques." Published in *Applied Water Science* in 2017, this study focuses on assessing groundwater potential through the application of geospatial techniques.

Geospatial techniques, such as Geographic Information Systems (GIS) and remote sensing, are

increasingly being employed in groundwater studies due to their ability to integrate spatial data from various sources and analyze complex relationships among different factors influencing groundwater occurrence.

The study likely involves collecting spatial data on factors such as geology, land use/land cover, soil characteristics, topography, and hydrological parameters. These data are then processed and analyzed using GIS and remote sensing tools to delineate areas with high groundwater potential.

By evaluating the spatial distribution of influencing factors and their relationships with known groundwater occurrences, the study aims to identify areas that are most likely to have abundant groundwater resources.

This information can be valuable for water resource management, land use planning, and decision-making regarding groundwater exploitation and conservation.

The findings of this research contribute to the understanding of groundwater dynamics in the study area and can support sustainable groundwater development and management practices.

13. Jhariya, D. C., Mondal, K. C., Kumar, T., Indhulekha, K., Khan, R., & Singh, V. K. (2021). "Assessment of groundwater potential zone using GIS-based multi-influencing factor (MIF), multi-criteria decision analysis (MCDA), and electrical resistivity survey techniques in Raipur city, Chhattisgarh, India." This study, published in *Aqua Water Infrastructure, Ecosystems and Society* in 2021, focuses on assessing groundwater potential zones in Raipur city, Chhattisgarh, India, utilizing a combination of GIS-based multi-influencing factor (MIF) analysis, multi-criteria decision analysis (MCDA), and electrical resistivity survey techniques.

The research likely involves collecting various geospatial datasets related to factors influencing groundwater occurrence, such as geology, land use/land cover, soil properties, topography, and hydrological parameters. These datasets are integrated within a GIS framework to create thematic layers representing the spatial distribution of each factor. The multi-influencing factor (MIF) analysis involves assigning weights to each thematic layer based on their relative importance in influencing groundwater occurrence. These weights are determined through expert judgment or statistical methods, reflecting the significance of each factor in contributing to groundwater availability.

The multi-criteria decision analysis (MCDA) is then applied to combine the weighted thematic layers and generate a composite groundwater potential map. MCDA involves decision rules or algorithms to integrate the weighted layers and rank the suitability of different locations for groundwater development. Additionally, electrical resistivity survey techniques may have been employed to validate the findings of the GIS-based analysis. Electrical resistivity surveys provide direct subsurface information regarding the lithological characteristics and groundwater potential of the study area.

By integrating these techniques, the study aims to provide a comprehensive understanding of groundwater potential zones in Raipur city, which can be valuable for urban water resource management, infrastructure planning, and sustainable groundwater utilization.

14. Kattimani, J., Murthy, A., S, R., Kumar, S., & R, V. (2018). "Identification of Ground Water Potential Zone Using Remote Sensing and GIS Techniques." Published in the *International Journal of Advanced*

Research in 2018, this study focuses on identifying groundwater potential zones using remote sensing and GIS techniques.

The research likely involves the integration of satellite imagery and GIS data to analyze various environmental parameters that influence groundwater occurrence. These parameters may include land use/land cover, geology, soil properties, slope, and hydrological features.

Remote sensing data, such as optical and/or radar imagery, are processed and analyzed to derive thematic layers representing the aforementioned parameters. GIS techniques are then used to overlay and analyze these layers to identify areas with high groundwater potential.

The study may employ techniques such as image classification, spectral analysis, and spatial analysis within a GIS environment to delineate groundwater potential zones. Additionally, field validation and groundwater monitoring data may be used to calibrate and validate the results obtained from remote sensing and GIS analysis.

By identifying groundwater potential zones, the study aims to provide valuable information for groundwater resource management, land use planning, and sustainable development in the study area.

15. Kumar, A., & Krishna, A. P. (2018). "Assessment of groundwater potential zones in coal mining impacted hard-rock terrain of India by integrating geospatial and analytic hierarchy process (AHP) approach." Published in Geocarto International in 2018, this study focuses on assessing groundwater potential zones in a hard-rock terrain impacted by coal mining activities in India.

The study likely integrates geospatial techniques, such as remote sensing and GIS, with the Analytic Hierarchy Process (AHP) to evaluate and prioritize factors influencing groundwater occurrence.

Geospatial data, including satellite imagery, digital elevation models, land use/land cover maps, geological maps, and hydrological data, are processed and analyzed within a GIS environment to derive thematic layers representing various factors affecting groundwater potential.

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making technique that allows researchers to systematically evaluate and prioritize factors based on their relative importance. Stakeholder preferences and expert opinions may also be incorporated into the AHP framework to assign weights to different factors.

By integrating geospatial analysis with the AHP approach, the study aims to provide a comprehensive assessment of groundwater potential zones in the coal mining impacted hard-rock terrain. This information can be valuable for sustainable groundwater management, environmental planning, and mitigating the impacts of coal mining activities on groundwater resources in the study area.

CHAPTER-4**METHODOLOGY**

The methodology is given in the following flow chart,



Fig. 2 methodology

4.1 SOFTWARE USED**4.1.1 GIS**

1. ArcGIS is a powerful geographic information system (GIS) software developed by Esri that is widely used in various industries and sectors for spatial data analysis, visualization, and mapping. Some of the key uses of ArcGIS include:

2. **Spatial Analysis:** ArcGIS allows users to conduct spatial analysis to explore relationships, patterns, and trends within geographic data. This can include proximity analysis, overlay analysis, spatial statistics, and suitability modeling.
3. **Mapping and Cartography:** ArcGIS provides tools for creating high-quality maps and visualizations that can be customized to display different types of data layers, symbols, labels, and annotations. Users can create interactive web maps, print maps, and 3D visualizations.
4. **Data Management:** ArcGIS enables users to manage and organize spatial data efficiently, including importing, exporting, editing, and querying geospatial datasets. Users can create geodatabases to store and manage different types of spatial data in a structured manner.
5. **Geocoding and Geolocation:** ArcGIS includes tools for geocoding addresses and place names to convert them into geographic coordinates, as well as reverse geocoding to identify the address or location associated with specific coordinates. This is useful for spatial analysis and visualization.
6. **Network Analysis:** ArcGIS provides tools for network analysis, such as routing, closest facility analysis, service area analysis, and vehicle routing problem analysis. These tools are commonly used in transportation planning, logistics, and emergency response.
7. **Spatial Modeling:** ArcGIS allows users to create and run spatial models using Model Builder, a visual programming environment. Users can automate complex geoprocessing tasks, workflows, and analyses by connecting geoprocessing tools in a sequence.
8. **Field Data Collection:** ArcGIS supports mobile data collection through apps like Collector for ArcGIS and Survey123 for ArcGIS, which allow users to collect field data, update maps in real-time, and share information with colleagues.
9. **Decision Support Systems:** ArcGIS can be used to develop decision support systems that integrate spatial data, models, and analytical tools to help organizations make informed decisions based on geographic information.

4.1.3 MS ACCESS

1. Microsoft Access is a versatile database management system that offers a wide range of uses across various industries and applications. Some key uses of MS Access include:
2. **Data Storage and Management:** MS Access provides an efficient platform for storing, organizing, and managing large volumes of data. It allows users to create tables, forms, queries, and reports to effectively store and retrieve information.
3. **Business Applications:** MS Access is commonly used to develop custom business applications such as inventory management systems, customer relationship management (CRM) tools, project tracking databases, and employee databases. It enables businesses to streamline processes, improve data accuracy, and enhance decision-making.
4. **Reporting and Analysis:** MS Access offers robust reporting and analysis capabilities, allowing users to generate custom reports, charts, and graphs based on the stored data. This helps in gaining insights, identifying trends, and making informed decisions.
5. **Data Entry Forms:** MS Access enables the creation of user-friendly data entry forms that simplify the process of inputting data into the database. These forms can be customized to include validation rules, drop-down lists, and other features to ensure data accuracy.
6. **Integration with Other Microsoft Tools:** MS Access seamlessly integrates with other Microsoft Office applications such as Excel, Word, and Outlook. This facilitates data sharing, importing/exporting data, and creating mail merge documents for enhanced productivity.
7. **Web-Based Applications:** MS Access can be used to develop web-based applications by integrating it with SharePoint or using Access Services. This allows users to access and interact with the database

through a web browser, enabling remote collaboration and data sharing.

8. **Small Business Management:** MS Access is often used by small businesses to manage various aspects of their operations, including customer information, sales tracking, inventory control, and financial data. It provides an affordable and user-friendly solution for organizing business processes.
9. **Educational Purposes:** MS Access is commonly used in educational settings for teaching database concepts, data management skills, and application development. Students can learn how to design databases, create queries, and build forms using this intuitive platform.

4.2.1 DOWNLOADING DEM

Downloading Digital Elevation Model (DEM) data is a crucial step in geospatial analysis and modeling, as it provides valuable information about the topography and elevation of a specific area. DEM data can be used to create detailed terrain models, analyze slope and aspect, identify drainage patterns, and assess landform characteristics. By downloading DEM data, researchers and analysts can gain insights into the spatial distribution of elevation across a study area, which is essential for various applications such as flood modeling, land use planning, and natural resource management. Access to accurate and high-quality DEM data enables users to perform detailed spatial analysis and generate valuable information for decision-making processes. Therefore, downloading DEM data is a key component in geospatial research and analysis, facilitating the development of informed and effective solutions for a wide range of environmental and geospatial challenges.

4.2.2 MOSAIC DEM

A mosaic DEM is a composite digital elevation model created by combining multiple individual DEM datasets to cover a larger geographic area or improve the resolution and accuracy of elevation data. This process involves stitching together adjacent DEM tiles or overlapping datasets to create a seamless and continuous representation of the terrain.

Mosaic DEMs are commonly used in geospatial analysis, mapping, and modeling applications that require a comprehensive and consistent elevation dataset across a region.

By creating a mosaic DEM, researchers and analysts can overcome limitations of individual DEM datasets, such as data gaps, inconsistencies, or varying quality. Mosaic DEMs provide a more complete and detailed representation of the topography, allowing for more accurate terrain analysis, slope calculations, and visualization of landforms. Additionally, mosaic DEMs can be used to generate 3D terrain models, conduct hydrological modeling, assess landscape changes over time, and support various environmental and engineering projects.

Overall, mosaic DEMs play a crucial role in enhancing the accuracy and usability of elevation data for a wide range of geospatial applications.

By combining multiple DEM datasets into a seamless mosaic, researchers can access comprehensive terrain information that supports informed decision-making and spatial analysis in diverse fields such as natural resource management, urban planning, disaster response, and environmental monitoring.

4.2.3 UTM ZONES AND REPROJECT

UTM (Universal Transverse Mercator) zones are used for accurate mapping and navigation, divided into 60 zones, each spanning 6 degrees of longitude. To identify the appropriate UTM zone for a location, determine its longitude and find the corresponding zone. For example, if a location falls within -120 to -114 degrees longitude, it lies in UTM zone 11. Once you've identified the zone, you can reprojected data to that zone using GIS software like QGIS or ArcGIS. Reprojection involves converting data from one coordinate system to another, ensuring accurate spatial analysis and visualization within the chosen UTM zone. In GIS software, you'll typically use the "Project" tool to specify the input coordinate system (e.g., geographic WGS84) and the desired output UTM zone, allowing for seamless integration and analysis of geographic data across different regions.

4.2.4 FILL

Identifying the appropriate UTM (Universal Transverse Mercator) zone for a specific location involves determining its longitude and finding the corresponding zone, as each zone covers 6 degrees of longitude. For instance, a location falling within -120 to -114 degrees longitude would be situated in UTM zone 11. Once the UTM zone is identified, data can be reprojected to that zone using Geographic Information System (GIS) software like QGIS or ArcGIS.

Reprojection is crucial for accurate spatial analysis and visualization within the chosen UTM zone. GIS tools typically offer a "Project" function to specify the input coordinate system (e.g., geographic WGS84) and the desired output UTM zone, ensuring seamless integration and analysis of geographic data across different regions.

4.2.5 FLOW DIRECTION

Flow direction analysis is a fundamental aspect of hydrological modeling and terrain analysis in Geographic Information Systems (GIS). It involves determining the direction of water flow across a digital elevation model (DEM) surface. In GIS software like QGIS or ArcGIS, flow direction is typically calculated using algorithms such as D8 (eight-direction) or D-infinity flow algorithms. These algorithms assign each cell in the DEM a direction indicating where water would flow from that cell.

The resulting flow direction raster depicts the path water would take from each cell to its neighboring cells, forming a network of drainage patterns. Flow direction analysis is crucial for various applications, including watershed delineation, flood risk assessment, and environmental planning. It provides valuable insights into surface water dynamics and helps inform decision-making processes related to water resource management and land use planning.

4.2.6 DRAINAGE LINE GENERATION

Drainage line generation in Geographic Information Systems (GIS) involves the delineation of natural and artificial watercourses based on terrain characteristics and flow accumulation patterns derived from digital elevation models (DEMs). Using GIS software like QGIS or ArcGIS, drainage lines can be generated by

first performing flow direction analysis to determine the direction of water flow across the landscape. Then, flow accumulation analysis is conducted to identify areas of concentrated flow. Thresholds are applied to the flow accumulation raster to delineate streams and rivers, creating a network of drainage lines representing the path of surface water flow. Additional refinement techniques, such as stream ordering and stream segmentation, can be applied to classify and organize the drainage network based on the hierarchy and characteristics of the watercourses. Drainage line generation is essential for various applications, including watershed management, floodplain mapping, and ecological studies, providing valuable insights into the hydrological connectivity and dynamics of river systems within a geographic area.

4.2.7 GIVING OUTLET

Identifying outlets in hydrological modeling and Geographic Information Systems (GIS) involves locating points where water flow exits a watershed or drainage basin. These outlets serve as endpoints for stream networks and are crucial for delineating watersheds, analyzing flow paths, and understanding drainage patterns. In GIS software such as QGIS or ArcGIS, outlets can be identified manually by selecting specific points where streams converge or by using automated algorithms based on flow accumulation thresholds or channel network connectivity. Outlets can represent various features, including natural stream mouths, man-made drainage structures, or points where water discharges into larger water bodies such as lakes or oceans. Properly identifying outlets is essential for accurate watershed delineation, flood risk assessment, and water resources management, providing valuable information for decision-making processes related to land use planning, environmental conservation, and infrastructure development.

4.2.8 WATERSHED DELINEATION

Identifying outlets in hydrological modeling and Geographic Information Systems (GIS) involves locating points where water flow exits a watershed or drainage basin. These outlets serve as endpoints for stream networks and are crucial for delineating watersheds, analyzing flow paths, and understanding drainage patterns. In GIS software such as QGIS or ArcGIS, outlets can be identified manually by selecting specific points where streams converge or by using automated algorithms based on flow accumulation thresholds or channel network connectivity. Outlets can represent various features, including natural stream mouths, man-made drainage structures, or points where water discharges into larger water bodies such as lakes or oceans. Properly identifying outlets is essential for accurate watershed delineation, flood risk assessment, and water resources management, providing valuable information for decision-making processes related to land use planning, environmental conservation, and infrastructure development.

4.2.9 AREA PREPRATION (Cut Drainage and Dem)

Area preparation involving the cutting of drainage features and digital elevation models (DEMs) is an essential stage in hydrological modeling and Geographic Information Systems (GIS) analysis. This process aims to define a specific study area or isolate a particular region of interest for further investigation.

In GIS software such as QGIS or ArcGIS, cutting drainage features entails excluding streams, rivers, and other water bodies from the DEM to prevent their influence on subsequent analyses like watershed delineation or flow accumulation calculations. Simultaneously, cutting the DEM involves extracting the elevation data corresponding to the desired study area, thereby focusing the analysis on a specific geographic extent. This meticulous area preparation ensures that subsequent hydrological analyses are precise and relevant to the research or management objectives at hand. It enables more accurate modeling and facilitates informed decision-making processes concerning water resource management, flood risk assessment, and environmental planning within the delineated area.

4.2.10 SLOPE

Slope analysis in Geographic Information Systems (GIS) involves calculating the rate of change in elevation between neighboring cells in a digital elevation model (DEM). This calculation typically employs methods such as the slope gradient or the tangent of the angle of inclination.

Slope values are expressed in degrees, percentage, or radians, providing insights into the steepness of the terrain surface.

The process involves computing the slope for each cell based on the elevation values of its neighboring cells, taking into account cell size and elevation differences. In GIS software like QGIS or ArcGIS, slope analysis tools allow users to generate slope maps and visualize terrain gradients. These maps are invaluable for various applications, including land suitability assessment, hydrological modeling, environmental planning, and infrastructure design. Detailed slope analysis facilitates the identification of areas with varying degrees of steepness, aiding in decision-making processes related to land use management, slope stability assessment, and natural hazard mitigation. Additionally, slope information is essential for understanding terrain characteristics, surface water flow patterns, erosion susceptibility, and ecological habitat suitability, contributing to informed and sustainable land management practices.

4.2.11 DRAINAGE DENSITY

Drainage density is a geomorphological parameter used to quantify the abundance of stream channels within a given area. It is calculated by dividing the total length of all stream channels (measured in kilometers) by the area of the watershed or study area (measured in square kilometers). Drainage density is typically expressed in units of kilometers per square kilometer (km/km²).

High drainage density indicates a dense network of streams and rivers, often found in regions with high rainfall, steep slopes, or young, actively eroding landscapes. Conversely, low drainage density suggests fewer and longer streams, which are characteristic of arid or flat terrains with less runoff.

Drainage density is an important metric in hydrology, geomorphology, and environmental studies. It provides insights into the hydrological characteristics of a watershed, such as runoff potential, soil erosion susceptibility, and groundwater recharge rates.

Additionally, it helps in understanding landscape evolution, land use planning, and natural resource management. GIS software like QGIS or ArcGIS is commonly used to analyze drainage density by overlaying stream network data with watershed boundaries and calculating the total length of streams within each watershed.

4.2.12 LANDUSE

Land use refers to the way in which humans utilize and manage land for various purposes to meet societal, economic, and environmental needs. It encompasses a wide range of activities, including residential development, commercial establishments, agriculture, industrial facilities, recreational spaces, and conservation areas. Effective land use planning involves analyzing the characteristics of the land, considering factors such as soil quality, topography, climate, and proximity to resources and infrastructure, to determine the most suitable uses for different areas. Sustainable land use practices aim to balance economic development with environmental protection, ensuring that land resources are utilized efficiently and responsibly for the benefit of present and future generations.

4.2.13 RAINFALL MAP PREPATION

Preparing a rainfall map involves gathering rainfall data from various sources such as weather stations, satellites, and radar systems. This data is then processed and analyzed using Geographic Information Systems (GIS) software to create a visual representation of rainfall patterns across a specific geographic area. The map displays rainfall intensity, distribution, and frequency over a given time period, offering valuable insights for sectors like agriculture, water resource management, flood prediction, and climate research. By accurately depicting rainfall variability and trends, these maps aid decision-makers in planning and implementing strategies to mitigate the impacts of weather-related events and optimize resource allocation.

4.2.14 DATA ARRANGEMENT AND SOIL PREPARATION

Data arrangement and soil preparation are essential components of successful agriculture and gardening practices. Before embarking on any planting endeavor, it is crucial to gather relevant data about the soil, climate, and intended crops. This often involves conducting soil tests to assess pH levels, nutrient content, and overall soil health. Armed with this information, farmers and gardeners can make informed decisions about fertilization, irrigation, and crop selection. Once the data is organized, soil preparation begins with clearing the land of weeds, rocks, and debris. Tilling the soil helps to improve aeration and drainage, while the addition of organic matter such as compost or manure enriches the soil with essential nutrients.

Leveling the soil surface ensures uniform planting conditions, while mulching helps to retain moisture and suppress weeds. By meticulously arranging data and preparing the soil, growers lay the groundwork for robust plant growth and bountiful harvests.

4.2.15 DATA RECLARIFICATION

Data clarification is the process of ensuring that data is accurate, consistent, and understandable. This involves reviewing and verifying data to identify any errors, inconsistencies, or missing information.

Data clarification is essential for making informed decisions based on reliable and trustworthy information. By clarifying data, organizations can improve the quality of their data, enhance data analysis and reporting, and ultimately drive better business outcomes. This process often involves cleaning and organizing data, resolving discrepancies, and standardizing data formats to ensure consistency across different sources. Overall, data clarification is a crucial step in the data management process to ensure that data is reliable and can be effectively used for decision-making purposes.

4.2.16 PERFORMING GROUNDWATER ANALYSIS

Performing groundwater analysis is a crucial step in understanding the quality and quantity of groundwater resources in a specific area. Groundwater analysis involves collecting water samples from wells or other sources, testing them for various parameters such as pH, conductivity, dissolved oxygen, and contaminants like heavy metals, nitrates, and pesticides.

This analysis helps to assess the overall health of the groundwater system and identify any potential risks to human health or the environment.

Groundwater analysis also plays a vital role in monitoring changes in groundwater quality over time, identifying trends, and evaluating the effectiveness of remediation efforts. By analyzing groundwater data, hydrogeologists and environmental scientists can make informed decisions about water resource management, land use planning, and pollution control measures.

Furthermore, groundwater analysis is essential for regulatory compliance, as many countries have strict guidelines and standards for groundwater quality that must be met to ensure the protection of public health and the environment. Overall, performing groundwater analysis is a critical component of sustainable water resource management and environmental protection efforts.

4.2.17 FLOODRISK AND DROUGHT FROM SAME DATA

Groundwater analysis can provide valuable insights into both flood risk and drought conditions, as the same data can be used to assess the vulnerability of an area to these contrasting water-related challenges.

Understanding the groundwater levels, recharge rates, and overall water availability in an aquifer can help predict the potential for flooding during periods of heavy rainfall or rapid snowmelt. High groundwater levels can contribute to surface water inundation and increase the risk of flash floods in low-lying areas.

Conversely, groundwater analysis can also shed light on drought conditions by monitoring declining water levels, reduced recharge rates, and increased demand for groundwater extraction. Low groundwater levels can exacerbate drought impacts by limiting water availability for agriculture, drinking water supplies, and

ecosystem health. By analyzing groundwater data over time, hydrologists and water resource managers can identify trends that may indicate a heightened risk of drought and take proactive measures to mitigate its effects.

Overall, utilizing groundwater analysis for both flood risk and drought assessment allows for a comprehensive understanding of water resource dynamics in a region. By integrating this information into water management strategies and emergency response plans, stakeholders can better prepare for and respond to extreme weather events, ultimately enhancing resilience to both flooding and drought conditions.

4.2.18 GROUNDWATER FLUCTUATIONS FROM OBSERVED DATA

Groundwater fluctuations, as observed from data collected through monitoring wells and other hydrological instruments, provide valuable insights into the dynamic nature of underground water resources. By analyzing trends in groundwater levels over time, hydrologists can identify seasonal variations, long-term trends, and potential impacts of external factors such as climate change and human activities. Fluctuations in groundwater levels can be influenced by factors such as precipitation patterns, land use changes, groundwater pumping, and recharge rates.

Observations of groundwater fluctuations can help in assessing the overall health and sustainability of aquifers, as well as in predicting potential risks of water scarcity or contamination. Sudden drops in groundwater levels may indicate over-extraction or drought conditions, while rapid rises could signal excessive recharge or increased runoff from heavy rainfall events. Understanding these fluctuations is crucial for effective water resource management, as it enables stakeholders to make informed decisions regarding water allocation, conservation measures, and sustainable development practices.

By analyzing observed data on groundwater fluctuations, hydrologists can also develop models to forecast future trends and anticipate potential challenges related to water availability and quality. This information is essential for developing strategies to mitigate the impacts of climate variability, population growth, and land use changes on groundwater resources. Overall, monitoring and analyzing groundwater fluctuations play a key role in ensuring the resilience and sustainability of water supplies for both current and future generations.

CHAPTER-5

RESULT &

DISCUSSION

The examine on "Geospatial Analysis and Hydrogeological Modelling for Groundwater Potential Mapping in Mining-Impacted Zones of Karnataka" yielded numerous giant consequences and discussions that are critical for sustainable water useful resource control in the location.

1. Identification of High and Low Potential Groundwater Zones: The geospatial analysis and hydrogeological modelling techniques employed within the have a look at helped discover areas with high groundwater ability, in which sustainable water extraction and management practices may be

applied. Conversely, low ability groundwater zones had been also diagnosed, highlighting regions wherein water shortage may be a subject and necessitating centred interventions.

2. Assessment of Groundwater Quality: The examine additionally assessed the satisfactory of groundwater in mining-impacted zones of Karnataka. By analysing key water high-quality parameters together with pH, turbidity, and heavy metal concentrations, the studies provided insights into the capacity infection dangers associated with mining sports. This information is crucial for designing powerful water remedy and remediation techniques to safeguard groundwater quality.

3. Integration of Stakeholder Engagement: The study emphasised the significance of attractive stakeholders, which include nearby groups, government businesses, and mining businesses, in the water resource management method. By involving diverse stakeholders in decision-making tactics, the examine aimed to foster collaboration, transparency, and responsibility in addressing water useful resource demanding situations in mining-impacted zones.

4. Policy Recommendations for Sustainable Water Management: Based at the observes findings, the researchers proposed a hard and fast of policy pointers to promote sustainable water resource control in mining



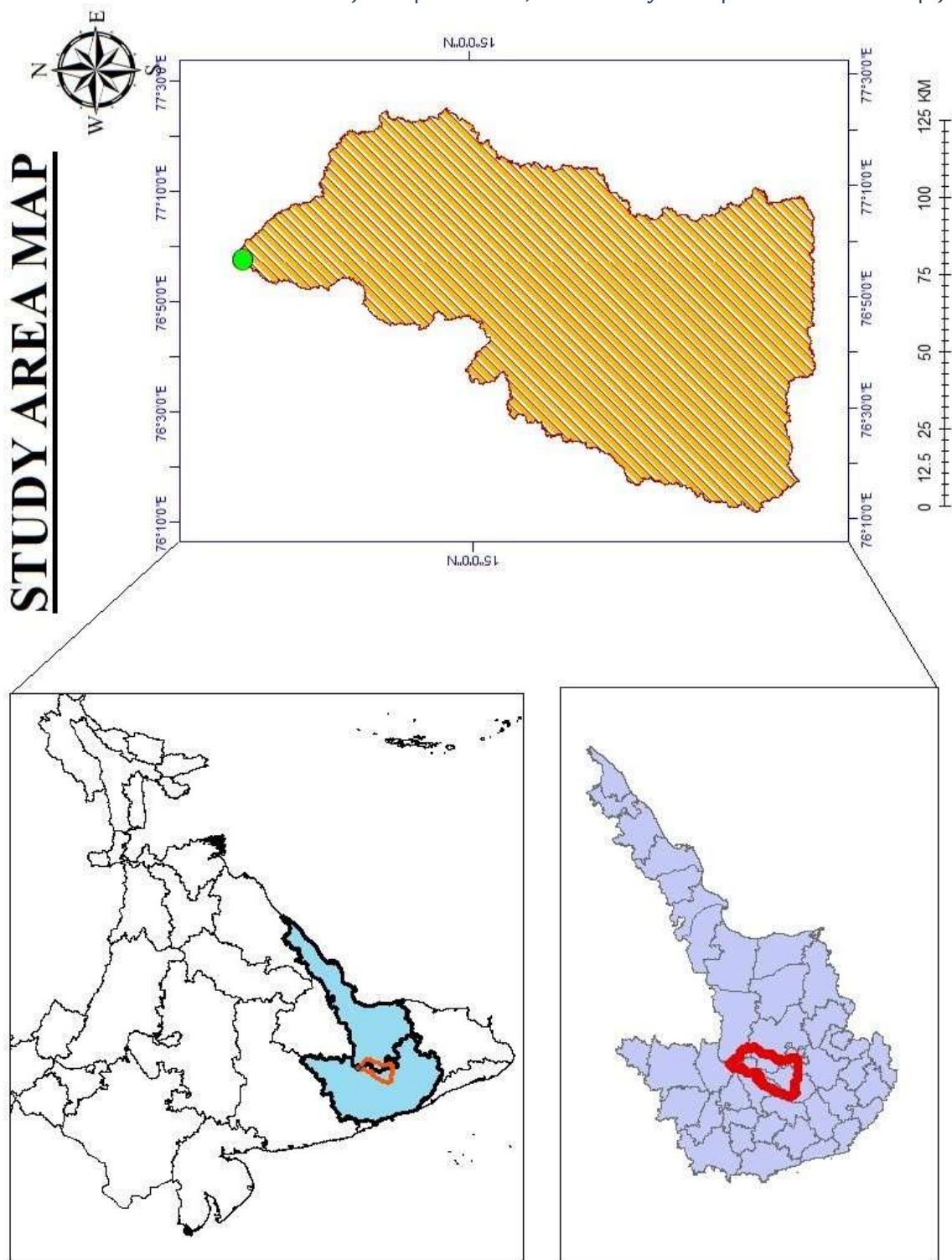


Fig 2: study area map

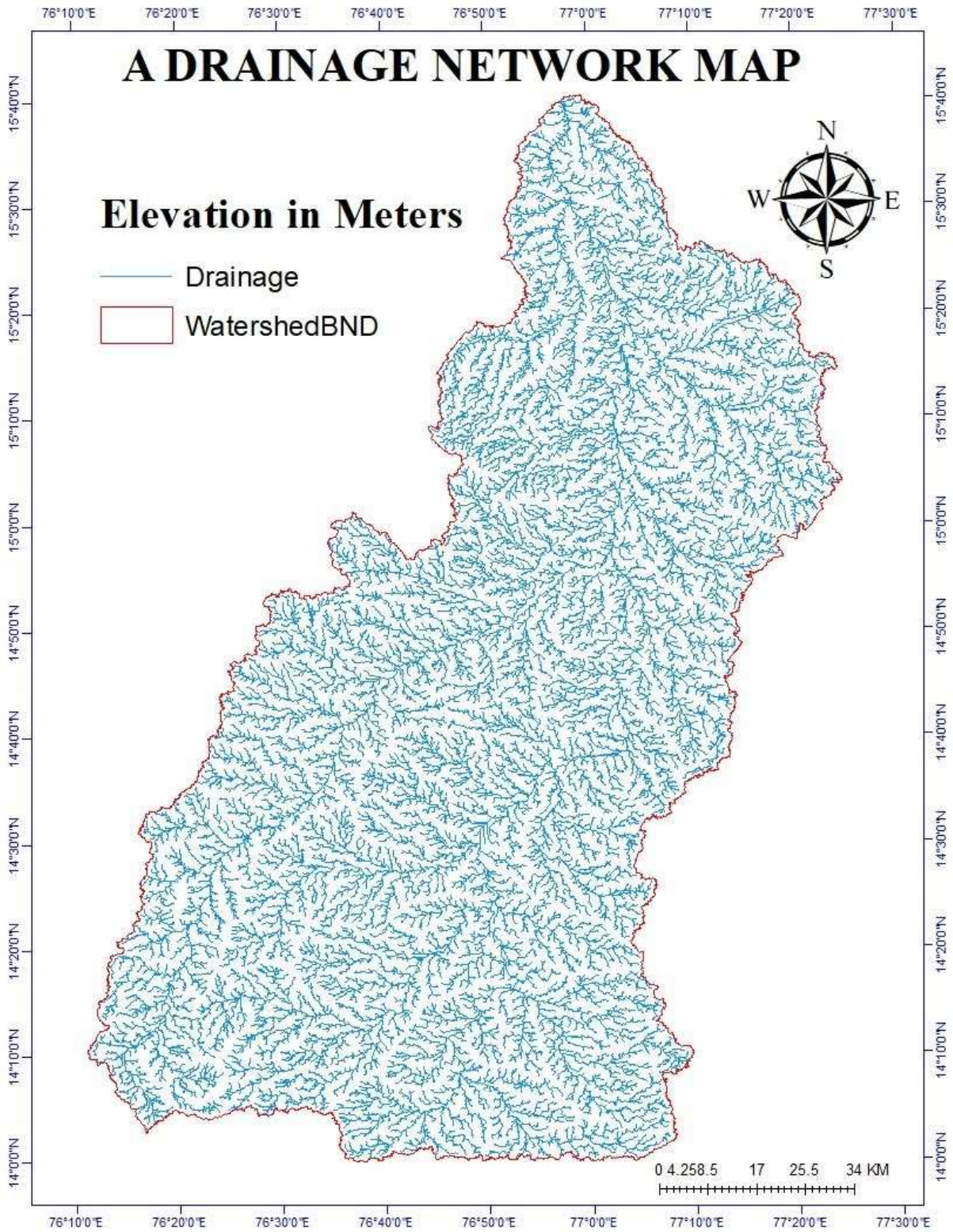
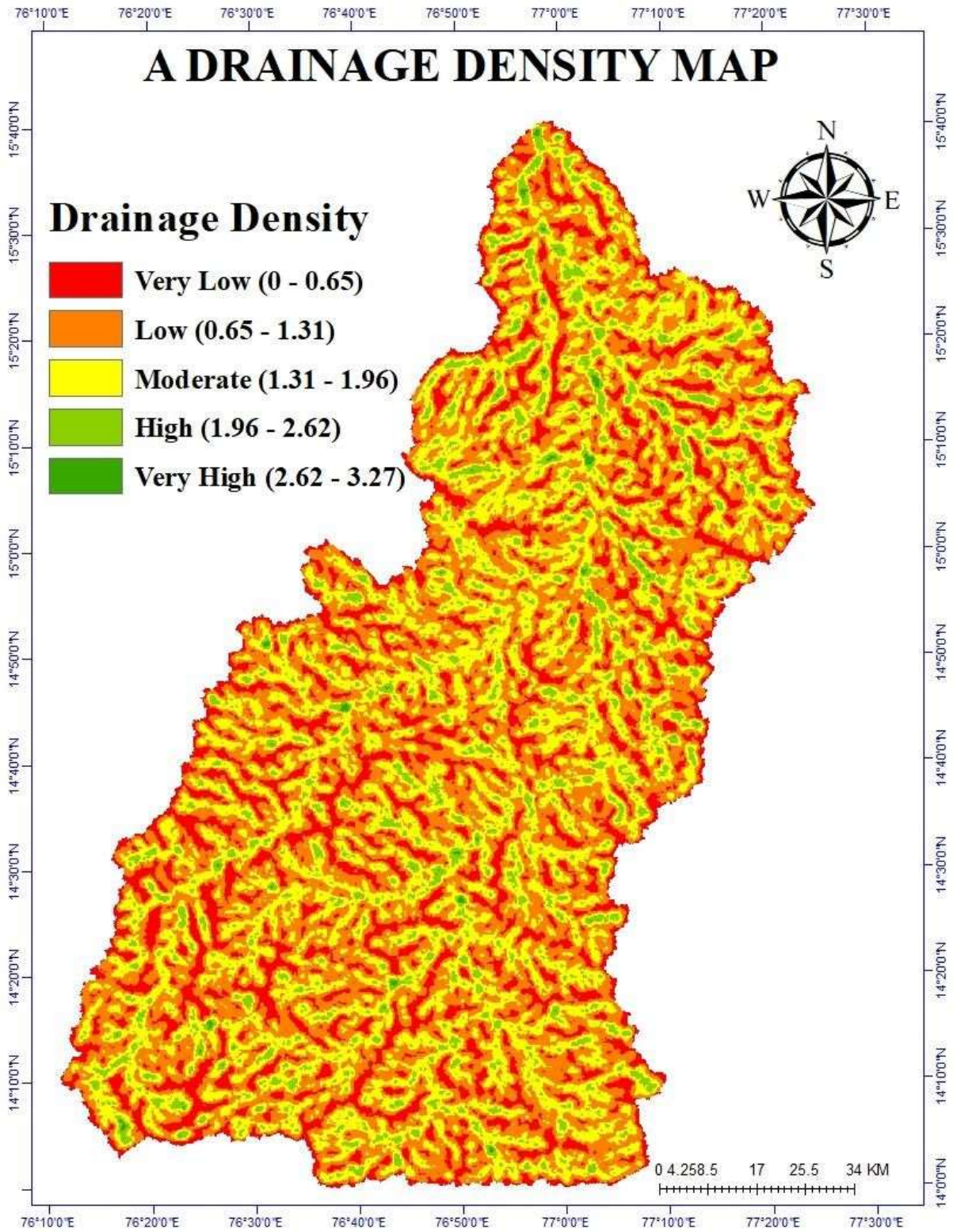


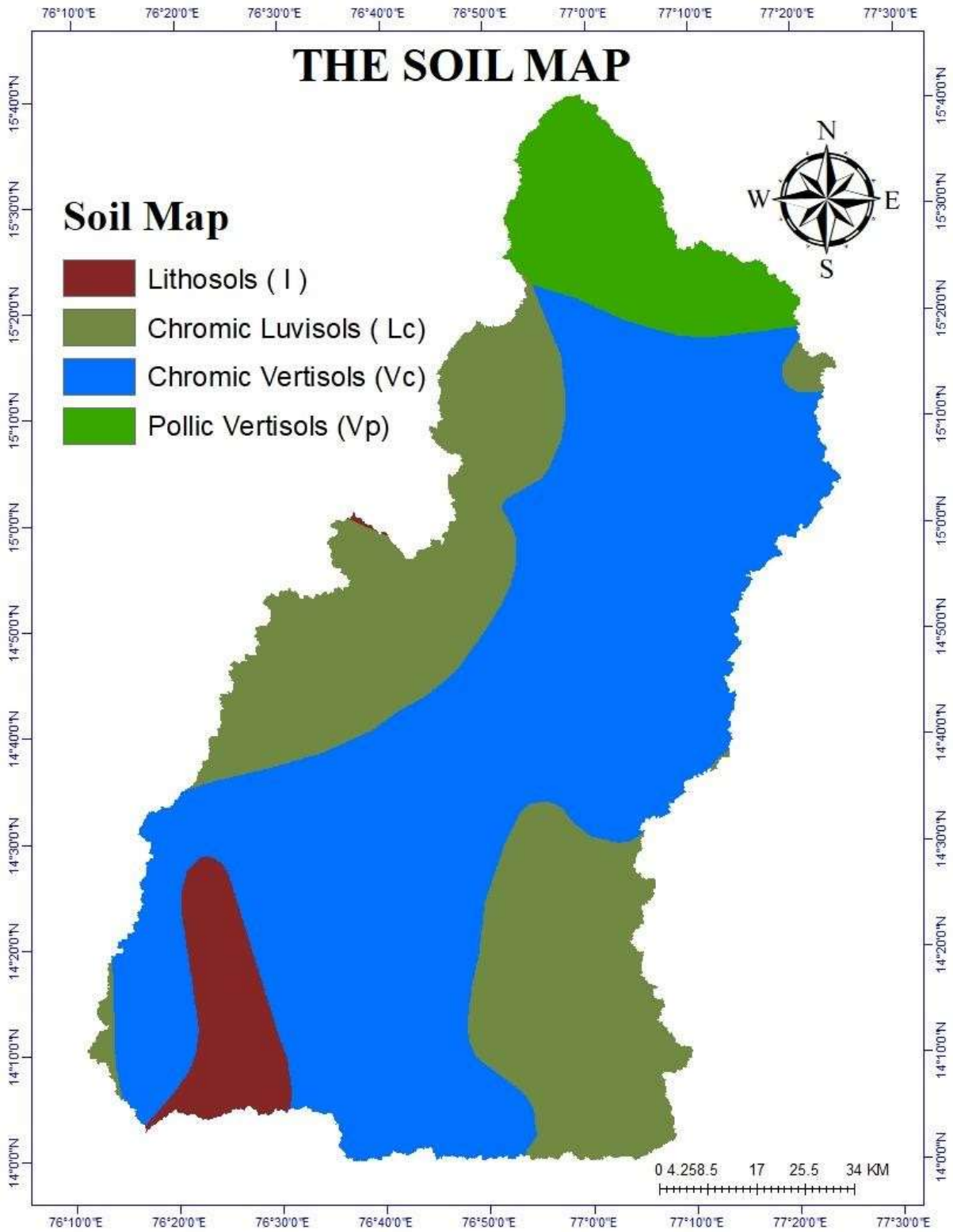
Fig 3: a drainage network map

Research Through Innovation



Research Through Innovation

Fig 4: a drainage density map



Research Through Innovation

Fig 5: the soil map

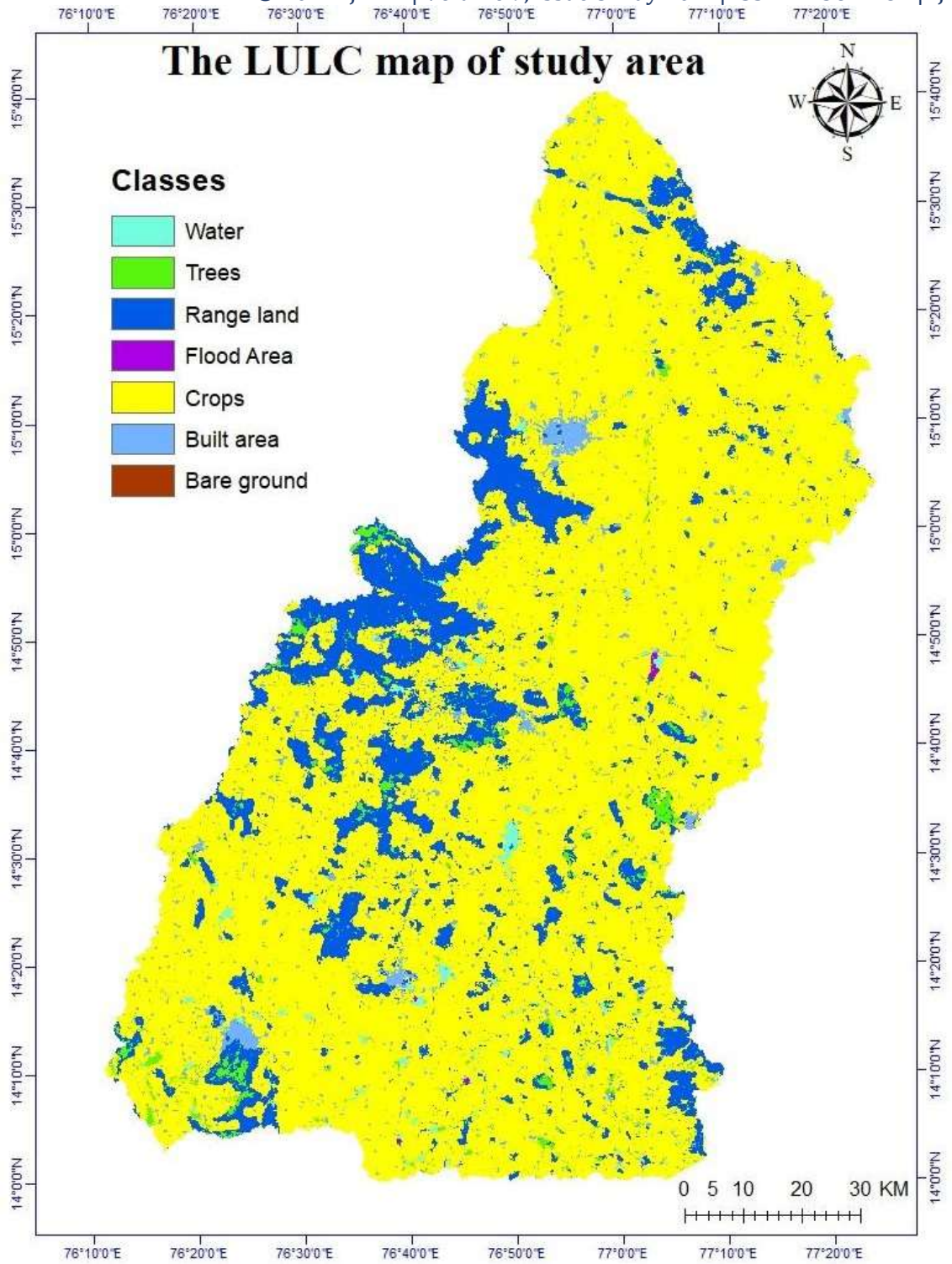


Fig 6: the land use land cover map of study area

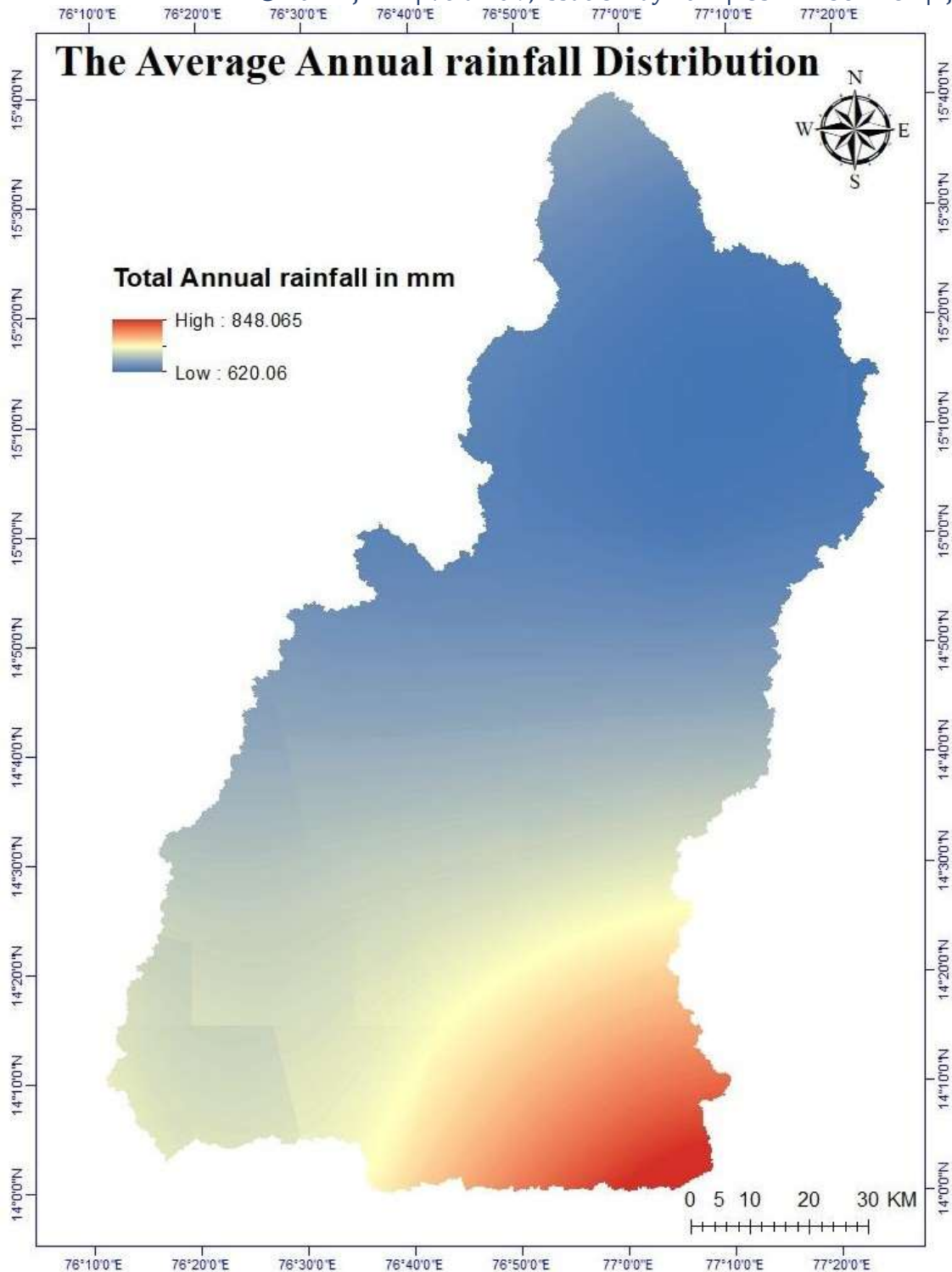
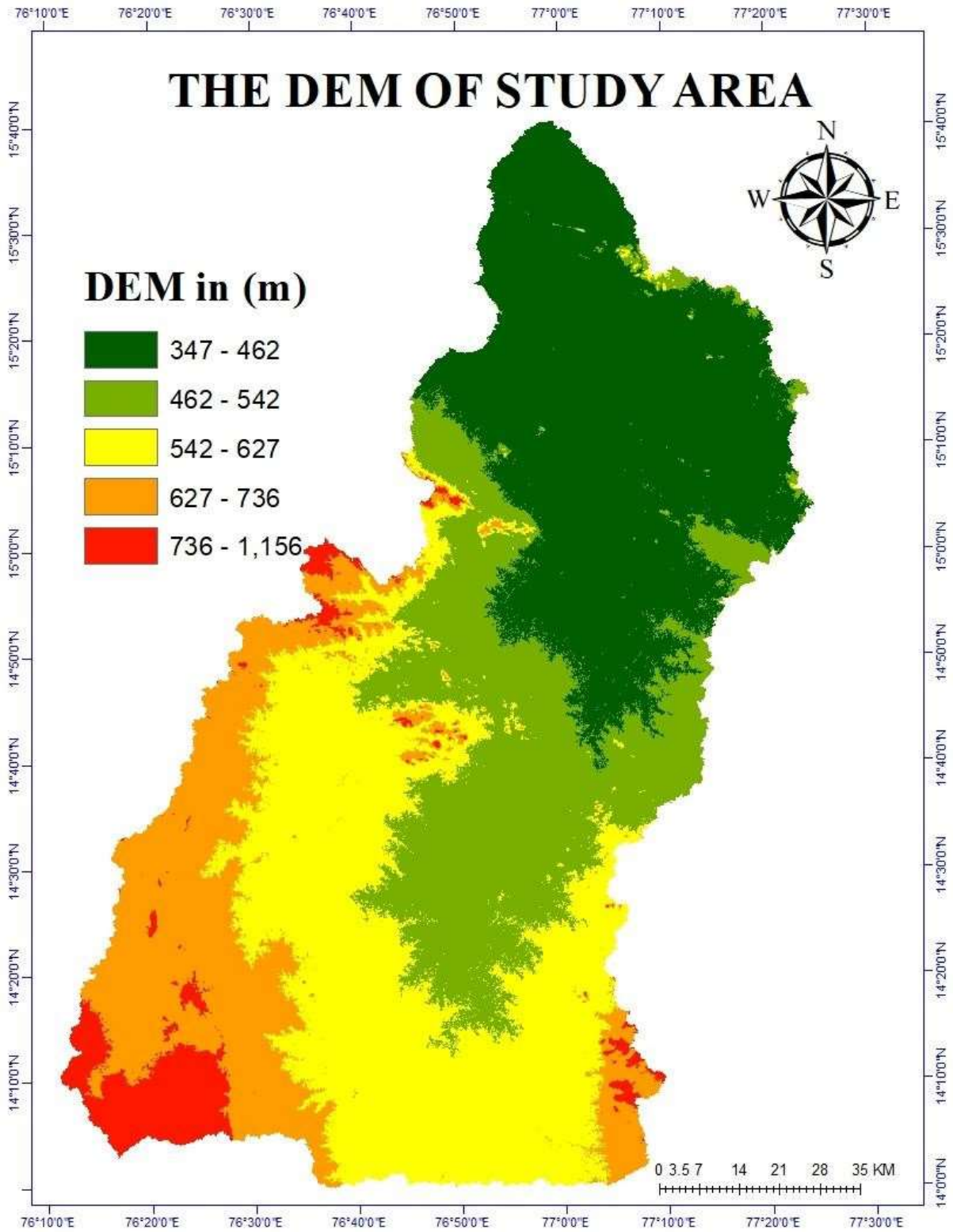


Fig 7: the average annual rainfall distribution



Research Through Innovation

Fig 8: the dem of study area

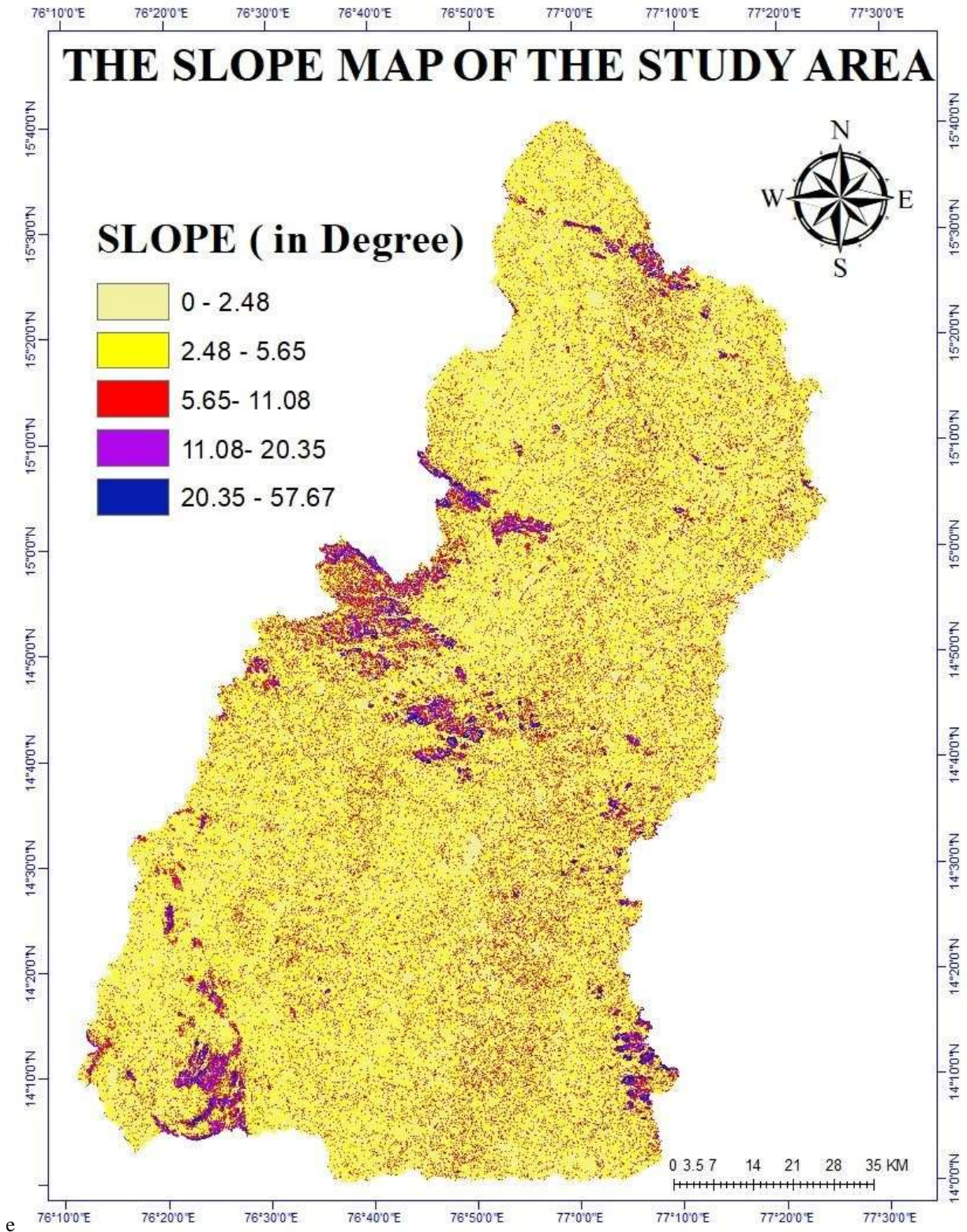


Fig 9: the slope map of the study area

Research Through Innovation

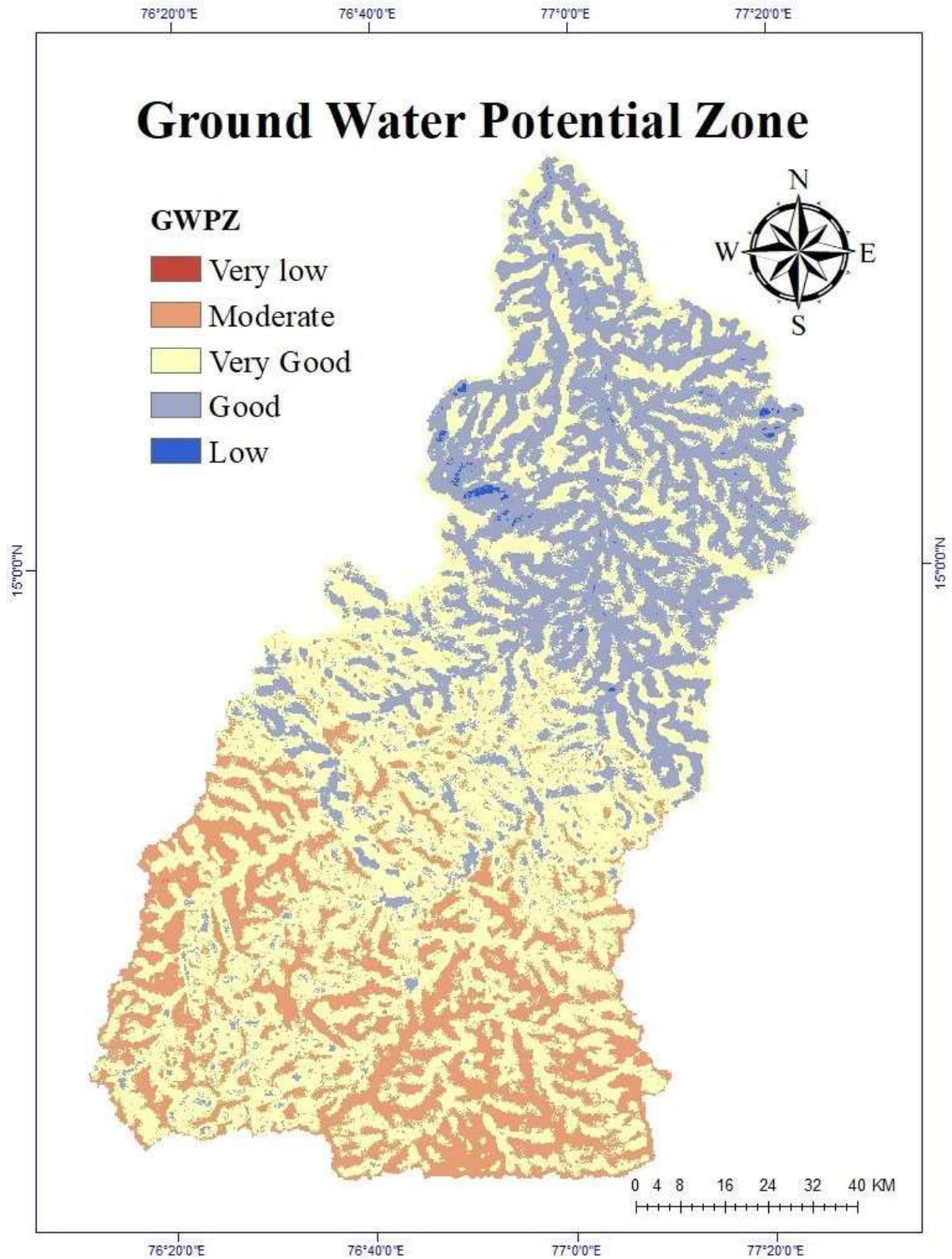


Fig 10: ground water potential zone

Research Through Innovation

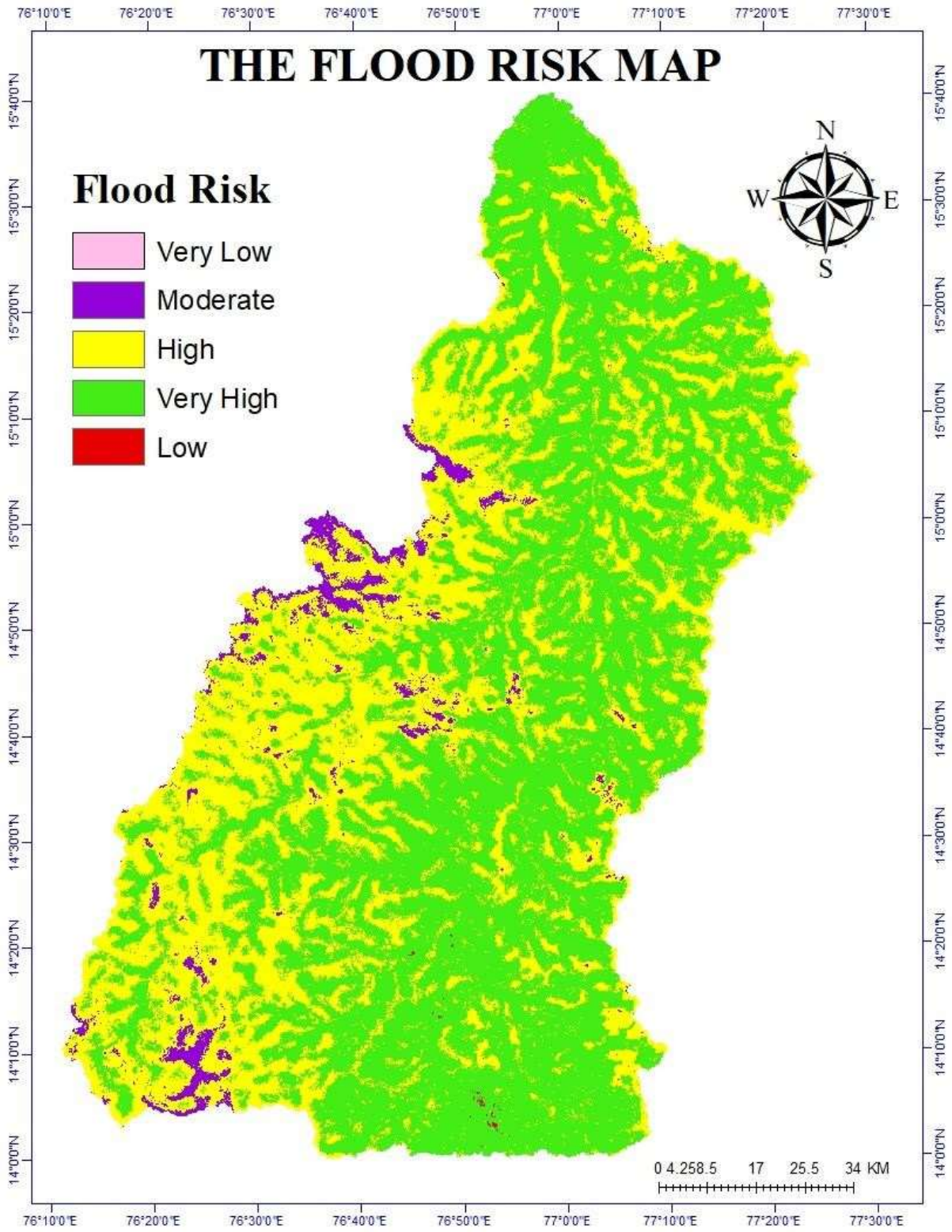
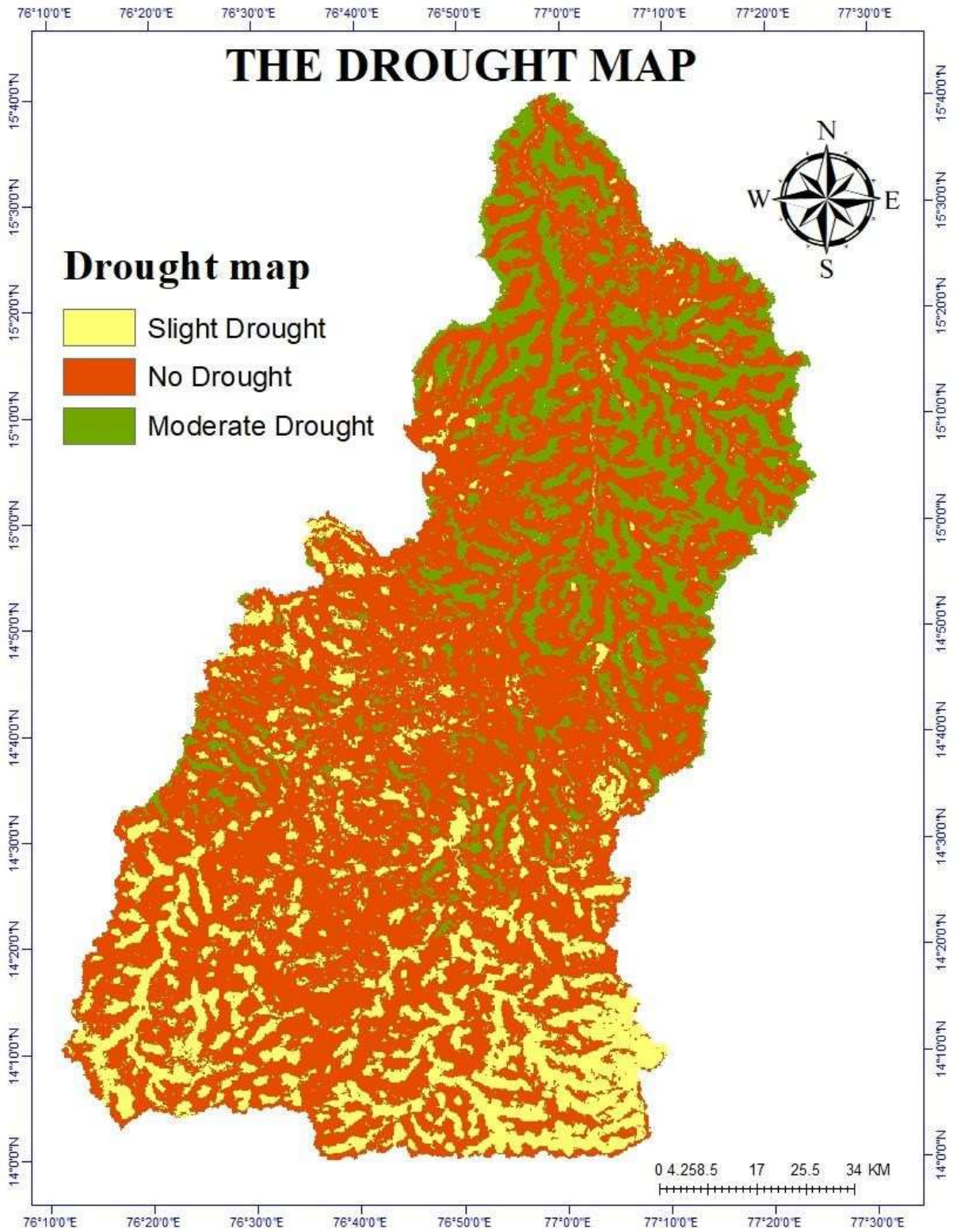


Fig 11: the flood risk map

Research Through Innovation



Research Through Innovation

Fig 12: the drought map

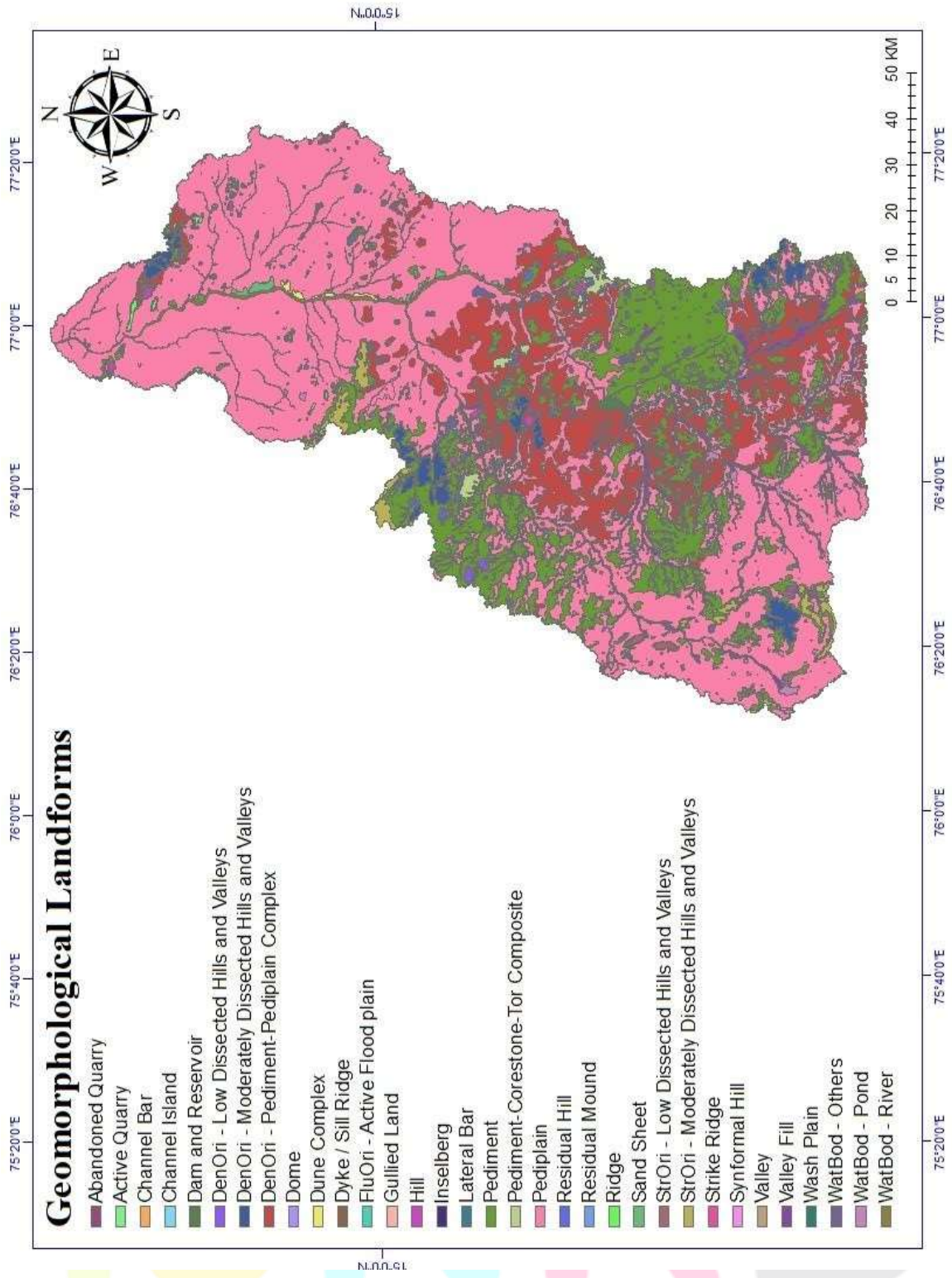
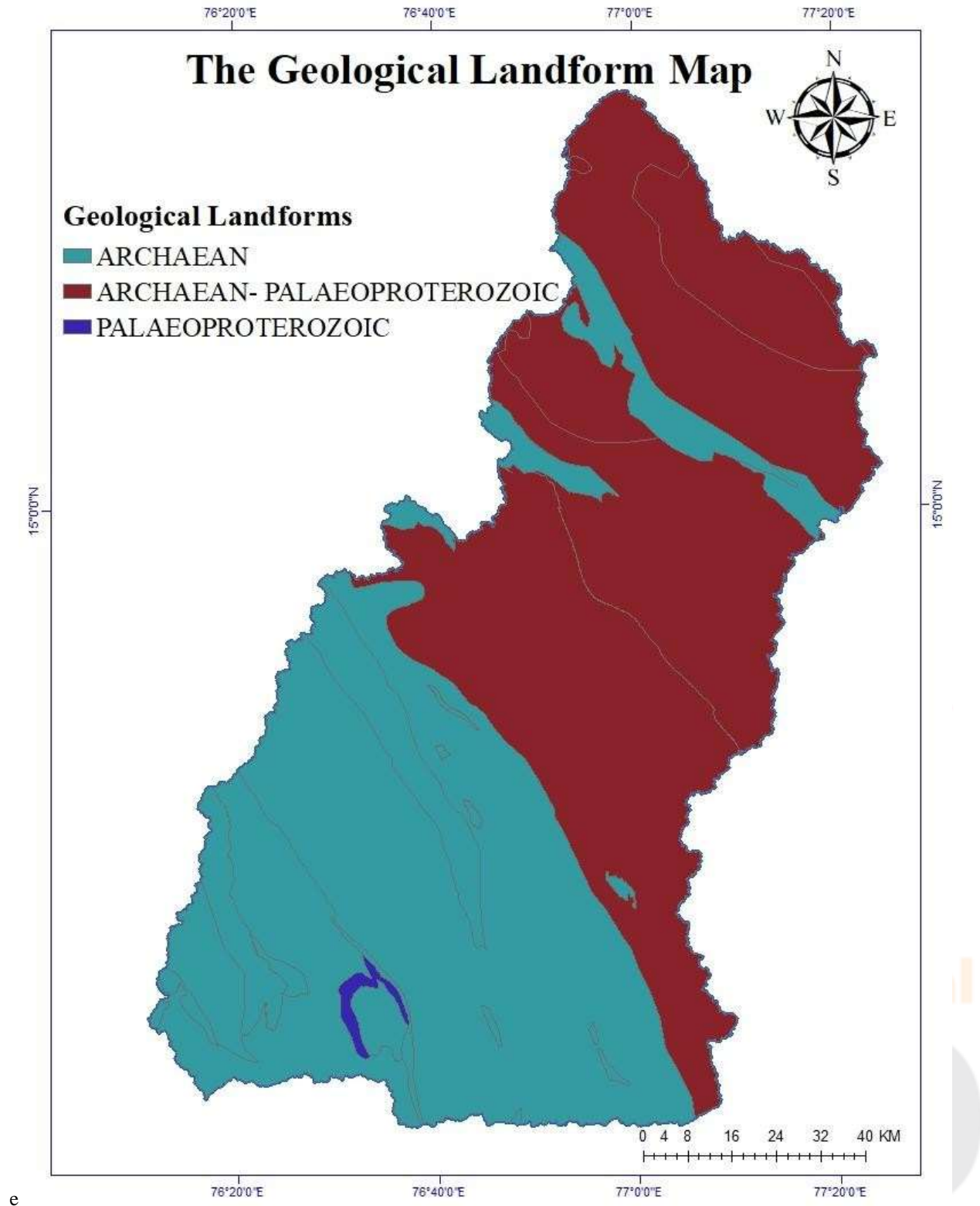


Fig 13: geomorphological landforms



e

Research Through Innovation

Fig 14: the geological landform map

<i>Thematic layer</i>	<i>Influence</i>	<i>Individual feature</i>	<i>Scale value (Each have importance 0 to 5)</i>
LULC	10%	Water	5
		Trees	4
		Crops	3
		Bare Ground	2
		Range Land	1
Slope (in Degree)	10%	0 – 2.48	5
		2.48 - 5.65	4
		5.65- 11.08	3
		11.08- 20.35	2
		20.35 - 57.67	1
Drainage Density (km/km ²)	30%	0 – 0.65	1
		0.65 - 1.31	2
		1.31 - 1.96	3
		1.96 - 2.62	4
		2.62 - 3.27	5
Soil	10%	Lithosols(l)	5
		Chromic Luvisols (Lc)	4
		Chromic Vertisols (Vc)	3
		Pollic Vertisols (Vp)	2
			1
Rainfall (in mm)	10%	620.06 - 645.99	5
		645.99 - 680.86	4
		680.86 - 719.30	3
		719.30 - 767.59	2
		767.59 - 848.06	1
Geology	20%	Archaean	5
		Archaean-Palaeopro	4
		Palaeoproterozoic	3
			1
Geomorphology	10%	Residual Mound	5
		WatBod – Others	4
		Pediment	3
		WatBod - Pond	1

Fig 15: Influence and scale value of each feature table

Value	Count Pixel	Area (sq.km)	Area (%)	Classes
1	511	0.459	0.003	Very low
2	2682095	2413.890	19.640	Moderate
3	7043270	6338.940	51.575	Very Good
4	3898093	3508.280	28.544	Good
5	32141	28.926	0.235	Low

Fig 16: value table

CHAPTER-6

CONCLUSION

The soil analysis and hydrologic modeling carried out in this study provided valuable insights into the groundwater potential of the mined areas in Karnataka. Developed plans for water availability and sustainability can be a useful tool for decision makers and stakeholders to make better use of groundwater. To identify areas with significant groundwater potential and apply appropriate management strategies to ensure a clean and reliable supply of water for current and future generations, this study highlights its importance. Emphasis on incorporating soil analysis and hydrologic modeling into water management practices.

CHAPTER-7

FUTURE SCOPE OF THE WORK

The geospatial analysis and hydrogeological modelling for groundwater ability mapping in mining-impacted zones of Karnataka lays a stable basis for destiny research and practical applications in the field of sustainable water resource management. Moving forward, there are numerous key areas of destiny scope that can construct upon the findings and methodologies of this study. Take a look at.

- 1. Long-Term Monitoring and Evaluation:** One crucial destiny direction is the established order of a comprehensive monitoring and evaluation framework to track changes in groundwater levels, quality, and availability over the years. Long-time period records collection and evaluation will provide valuable insights into the effect of mining activities on groundwater sources and allow adaptive control techniques to be developed.
- 2. Integration of Climate Change Considerations:** Given the growing challenges posed with the aid of weather alternate on water assets, future research ought to discover how changing climatic situations might also affect groundwater dynamics in mining-impacted zones. Incorporating climate alternate projections into hydrogeological fashions can help assume future water availability and tell proactive adaptation measures.
- 3. Advanced Remote Sensing Techniques:** Leveraging superior far flung sensing technology which includes satellite tv for pc imagery, LiDAR, and drones can decorate the accuracy and performance of geospatial analysis for groundwater potential mapping. Future research ought to explore the combination of those modern gear to enhance spatial information collection, mapping precision, and tracking talents.
- 4. Community-Based Water Resource Management:** Engaging neighbourhood communities and stakeholders in participatory water useful resource management tasks is vital for ensuring the sustainability and equity of water use practices. Future research should cognizance on growing network-pushed methods that empower residents to actively participate in selection-making procedures associated with groundwater management in mining-impacted zones.
- 5. Policy Implementation and Governance:** The translation of research findings into actionable policies and governance mechanisms is crucial for riding actual-international effect.

Future work may want to emphasize the implementation of policy guidelines derived from clinical studies,

as well as the improvement of regulatory frameworks that sell sustainable water management practices in mining-impacted areas.

By addressing these destiny scope regions, researchers, policymakers, and practitioners can keep to advance the information and management of groundwater assets in mining-impacted zones of Karnataka, ultimately contributing to the sustainable use and safety of water for present day and destiny generations.

CHAPTER-8

REFERENCES

1. Ackermann, W. C. (1976). Soil and water conservation. *Eos, Transactions American Geophysical Union*, 57(10), 708–711. <https://doi.org/10.1029/EO057i010p00708>
2. Allafta, H., Opp, C., & Patra, S. (2021). Identification of groundwater potential zones using remote sensing and GIS techniques: A case study of the shatt Al-Arab Basin. *Remote Sensing*, 13(1), 1–28. <https://doi.org/10.3390/rs13010112>
3. Andualem, T. G., & Demeke, G. G. (2019). Groundwater potential assessment using GIS and remote sensing: A case study of Guna tana landscape, upper blue Nile Basin, Ethiopia. *Journal of Hydrology: Regional Studies*, 24(August 2018), 100610. <https://doi.org/10.1016/j.ejrh.2019.100610>
4. Arulbalaji, P., Padmalal, D., & Sreelash, K. (2019). GIS and AHP Techniques Based Delineation of Groundwater Potential Zones: a case study from Southern Western Ghats, India. *Scientific Reports*, 9(1), 1–17. <https://doi.org/10.1038/s41598-019-38567-x>
5. Bhardwaj, A., Singh, A., & Singh, S. (2023). *Groundwater quality mapping of Singrauli district using ArcGIS*. 20(August), 418–434.
6. Burayu, D. G. (2022). Identification of Groundwater Potential Zones Using AHP, GIS and RS Integration: A Case Study of Didessa Sub-Basin, Western Ethiopia. *Remote Sensing of Land*, 6(1), 1–15. <https://doi.org/10.21523/gcj1.2022060101>
7. Dile, Y. T., Daggupati, P., George, C., Srinivasan, R., & Arnold, J. (2016). Introducing a new open source GIS user interface for the SWAT model. *Environmental Modelling and Software*, 85, 129–138. <https://doi.org/10.1016/j.envsoft.2016.08.004>
8. Farzana, S. Z., Zafor, M. A., & Shahariar, J. Al. (2019). Application of SWAT Model for Assessing Water Availability in Surma River Basin. *Journal of the Civil Engineering Forum*, 5(1), 29. <https://doi.org/10.22146/jcef.39191>
9. Gebeyehu, A., Ayenew, T., & Asrat, A. (2023). Delineation of groundwater potential zones of the transboundary aquifers within the semiarid Bulal catchment, Southern Ethiopia. *Environmental Monitoring and Assessment*, 195(4), 1–21. <https://doi.org/10.1007/s10661-023-11088-x>
10. Gebru, H., Gebreyohannes, T., & Hagos, E. (2020). Identification of Groundwater Potential Zones Using Analytical Hierarchy Process (AHP) and GIS-Remote Sensing Integration, the Case of Golina River Basin, Northern Ethiopia. *International Journal of Advanced Remote Sensing and GIS*, 9(1), 3289–3311. <https://doi.org/10.23953/cloud.ijarsg.460>

11. George, G. K., Vishnudas, S., & Abdu Rahiman, K. U. (2024). Optimizing among Analytical Hierarchy Process, Influencing Factor Method, and Frequency Ratio Model in the Determination of Groundwater Potential Zones. *Civil Engineering and Architecture*, 12(1), 560–576. <https://doi.org/10.13189/cea.2024.120140>
12. Hussein, A. A., Govindu, V., & Nigusse, A. G. M. (2017). Evaluation of groundwater potential using geospatial techniques. *Applied Water Science*, 7(5), 2447–2461. <https://doi.org/10.1007/s13201-016-0433-0>
13. Jhariya, D. C., Mondal, K. C., Kumar, T., Indhulekha, K., Khan, R., & Singh, V. K. (2021). Assessment of groundwater potential zone using GIS-based multi-influencing factor (MIF), multi-criteria decision analysis (MCDA) and electrical resistivity survey techniques in Raipur city, Chhattisgarh, India. *Aqua Water Infrastructure, Ecosystems and Society*, 70(3), 375–400. <https://doi.org/10.2166/aqua.2021.129>
14. Kattimani, J., Murthy, A., S, R., Kumar, S., & R, V. (2018). Identification of Ground Water Potential Zone Using Remote Sensing and Gis Techniques. *International Journal of Advanced Research*, 6(5), 948–953. <https://doi.org/10.21474/ijar01/7116>
15. Kumar, A., & Krishna, A. P. (2018). Assessment of groundwater potential zones in coal mining impacted hard-rock terrain of India by integrating geospatial and analytic hierarchy process (AHP) approach. *Geocarto International*, 33(2), 105–129. <https://doi.org/10.1080/10106049.2016.1232314>
16. Kumar, A., & Krishna, A. P. (2021). Groundwater quality assessment using geospatial technique based water quality index (WQI) approach in a coal mining region of India. *Arabian Journal of Geosciences*, 14(12). <https://doi.org/10.1007/s12517-021-07474-9>
17. Kumar, A., & Pramod Krishna, A. (2020). Groundwater vulnerability and contamination risk assessment using GIS-based modified DRASTIC-LU model in hard rock aquifer system in India. *Geocarto International*, 35(11), 1149–1178. <https://doi.org/10.1080/10106049.2018.1557259>
18. Mallick, J., Talukdar, S., Alsubih, M., Ahmed, M., Islam, A. R. M. T., Shahfahad, & Thanh, N. V. (2022). Proposing receiver operating characteristic-based sensitivity analysis with introducing swarm optimized ensemble learning algorithms for groundwater potentiality modelling in Asir region, Saudi Arabia. *Geocarto International*, 37(15), 4361–4389. <https://doi.org/10.1080/10106049.2021.1878291>
19. Merouchi, H., & Bouderbala, A. (2024). Mapping natural groundwater potential recharge zones using GIS-AHP in the Upper Cheliff alluvial aquifer, Algeria. 77–91. <https://doi.org/10.7343/as-2024-726>
20. Mir, S., Bhat, M. S., Rather, G. M., & Mattoo, D. (2021). Groundwater Potential Zonation using Integration of Remote Sensing and AHP/ANP Approach in North Kashmir, Western Himalaya, India. *Remote Sensing of Land*, 5(1), 41–58. <https://doi.org/10.21523/gcj1.2021050104>
21. Moisa, M. B., Gurmessa, M. M., Negasa, G. F., Oljira, D. G., Dinsa, M. L., Deribew, K. T., Roba, Z. R., & Gameda, D. O. (2023). Evaluation of the groundwater recharge potential zone by using GIS and remote sensing in Ziway Abijata sub-basin, Central Rift Valley of Ethiopia. *Water Supply*, 23(8), 3416–

22. Nabi, G., Hussain, F., Wu, R. S., Nangia, V., & Bibi, R. (2020). Micro-watershed management for erosion control using soil and water conservation structures and SWAT modeling. *Water (Switzerland)*, *12*(5), 1–25. <https://doi.org/10.3390/w12051439>
23. Nasir, M. J., Khan, S., Zahid, H., & Khan, A. (2018). Delineation of groundwater potential zones using GIS and multi influence factor (MIF) techniques: a study of district Swat, Khyber Pakhtunkhwa, Pakistan. *Environmental Earth Sciences*, *77*(10), 1–11. <https://doi.org/10.1007/s12665-018-7522-3>
24. Olivera, F., Valenzuela, M., Srinivasan, R., Choi, J., Cho, H., Koka, S., & Agrawal, A. (2006). ArcGIS-SWAT: A geodata model and GIS interface for SWAT. *Journal of the American Water Resources Association*, *42*(2), 295–309. <https://doi.org/10.1111/j.1752-1688.2006.tb03839.x>
25. Patel, A. K., Sharma, M., Singh, A., Dubey, S., Chandola, V. K., & Mishra, S. (2024). Groundwater Potential Zones Using Multi – Criteria Decision Making for. *14*(4), 27–45. <https://doi.org/10.9734/IJECC/2024/v14i44093>
26. Raghuwanshi, N. S., & Mishra, P. K. (2021). *Soil and Water Conservation Structures*.
27. Rahaman, M. H., Sajjad, H., Roshani, Masroor, M., Bhuyan, N., & Rehman, S. (2022). Delineating groundwater potential zones using geospatial techniques and fuzzy analytical hierarchy process (FAHP) ensemble in the data-scarce region: evidence from the lower Thoubal river watershed of Manipur, India. *Arabian Journal of Geosciences*, *15*(8), 1–20. <https://doi.org/10.1007/s12517-022-09946-y>
28. Raj, S., Rawat, K. S., Singh, S. K., & Mishra, A. K. (2024). Groundwater potential zones identification and validation in Peninsular India. *Geology, Ecology, and Landscapes*, *8*(1), 86–100. <https://doi.org/10.1080/24749508.2022.2097375>
29. Saravanan, S., Saranya, T., Jennifer, J. J., Singh, L., Selvaraj, A., & Abijith, D. (2020). Delineation of groundwater potential zone using analytical hierarchy process and GIS for Gundihalla watershed, Karnataka, India. *Arabian Journal of Geosciences*, *13*(15). <https://doi.org/10.1007/s12517-020-05712-0>
30. Sarwar, A., Ahmad, S. R., Rehmani, M. I. A., Asif Javid, M., Gulzar, S., Shehzad, M. A., Dar, J. S., Baazeem, A., Iqbal, M. A., Rahman, M. H. U., Skalicky, M., Brestic, M., & Sabagh, A. E. L. (2021). Mapping groundwater potential for irrigation, by geographical information system and remote sensing techniques: A case study of district lower dir, pakistan. *Atmosphere*, *12*(6). <https://doi.org/10.3390/atmos12060669>
31. Srinivasa Rao, Y., & Jugran, D. K. (2003). Delineation of groundwater potential zones and zones of groundwater quality suitable for domestic purposes using remote sensing and GIS. *Hydrological Sciences Journal*, *48*(5), 821–833. <https://doi.org/10.1623/hysj.48.5.821.51452>
32. Umugwaneza, A., Chen, X., Liu, T., Mind'je, R., Uwineza, A., Kayumba, P. M., Uwamahoro, S., Umuhoya, J., Gasirabo, A., & Maniraho, A. P. (2022). Integrating a GIS-based approach and a SWAT model to identify potential suitable sites for rainwater harvesting in Rwanda. *Aqua Water Infrastructure, Ecosystems and Society*, *71*(4), 415–432. <https://doi.org/10.2166/aqua.2022.111>

33. Upadhyay, R. K., Tripathi, G., Đurin, B., Šamanović, S., Cetl, V., Kishore, N., Sharma, M., Singh, S. K., Kanga, S., Wasim, M., Rai, P. K., & Bhardwaj, V. (2023). Groundwater Potential Zone Mapping in the Ghaggar River Basin, North-West India, Using Integrated Remote Sensing and GIS Techniques. *Water (Switzerland)*, 15(5), 1–21. <https://doi.org/10.3390/w15050961>
34. Yifru, B. A., Mitiku, D. B., Tolera, M. B., Chang, S. W., & Chung, I. M. (2020). Groundwater Potential Mapping Using SWAT and GIS-Based Multi-Criteria Decision Analysis. *KSCE Journal of Civil Engineering*, 24(8), 2546–2559. <https://doi.org/10.1007/s12205-020-0168-1>
35. Ackermann, W. C. (1976). Soil and water conservation. *Eos, Transactions American Geophysical Union*, 57(10), 708–711. <https://doi.org/10.1029/EO057i010p00708>
36. Allafta, H., Opp, C., & Patra, S. (2021). Identification of groundwater potential zones using remote sensing and GIS techniques: A case study of the shatt Al-Arab Basin. *Remote Sensing*, 13(1), 1–28. <https://doi.org/10.3390/rs13010112>
37. Andualem, T. G., & Demeke, G. G. (2019). Groundwater potential assessment using GIS and remote sensing: A case study of Guna tana landscape, upper blue Nile Basin, Ethiopia. *Journal of Hydrology: Regional Studies*, 24(August 2018), 100610. <https://doi.org/10.1016/j.ejrh.2019.100610>
38. Arulbalaji, P., Padmalal, D., & Sreelash, K. (2019). GIS and AHP Techniques Based Delineation of Groundwater Potential Zones: a case study from Southern Western Ghats, India. *Scientific Reports*, 9(1), 1–17. <https://doi.org/10.1038/s41598-019-38567-x>
39. Bhardwaj, A., Singh, A., & Singh, S. (2023). *Groundwater quality mapping of Singrauli district using ArcGIS*. 20(August), 418–434.
40. Burayu, D. G. (2022). Identification of Groundwater Potential Zones Using AHP, GIS and RS Integration: A Case Study of Didessa Sub-Basin, Western Ethiopia. *Remote Sensing of Land*, 6(1), 1–15. <https://doi.org/10.21523/gcj1.2022060101>
41. Dile, Y. T., Daggupati, P., George, C., Srinivasan, R., & Arnold, J. (2016). Introducing a new open source GIS user interface for the SWAT model. *Environmental Modelling and Software*, 85, 129–138. <https://doi.org/10.1016/j.envsoft.2016.08.004>
42. Farzana, S. Z., Zafor, M. A., & Shahariar, J. Al. (2019). Application of SWAT Model for Assessing Water Availability in Surma River Basin. *Journal of the Civil Engineering Forum*, 5(1), 29. <https://doi.org/10.22146/jcef.39191>
43. Gebeyehu, A., Ayenew, T., & Asrat, A. (2023). Delineation of groundwater potential zones of the transboundary aquifers within the semiarid Bulal catchment, Southern Ethiopia. *Environmental Monitoring and Assessment*, 195(4), 1–21. <https://doi.org/10.1007/s10661-023-11088-x>
44. Gebru, H., Gebreyohannes, T., & Hagos, E. (2020). Identification of Groundwater Potential Zones Using Analytical Hierarchy Process (AHP) and GIS-Remote Sensing Integration, the Case of Golina River Basin, Northern Ethiopia. *International Journal of Advanced Remote Sensing and GIS*, 9(1), 3289–3311. <https://doi.org/10.23953/cloud.ijarsg.460>

45. George, G. K., Vishnudas, S., & Abdu Rahiman, K. U. (2024). Optimizing among Analytical Hierarchy Process, Influencing Factor Method, and Frequency Ratio Model in the Determination of Groundwater Potential Zones. *Civil Engineering and Architecture*, 12(1), 560–576. <https://doi.org/10.13189/cea.2024.120140>
46. Hussein, A. A., Govindu, V., & Nigusse, A. G. M. (2017). Evaluation of groundwater potential using geospatial techniques. *Applied Water Science*, 7(5), 2447–2461. <https://doi.org/10.1007/s13201-016-0433-0>
47. Jhariya, D. C., Mondal, K. C., Kumar, T., Indhulekha, K., Khan, R., & Singh, V. K. (2021). Assessment of groundwater potential zone using GIS-based multi-influencing factor (MIF), multi-criteria decision analysis (MCDA) and electrical resistivity survey techniques in Raipur city, Chhattisgarh, India. *Aqua Water Infrastructure, Ecosystems and Society*, 70(3), 375–400. <https://doi.org/10.2166/aqua.2021.129>
48. Kattimani, J., Murthy, A., S, R., Kumar, S., & R, V. (2018). Identification of Ground Water Potential Zone Using Remote Sensing and Gis Techniques. *International Journal of Advanced Research*, 6(5), 948–953. <https://doi.org/10.21474/ijar01/7116>
49. Kumar, A., & Krishna, A. P. (2018). Assessment of groundwater potential zones in coal mining impacted hard-rock terrain of India by integrating geospatial and analytic hierarchy process (AHP) approach. *Geocarto International*, 33(2), 105–129. <https://doi.org/10.1080/10106049.2016.1232314>
50. Kumar, A., & Krishna, A. P. (2021). Groundwater quality assessment using geospatial technique based water quality index (WQI) approach in a coal mining region of India. *Arabian Journal of Geosciences*, 14(12). <https://doi.org/10.1007/s12517-021-07474-9>
51. Kumar, A., & Pramod Krishna, A. (2020). Groundwater vulnerability and contamination risk assessment using GIS-based modified DRASTIC-LU model in hard rock aquifer system in India. *Geocarto International*, 35(11), 1149–1178. <https://doi.org/10.1080/10106049.2018.1557259>
52. Mallick, J., Talukdar, S., Alsubih, M., Ahmed, M., Islam, A. R. M. T., Shahfahad, & Thanh, N. V. (2022). Proposing receiver operating characteristic-based sensitivity analysis with introducing swarm optimized ensemble learning algorithms for groundwater potentiality modelling in Asir region, Saudi Arabia. *Geocarto International*, 37(15), 4361–4389. <https://doi.org/10.1080/10106049.2021.1878291>
53. Merouchi, H., & Bouderbala, A. (2024). Mapping natural groundwater potential recharge zones using GIS-AHP in the Upper Cheliff alluvial aquifer, Algeria. 77–91. <https://doi.org/10.7343/as-2024-726>
54. Mir, S., Bhat, M. S., Rather, G. M., & Mattoo, D. (2021). Groundwater Potential Zonation using Integration of Remote Sensing and AHP/ANP Approach in North Kashmir, Western Himalaya, India. *Remote Sensing of Land*, 5(1), 41–58. <https://doi.org/10.21523/gcj1.2021050104>
55. Moisa, M. B., Gurmessa, M. M., Negasa, G. F., Oljira, D. G., Dinsa, M. L., Deribew, K. T., Roba, Z. R., & Gemed, D. O. (2023). Evaluation of the groundwater recharge potential zone by using GIS and remote sensing in Ziway Abijata sub-basin, Central Rift Valley of Ethiopia. *Water Supply*, 23(8), 3416–3431. <https://doi.org/10.2166/ws.2023.183>

56. Nabi, G., Hussain, F., Wu, R. S., Nangia, V., & Bibi, R. (2020). Micro-watershed management for erosion control using soil and water conservation structures and SWAT modeling. *Water (Switzerland)*, *12*(5), 1–25. <https://doi.org/10.3390/w12051439>
57. Nasir, M. J., Khan, S., Zahid, H., & Khan, A. (2018). Delineation of groundwater potential zones using GIS and multi influence factor (MIF) techniques: a study of district Swat, Khyber Pakhtunkhwa, Pakistan. *Environmental Earth Sciences*, *77*(10), 1–11. <https://doi.org/10.1007/s12665-018-7522-3>
58. Olivera, F., Valenzuela, M., Srinivasan, R., Choi, J., Cho, H., Koka, S., & Agrawal, A. (2006). ArcGIS-SWAT: A geodata model and GIS interface for SWAT. *Journal of the American Water Resources Association*, *42*(2), 295–309. <https://doi.org/10.1111/j.1752-1688.2006.tb03839.x>
59. Patel, A. K., Sharma, M., Singh, A., Dubey, S., Chandola, V. K., & Mishra, S. (2024). Groundwater Potential Zones Using Multi – Criteria Decision Making for. *14*(4), 27–45. <https://doi.org/10.9734/IJECC/2024/v14i44093>
60. Raghuwanshi, N. S., & Mishra, P. K. (2021). *Soil and Water Conservation Structures*.
61. Rahaman, M. H., Sajjad, H., Roshani, Masroor, M., Bhuyan, N., & Rehman, S. (2022). Delineating groundwater potential zones using geospatial techniques and fuzzy analytical hierarchy process (FAHP) ensemble in the data-scarce region: evidence from the lower Thoubal river watershed of Manipur, India. *Arabian Journal of Geosciences*, *15*(8), 1–20. <https://doi.org/10.1007/s12517-022-09946-y>
62. Raj, S., Rawat, K. S., Singh, S. K., & Mishra, A. K. (2024). Groundwater potential zones identification and validation in Peninsular India. *Geology, Ecology, and Landscapes*, *8*(1), 86–100. <https://doi.org/10.1080/24749508.2022.2097375>
63. Saravanan, S., Saranya, T., Jennifer, J. J., Singh, L., Selvaraj, A., & Abijith, D. (2020). Delineation of groundwater potential zone using analytical hierarchy process and GIS for Gundihalla watershed, Karnataka, India. *Arabian Journal of Geosciences*, *13*(15). <https://doi.org/10.1007/s12517-020-05712-0>
64. Sarwar, A., Ahmad, S. R., Rehmani, M. I. A., Asif Javid, M., Gulzar, S., Shehzad, M. A., Dar, J. S., Baazeem, A., Iqbal, M. A., Rahman, M. H. U., Skalicky, M., Brestic, M., & Sabagh, A. E. L. (2021). Mapping groundwater potential for irrigation, by geographical information system and remote sensing techniques: A case study of district lower dir, pakistan. *Atmosphere*, *12*(6). <https://doi.org/10.3390/atmos12060669>
65. Srinivasa Rao, Y., & Jugran, D. K. (2003). Delineation of groundwater potential zones and zones of groundwater quality suitable for domestic purposes using remote sensing and GIS. *Hydrological Sciences Journal*, *48*(5), 821–833. <https://doi.org/10.1623/hysj.48.5.821.51452>
66. Umugwaneza, A., Chen, X., Liu, T., Mind'je, R., Uwineza, A., Kayumba, P. M., Uwamahoro, S., Umuhoza, J., Gasirabo, A., & Maniraho, A. P. (2022). Integrating a GIS-based approach and a SWAT model to identify potential suitable sites for rainwater harvesting in Rwanda. *Aqua Water Infrastructure, Ecosystems and Society*, *71*(4), 415–432. <https://doi.org/10.2166/aqua.2022.111>
67. Upadhyay, R. K., Tripathi, G., Đurin, B., Šamanović, S., Cetl, V., Kishore, N., Sharma, M., Singh, S. K., Kanga, S., Wasim, M., Rai, P. K., & Bhardwaj, V. (2023). Groundwater Potential Zone Mapping

68. Yifru, B. A., Mitiku, D. B., Tolera, M. B., Chang, S. W., & Chung, I. M. (2020). Groundwater Potential Mapping Using SWAT and GIS-Based Multi-Criteria Decision Analysis. *KSCE Journal of Civil Engineering*, 24(8), 2546–2559. <https://doi.org/10.1007/s12205-020-0168-1>
69. (Ackermann, 1976; Allafta et al., 2021; Andualem & Demeke, 2019; Arulbalaji et al., 2019, 2019; Bhardwaj et al., 2023; Burayu, 2022; Dile et al., 2016; Farzana et al., 2019; Gebeyehu et al., 2023; Gebru et al., 2020; George et al., 2024; Hussein et al., 2017; Jhariya et al., 2021; Kattimani et al., 2018; Kumar & Krishna, 2018, 2021; Kumar & Pramod Krishna, 2020; Mallick et al., 2022; Merouchi & Bouderbala, 2024; Mir et al., 2021; Moisa et al., 2023; Nabi et al., 2020; Nasir et al., 2018; Olivera et al., 2006; Patel et al., 2024; Raghuwanshi & Mishra, 2021; Rahaman et al., 2022; Raj et al., 2024; Saravanan et al., 2020; Sarwar et al., 2021; Srinivasa Rao & Jugran, 2003; Umugwaneza et al., 2022; Upadhyay et al., 2023; Yifru et al., 2020)

