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GIS-Based Assessment of Environmental Factors Influencing Groundwater Potential in Nueva Ecija

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ABSTRACT: Groundwater plays a vital role in supporting domestic, agricultural, and economic activities in Nueva Ecija. This study assessed the observed spatial relationships between selected environmental factors and groundwater availability using Geographic Information System (GIS)-based spatial analysis techniques. Secondary geospatial datasets on groundwater availability, soil types, elevation, and stream networks were obtained from the Philippine Geoportal and related sources and analyzed using QGIS. Overlay Analysis, Zonal Statistics, and Euclidean Distance Analysis were employed to examine spatial patterns among variables. Results indicated that areas with lower elevations, favorable soil types such as sandy loam and silt loam, and closer proximity to stream networks generally corresponded to more productive groundwater availability classes. Among the evaluated variables, elevation showed the strongest observed spatial association with groundwater availability, followed by soil type and distance to rivers and drainage systems. The findings suggest that topographic conditions and soil characteristics may be spatially associated with groundwater distribution patterns within the province. The study demonstrates the usefulness of GIS-based spatial analysis as a preliminary tool for regional groundwater assessment and water resource planning. However, the results remain interpretative due to the use of secondary datasets and the absence of field validation and hydrogeological measurements. Groundwater studies commonly use GIS-based spatial analysis for preliminary groundwater assessment and resource planning, particularly in data-limited areas.

KEYWORDS: Groundwater Potential, Groundwater Availability, GIS-based Assessment, Nueva Ecija Soil Types, Nueva Ecija Elevations, Nueva Ecija Stream Networks, Environmental Factors

CHAPTER I

THE PROBLEM AND ITS SETTING

INTRODUCTION

Groundwater, or water found beneath the Earth's surface, is an essential resource for domestic and agricultural use, particularly in areas with limited or seasonal surface water supply. Its occurrence and distribution are influenced by various environmental factors, making groundwater assessment complex and dependent on multiple interacting variables (Lee et al., 2020; Dapar & Espina, 2026).

Geographic Information Systems (GIS) are widely used to support groundwater studies by integrating and analyzing spatial data (Ajadi et al., 2025; Inson et al., 2021). Although GIS does not directly predict groundwater presence, it enables the combination of thematic layers to identify spatial patterns associated with groundwater availability.

Key factors influencing groundwater potential include soil characteristics, elevation, and stream proximity. Soil affects infiltration and permeability, where more permeable soils enhance groundwater recharge (Joleha et al., 2024; Lee et al., 2020). Elevation influences water movement, with lower and flatter areas favoring infiltration, as analyzed using Digital Elevation Models (Touré et al., 2025; Ajadi et al., 2025). Stream proximity also plays a role, as areas near streams may experience increased recharge, while high drainage density may reduce infiltration (Alemu et al., 2025; Dapar & Espina, 2026).

In the Philippine context, groundwater is a vital resource, especially in agricultural regions. Studies emphasize the importance of integrating spatial and hydrogeological data and conducting localized assessments (Quitaneg et al., 2021; Dapar & Espina, 2026). Nueva Ecija, known as the "Rice Granary of the Philippines," has a high demand for water due to intensive agricultural activities, increasing reliance on groundwater for irrigation (Philippine Statistics Authority, 2023; National Irrigation Administration, 2023).

Given these conditions, this study examines the spatial relationship between soil types, elevation, and stream proximity in relation to groundwater potential in Nueva Ecija using GIS. The study aims to identify spatial patterns that may indicate areas showing relatively higher groundwater potential and provide baseline information for future, more detailed investigations (Philippine Statistics Authority, 2023)

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CONCEPTUAL FRAMEWORK

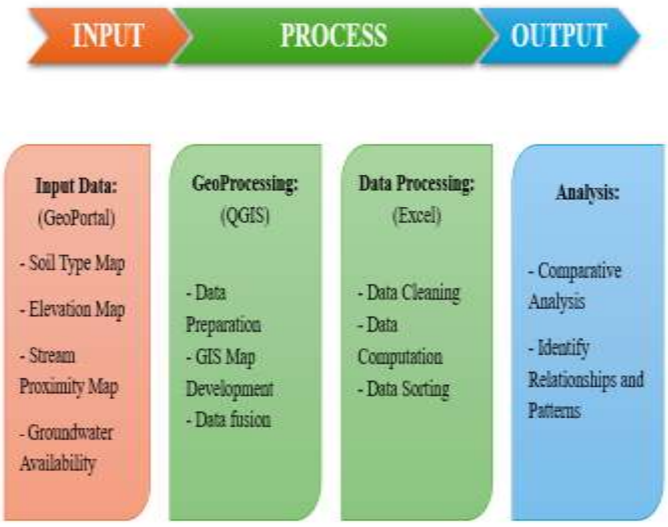


Figure 1.

The figure above presents a systematic workflow that transforms raw geospatial data into analytical insights through three main stages: input, process, and output.

The input stage involves the collection of geospatial datasets from Geoportal PH., including soil types, elevation, rivers and drainage, and groundwater availability data used for environmental and hydrological assessment. These datasets provide the necessary information for examining the characteristics of the study area.

In the process stage, the datasets undergo geoprocessing in QGIS, including data preparation, spatial alignment, map development, and data integration. Excel was also used for data cleaning, computation, and organization to improve dataset consistency for analysis.

Finally, in the output stage, the processed data undergoes comparative spatial analysis to identify observed spatial relationships and distribution patterns among variables. The results are interpreted through maps and descriptive analysis to examine how soil types, elevation, and stream proximity appear spatially associated with groundwater availability within the study area.

Statement of the Problem

Groundwater is an essential natural resource that supports domestic, agricultural, and industrial activities. However, the availability and distribution of groundwater are significantly influenced by factors such as soil types, elevation, and proximity of surface water bodies.

This study aims to analyze the spatial relationships between groundwater availability and these environmental factors using GIS techniques. Specifically, it seeks to answer the following questions:

1. What are the spatial distributions of groundwater availability, soil types, elevation, and river and drainage formations within the study area?
2. What is the spatial relationship between groundwater availability and soil types, as determined through overlay analysis using the Intersect tool to identify areas of overlap?
3. What is the relationship between groundwater availability and elevation, as assessed using zonal statistics applied to an interpolated Digital Elevation Model (DEM) to derive mean elevation values for each groundwater zone?
4. What is the relationship between groundwater availability and proximity to rivers and drainage systems, as measured through Euclidean Distance Analysis to calculate distances from water bodies?
5. Which factor shows the strongest observed spatial association with groundwater classes?

The Objective of the Study

To assess the spatial relationship of soil types, elevation, rivers, and drainages on groundwater potential in selected areas of Nueva Ecija using GIS-based spatial analysis techniques.

Specific Objectives:

1. Map groundwater availability, soil types, elevation, and stream networks.
2. Analyze overlap between soil types and groundwater classes.
3. Compare elevation ranges among groundwater classes.
4. Examine stream proximity patterns among groundwater classes.
5. Identify the factor showing the strongest observed spatial association.

Significance of the Study

This GIS-based assessment examines how soil types, elevations, rivers, and drainages influence groundwater potential in selected areas of Nueva Ecija. It provides clearer insights into the role of local geology on groundwater availability and productivity.

The results benefit:

Local Communities. Identifies high-potential zones for reliable water access in daily needs, farming, and drinking while promoting safer and more sustainable resource use.

LGUs. Supports planning of water supply projects, prioritization of sourcing areas, and groundwater preservation measures for better development and disaster-resilient decisions in water-limited zones.

Farmers. Improves irrigation planning and efficient water management, reducing risks of drought and groundwater depletion in agriculture-dependent areas.

Researchers. Serves as a reference for future work on geological mapping, GIS evaluation, and groundwater systems, encouraging deeper studies on long-term sustainability, water quality, and vulnerability in Nueva Ecija and similar regions.

Scope and Limitation of the Study

This study assesses the influence of soil types, elevations, rivers, and drainages on groundwater potential in selected areas of Nueva Ecija using a Geographic Information System (GIS)-based approach. It relies on existing government data and available digital maps to generate basic GIS layers of geologic formations, elevation, and drainage networks, and to identify zones with relatively higher or lower groundwater potential. The outputs provide a cost-effective basis for understanding groundwater distribution patterns and supporting preliminary water resource planning and future research. The study does not establish hydrogeologic causation and remains limited to GIS-based interpretative spatial analysis.

The study is strictly limited to secondary data and spatial information processed through the GIS workflow. It does not replace detailed field investigations required to verify actual groundwater conditions.

Key limitations are as follows:

- The groundwater potential map is secondary interpreted data.
- Soil and groundwater datasets used are older datasets.
- DEM-derived streams represent modeled flow paths and are not fully field-verified rivers.
- No pumping tests or groundwater level measurements were conducted.
- Results serve only as preliminary screening.

CHAPTER II
REVIEW OF RELATED LITERATURE

2.1. GIS in Groundwater Studies

GIS serves as a core tool for multi-criteria decision analysis (MCDA), AHP, and weighted overlay in groundwater potential mapping, integrating thematic layers such as soil, elevation, drainage, and geology for spatial assessments. Foreign studies demonstrate high predictive accuracy when validated against wells or geophysical data. Phong et al. (2021) developed hybrid AI-GIS models in Vietnam, while Nigusse et al. (2025) and Zhang et al. (2023) applied weighted overlay and AHP-GIS for groundwater and recharge mapping. Jaafarzadeh et al. (2021) also applied ensemble models for reliable zonation.

In the Philippines, Dapar et al. (2026) utilized AHP-GIS in Tagum City to evaluate groundwater potential, while Galoso et al. (2024) applied GIS in irrigation system management. These studies highlight GIS as an effective tool for spatial groundwater assessment.

2.2. Philippine Studies

Philippine groundwater research has increasingly adopted GIS and AHP for potential mapping, recharge suitability, and quality assessment, particularly in agricultural and urbanizing areas. Dapar et al. (2026) and Galvez et al. (2026) identified groundwater potential and recharge suitability using multiple environmental factors.

Sandoval and Tiburan (2019) identified artificial recharge sites in Mount Makiling, while Juanico (2020) improved groundwater mapping in Cebu and Mactan.

Other studies, including Cuevas et al. (2026), Kawo et al. (2018), and Flores (2025), focused on recharge estimation and optimization. Rances et al. (2025) highlighted groundwater quality concerns in Luzon, including Nueva Ecija, emphasizing the need for sustainable groundwater management.

2.3. Research Gap

Despite these studies, gaps remain in integrated GIS-based assessments that evaluate soil types, elevation, and surface water features in relation to groundwater potential, particularly in Nueva Ecija. Fraga (2026) highlighted limited focus on site-specific potential mapping, while Robles et al. (2025) noted data limitations in Central Luzon.

Rances et al. (2025) further emphasized the lack of localized models linking soil, elevation, and surface water interactions, indicating the need for more comprehensive and site-specific groundwater assessments.

CHAPTER III
METHODS AND PROCEDURE

Research Design

This study utilizes descriptive comparative spatial analysis using GIS to examine the spatial relationship between selected environmental factors and groundwater availability. This approach is appropriate because it allows the researchers to describe existing spatial conditions and analyze the degree to which variables are spatially associated without manipulating them (Bhandari, 2021).

In this study, variables such as soil type, elevation and slope, and rivers and drainage systems are treated as comparison variables, while groundwater availability classes served as the primary comparison variable. Using GIS techniques, the researchers analyze spatial data through map overlay and spatial comparison to identify patterns and relationships among variables. The approach focuses on determining the strength and direction of spatial associations based on the distribution and overlap of these factors.

This method does not aim to establish cause-and-effect relationships but rather to provide a systematic description of how variables are spatially related within the study area. This aligns with descriptive correlational research principles that focus on observing and analyzing relationships among variables as they naturally occur, without experimental manipulation (Bhandari, 2021).

Locale of the Study

The study is conducted in selected areas of Nueva Ecija, Philippines. The province is known for its diverse landforms, varying elevations, and agricultural landscapes, which make it suitable for analyzing groundwater distribution in relation to environmental factors such as soil type, slope, and elevation.

Spatial data used in the study are obtained from the Philippine Geoportal and other publicly available geospatial databases. These sources were selected because they provide standardized spatial layers that are necessary for consistent mapping and comparative analysis across the study area.

Research Instrument

This study utilizes Geographic Information System (GIS) software, specifically QGIS 4.0 'Norrköping', as the primary research instrument for spatial data processing and analysis. QGIS is widely used in environmental and hydrological studies because it enables researchers to organize, process, analyze, and visualize geographic information effectively. It allows the examination of spatial relationships among different variables through various GIS analytical tools.

All spatial datasets were processed under the WGS 84 / UTM Zone 51N coordinate reference system (CRS) to ensure consistency in projection, distance measurements, and overlay operations across layers. The datasets used in this study include maps or layers for soil type, elevation, slope, rivers and drainage, and groundwater availability derived from reliable sources. These data were processed using GIS techniques such as clipping, projection alignment, reclassification, spatial comparison, and overlay-based analysis. GIS-based analysis is effective for groundwater studies because it allows the integration of multiple spatial factors and provides results that can be interpreted through both map outputs and quantitative measurements (Machiwal et al., 2018)

Data Gathering Procedure

The data gathering process begins with the identification and collection of relevant spatial datasets, including soil type, elevation and slope, drainage systems, and groundwater availability or potential zones. The province's shapefile of the Philippines was obtained from SimpleMaps (2023). Groundwater availability data and soil type shapefiles for Regions III and IV were acquired from the Philippine Geoportal (2020). These groundwater datasets represent the Mines and Geosciences Bureau (MGB) Hydrogeology/Groundwater Availability Map, which delineates hydrogeologic formations and classifies aquifer productivity according to lithology and expected well-yield potential (e.g., high-, moderate-, or low-productivity aquifer classes). Soil type shapefiles were likewise sourced from the same portal.

Elevation data were derived from Digital Elevation Models (DEM) accessed through QGIS plugins and OpenTopography (2020), providing raster data necessary for terrain analysis, including slope derivation. From the acquired DEM, stream networks were generated using the ArcGeek Calculator plugin in QGIS, which extracts DEM-derived hydrologic drainage paths based on elevation values. These represent modeled drainage patterns and are not necessarily equivalent to actual surveyed rivers or field-verified drainage systems.

After data collection, the researchers imported all datasets into QGIS for processing. Preprocessing steps such as clipping the layers to the study boundary, aligning coordinate systems to a common projection, and formatting datasets were performed to ensure consistency among the layers and to avoid errors during analysis.

Once the datasets were prepared, spatial analysis was conducted using GIS tools to determine the relationship between groundwater availability and each environmental factor. Overlay analysis and spatial measurements were performed to examine correlations among variables such as soil type, elevation, and proximity to DEM-derived stream networks. The resulting outputs were then exported and organized for further tabulation, computation, and interpretation.

Data Analysis:

3.1. Soil Type and Groundwater Availability Analysis:

The relationship between soil type and groundwater availability was determined using Overlay Analysis (Intersect). This method was used to precisely identify and measure the spatial overlap between soil type polygons and groundwater availability zones. The area of each soil type within a given groundwater zone was first computed. Since some soil types are distributed in multiple locations, the areas of all polygons belonging to the same soil category were summed.

The total area of each groundwater availability zone was then calculated by summing all intersected soil type areas within that zone:

$$\boldsymbol{A_t} = \sum \boldsymbol{A_S}$$

Where:

$\boldsymbol{A_t}$ = Total area of each groundwater availability zones

$\boldsymbol{A_s}$ = Area of each soil type polygon within the zone.

The percentage of soil type occupation was then computed using:

$$\boldsymbol{Percentage} = \left(\frac{\boldsymbol{A_s}}{\boldsymbol{A_t}}\right) \times \mathbf{100}$$

This procedure was repeated for all soil types across each groundwater availability zone.

3.2. Elevation Analysis:

The relationship between elevation and groundwater availability was analyzed using Zonal Statistics on an interpolated Digital Elevation Model (DEM). This method was used to compute the mean elevation within each groundwater availability zone.

The mean elevation was automatically derived in QGIS using the formula:

$$\underline{\boldsymbol{Z}} = \frac{\sum \boldsymbol{Z_i}}{\boldsymbol{n}}$$

Where:

$\underline{\boldsymbol{Z}}$ = Mean elevation of the zone

$\sum \boldsymbol{Z_i}$ = Elevation value of each raster cell

$\boldsymbol{n}$ = Total number of raster cells within the zone

This allowed for the comparison of average elevation values across different groundwater availability classes.

3.3. Stream Network Proximity Analysis:

The relationship between stream networks and groundwater availability was assessed using Euclidean Distance Analysis. Euclidean Distance Analysis only measures spatial proximity, not the actual groundwater recharge. Stream networks were derived from the DEM and buffer zones were created at distances of 1 km, 2 km, 3 km, and greater than 3 km.

The area of each distance zone was calculated and then summed to determine the total area of the study region (Nueva Ecija):

$$A_{total} = A_{1km} + A_{2km} + A_{3km} + A_{>3km}$$

The proportion of each distance class was then computed as:

$$Percentage\ of\ Distance\ Zone = \left(\frac{A_d}{A_{total}}\right) \times 100$$

Where:

A_d = Area of each distance buffer zone

A_{total} = Total area of Nueva Ecija

All spatial analyses were conducted using QGIS, while tabulation and statistical summarization were performed in Microsoft Excel. Overlay Analysis (Intersect) was used for categorical comparisons, Zonal Statistics for elevation analysis, and Euclidean Distance Analysis for proximity to streams.

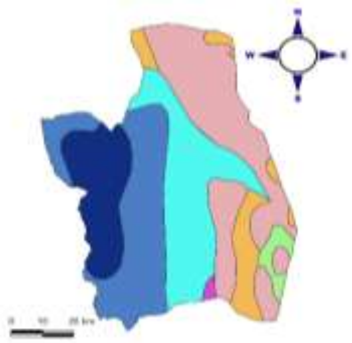
After processing, results such as area measurements, mean elevation values, and percentage distributions were encoded in Excel. Descriptive statistics, including frequency and percentage analysis, were used to summarize the data. The findings are presented through tables, charts, and thematic maps to clearly illustrate spatial patterns and relationships among soil type, elevation, stream network proximity, and groundwater availability.

CHAPTER IV
RESULTS AND DISCUSSION

This section presents and discusses the results of the GIS-based spatial analysis conducted in the study. It examines the relationship between groundwater availability and selected environmental factors, namely soil types, elevation, and proximity to stream networks within the study area. GIS techniques such as Overlay Analysis (Intersect), Zonal Statistics, and Euclidean Distance Analysis were used to identify and measure spatial relationships among the variables.

The overlap between soil types and groundwater zones was analyzed to determine possible influences of soil characteristics on groundwater distribution. Mean elevation values were also computed for each groundwater availability class to assess topographic effects, while distance analysis from stream networks was used to evaluate the relationship between proximity to water bodies and groundwater occurrence. The results are interpreted to identify spatial patterns and correlations that explain how soil type, elevation, and stream proximity may be spatially associated with groundwater availability in the study area.

Figure 2. Groundwater Availability Map (Nueva Ecija)



Note. Groundwater Availability Map of Nueva Ecija.

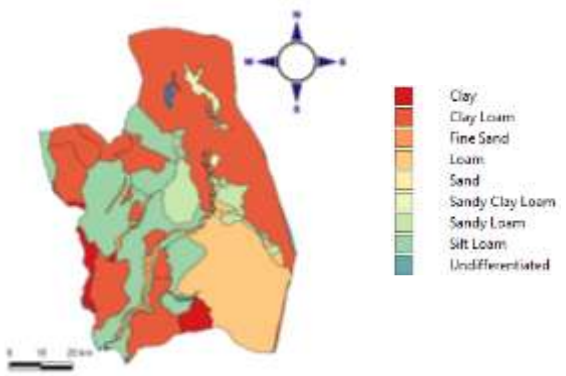
Adapted and processed from Geoportal dataset using QGIS, based on data from GeoPortal PH.

Figure 2. shows the groundwater availability map of Nueva Ecija, classified into seven categories: Extensive and Highly Productive Aquifers; Fairly Extensive and Productive Aquifers; Local and Less Productive Aquifers; Fairly Extensive and Productive Aquifers with High Potential Recharge; Fairly to Less Extensive and Productive Aquifers with Low to Moderate Potential Recharge; Rocks with Limited Potential and Low to Moderate Permeability; and Rocks without any Known Significant Groundwater Obtainable through Drilled Wells (largely untested). These classifications illustrate the spatial variation in groundwater potential, ranging from areas with high aquifer productivity and recharge capacity to zones with minimal or uncertain groundwater availability. The map provides a clear visualization of how groundwater resources are distributed across the study area, serving as a foundational layer for analysis.

This groundwater availability variable will be used as the primary basis for correlation with the other three variables in the study, namely Soil Types, Elevations, and Rivers and Drainages. The relationships identified will help explain patterns of groundwater occurrence and contribute to a better understanding of the factors affecting groundwater availability in the area.

Figure 3. Soil Types Map (Nueva Ecija)

Note. Soil Types Map of Nueva Ecija. Adapted and

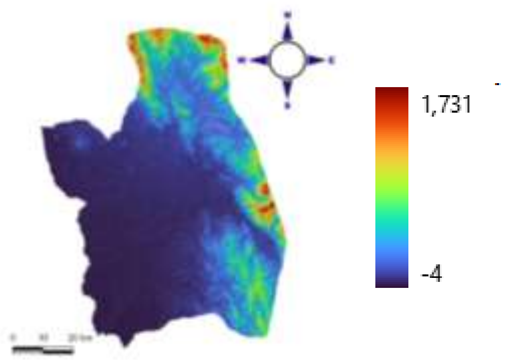


processed from Geoportal dataset using QGIS, based on data of Soil Types in Region 3 and 4 from GeoPortal PH..

Figure 3. presents the soil type map of Nueva Ecija,

showing the spatial distribution of different soil classifications across the province. The map identifies nine soil types present in the area: Clay, Clay Loam, Fine Sand, Loam, Sand, Sandy Clay Loam, Sandy Loam, Silt Loam, and Undifferentiated soils. These soil types vary in texture, composition, and permeability, which influence their capacity for water retention and infiltration. The map provides an important basis for understanding how soil characteristics may affect groundwater availability in different parts of the study area.

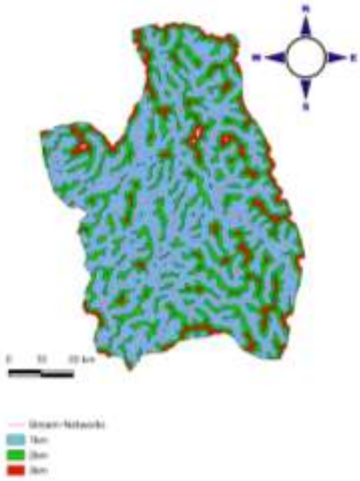
Figure 4. 2D DEM Elevation Map (Nueva Ecija)



Note. DEM Elevation Map of Nueva Ecija. Created by the author using QGIS, based on data from OpenTopography.

Figure 4. presents the Digital Elevation Model (DEM) map of Nueva Ecija in 2D representations. The map illustrates the variation in terrain elevation across the province, with the lowest elevation recorded at -4 meters and the highest at 1,731 meters. These variations highlight the topographic differences from low-lying plains to mountainous areas, providing a clear visualization of how elevation is distributed throughout the study area.

Figure 5. Rivers and Drainages with Euclidean Distance (Nueva Ecija)



Note. Stream Network Map of Nueva Ecija. Created by the author using QGIS, based on data from OpenTopography and using ArcGeek Calculator.

Figure 5. shows the Euclidean Distance Map of the stream networks in the study area. The Stream Networks are represented in Pink, while the surrounding distances are classified into four zones: Light Blue for areas within 1 km from the streams, Green for 2 km, Red for 3 km, and the remaining areas representing distances greater than 3 km. This map illustrates the spatial variation in proximity to rivers and drainage systems, helping identify areas that are nearer to or farther from potential surface water sources that may be spatially associated with groundwater availability.

Table 1. Soil Type and Groundwater Availability (Overlay Analysis)

Soil Types:

1. Clay
2. Clay Loam
3.Fine Sand
4. Loam
5. Sand
6. Sandy Clay Loam
7 Sandy Loam
8. Silt Loam
9. Undifferentiated

Groundwater Availability	Soil Types (Area in km²)								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Extensive and highly productive Aquifers	79.198	348.729	11.319	0	0	0	0	337.663	0
Fairly Extensive and Productive Aquifers	15.645	443.52	75.19	0	0.396	0	0	764.71	0
Local and Less Productive Aquifers	68.508	414.013	24.452	167.233	29.478	5.649	215.744	358.297	7.473
Fairly Extensive and Productive Aquifer with high Potential Recharge	0	0	16.616	8.299	0	0	0	0	0
Fairly to Less Extensive and Productive Aquifers with Low to Moderate Potential Recharge	0	17.64	0	101.899	0	0	5.107	0	0
Rocks with limited potential, low to moderate permeability	0	1000.694	3.744	453.901	31.282	54.718	51	0.254	17.168
Rocks without any known significant groundwater obtainable through drilled wells largely, untested	0	156.017	0.028	253.862	5.155	0	0	0	5.213

Overall, Clay Loam and Silt Loam were commonly present across several groundwater classes, indicating that soil type alone may not sufficiently distinguish groundwater potential zones. These soils may contribute to higher groundwater availability through balanced permeability water retention, allowing efficient infiltration and storage (Food and Agriculture Organization, 2021; U.S. Geological Survey, 2016).

Local studies support this, showing that soil texture influences recharge but is only one moderate factor that must be combined with lithology, slope, rainfall, and drainage density, confirming that soil type alone cannot reliably delineate potential zones (Dapar & Espina, 2026; Sandoval & Tiburan, 2019).

Sandy Loam also appears frequently but is more dominant in moderate to low availability categories, suggesting only moderate suitability due to higher permeability and lower moisture retention (Natural Resources Conservation Service, 2020).

In contrast, Fine Sand and highly sandy soils dominate areas with recharge-dependent or lower groundwater potential, as coarse soils promote rapid drainage but minimal storage (International Water Management Institute, 2015). Therefore, while balanced soils appear associated with higher availability and coarse soils with lower potential, other factors such as subsurface geology and recharge rates also play significant roles (Food and Agriculture Organization, 2021; U.S. Geological Survey, 2016; Dapar & Espina, 2026; Sandoval & Tiburan, 2019).

Table 2. Elevation and Groundwater Availability (Zonal Statistics)

Groundwater Availability	Mean of Elevation	Min. Elevation	Max. Elevation	Groundwater Availability	Mean of Elevation	Min. Elevation	Max. Elevation
Extensive and highly productive Aquifers	39.731m	-29m	386m	Fairly to Less Extensive and Productive Aquifers with Low to Moderate Potential Recharge	409.068m	99m	1015m
Fairly Extensive and Productive Aquifers	47.110m	-15m	589m	Rocks with limited potential, low to moderate permeability	439.953m	53m	1797m
Local and Less Productive Aquifers	149.317m	19m	1466m	Rocks without any known significant groundwater obtainable through drilled wells largely, untested	615.402m	73m	1726m
Fairly Extensive and Productive Aquifer with high Potential Recharge	120.031m	55m	221m				

Lower elevation plains generally correspond to higher groundwater productivity, while upland and mountainous areas are associated with limited groundwater potential, suggesting a possible inverse relationship between elevation and groundwater availability. This may be influenced by topography, where lower slopes reduce runoff and increase infiltration, while steeper slopes promote rapid runoff and limit recharge (Jaafarzadeh et al., 2021).

Studies support this pattern, indicating that flat areas enhance infiltration and groundwater recharge, while steep slopes reduce groundwater potential due to faster runoff (Kakish et al., 2017). Local studies in the Philippines also show that higher elevation and steeper terrains limit groundwater availability, reinforcing the influence of elevation on groundwater distribution (Contreras et al., 2013; Velasco et al., 2024).

Table 3. "Rivers and Drainages" and Groundwater Availability (Euclidean Distance Analysis)

Groundwater Availability	Euclidean Distance (in Percentage)				Groundwater Availability	Euclidean Distance (in Percentage)			
	0-1km	1km-2km	2km-3km	3km+		0-1km	1km-2km	2km-3km	3km+
Extensive and	68.80%	25.22%	3.79%	2.18%	Fairly to Less	42.39%	38.59%	15.01%	4.01%

highly productive Aquifers					Extensive and Productive Aquifers with Low to Moderate Potential Recharge				
Fairly Extensive and Productive Aquifers	70.70%	24.33%	4.54%	0.42%	Rocks with limited potential, low to moderate permeability	58.15%	30.36%	9.64%	1.85%
Local and Less Productive Aquifers	67.27%	26.85%	5.67%	0.21%	Rocks without any known significant groundwater obtainable through drilled wells largely, untested	44.06%	34.45%	15.34%	6.15%
Fairly Extensive and Productive Aquifer with high Potential Recharge	47.88%	27.20%	22.81%	2.11%					

Groundwater availability shows a spatial tendency to be higher in areas closer to stream networks, with productive aquifers predominantly located within shorter distances (0–1 km). As distance increases, the proportion of less productive aquifers and rock formations also increases, suggesting a spatial association between stream proximity and aquifer productivity. This aligns with the hydraulic connection between rivers and aquifers, which may support infiltration and recharge processes in nearby areas (Sophocleous, 2002).

Studies also show that aquifers near rivers may have higher productivity due to surface water interaction, while farther areas experience reduced infiltration and are often dominated by less permeable formations (Gao et al., 2022; Bajracharya et al., 2020). Local studies support this pattern, showing that high groundwater potential zones are commonly located near rivers, indicating that proximity to streams influences groundwater productivity, although multiple hydrological processes are involved (Dapar & Espina, 2026).

Table 4. Influence of Soil Types, Elevation, and Proximity to Rivers and Drainage Systems on Groundwater Availability

Factors	Observed Spatial Association	Findings
Elevation	Most Apparent Spatial Pattern	Elevation appeared to show the strongest observed spatial association. Areas with lower mean elevation (39.731m to 47.110m) correspond to Extensive and Highly Productive Aquifers. In contrast, higher elevations are associated with rocks having limited potential or no known significant groundwater.
Soil Types	Strong Apparent Spatial Pattern	Also demonstrated an observed pattern. Specific soil types such as Clay Loam (44.89%) and Silt Loam dominate areas classified with high groundwater potential, while sandy soils are associated with lower potential.
Proximity to Rivers and Drainage Systems	Moderate Apparent Spatial Pattern	Shows observed spatial association but to a lesser degree. While productive zones are generally located near streams (68.80% within 0-1km), the pattern is not as distinct compared to elevation and soil types.

Based on observed spatial patterns, elevation showed the strongest observed spatial association among the evaluated factors in relation to the presence, distribution, and recharge potential of groundwater resources in the study area. This is attributable to Elevation's role in commonly associated with surface runoff behavior, hydraulic gradients, and the duration available for infiltration; lower to moderate elevations generally promote prolonged surface water retention and enhanced percolation into underlying aquifers, whereas higher elevations accelerate runoff and limit recharge. These findings align with established hydrogeological principles and are consistent with geospatial studies employing Analytic Hierarchy Process (AHP) methodologies in comparable environments, including studies in Iligan City and Ethiopia where elevation and slope were among the most influential factors (Galvez et al., 2026; Kassa et al., 2025).

Soil Types ranked second in relative observed spatial association, reflecting the contribution of soil texture, porosity, and permeability to infiltration rates and subsurface storage capacity. Soils with higher sand or loam content facilitate vertical movement of water into the vadose zone, while finer-textured or compacted soils promote surface ponding and runoff. This secondary ranking is supported by related studies identifying soil properties as a key but subordinate factor to topographic controls (Galvez et al., 2026; Owolabi et al., 2020; Kassa et al., 2025).

Proximity to Rivers and Drainage Systems exhibited the lowest level of observed spatial association. Although proximity can augment recharge through hydraulic connectivity, its effect in Nueva Ecija appears less pronounced, likely due to stronger topographic and edaphic controls. Similar patterns were observed in Tagum City, where drainage density ranked below slope in AHP weighting (Dapar et al., 2026).

Collectively, the results indicate that elevation appeared to have the greatest observed spatial association on groundwater availability in Nueva Ecija, followed by soil types and, to a lesser extent, proximity to rivers and drainage systems. The relative observed spatial association levels were based on observed spatial trends and interpretative comparison only.

CHAPTER V
SUMMARY, CONCLUSION, AND RECOMMENDATION

Summary

This study examined the observed spatial relationships between selected environmental factors and groundwater availability in Nueva Ecija using GIS-based spatial analysis techniques. Secondary geospatial datasets on groundwater availability, soil types, elevation, and rivers and drainage systems were obtained from Geoportal PH. and related sources. These datasets were processed and analyzed in QGIS through overlay analysis, zonal statistics, and Euclidean distance analysis to examine spatial patterns and relationships among variables.

The analysis indicated that productive groundwater availability classes were more commonly observed in areas with lower elevations, favorable soil types such as sandy loam and silt loam, and locations nearer to rivers and drainage systems. Among the evaluated variables, elevation showed the strongest observed spatial association with groundwater availability, followed by soil type and stream proximity. The findings suggest that topographic conditions, soil characteristics, and proximity to surface water systems may be spatially associated with groundwater distribution patterns within the province.

The study highlights the usefulness of GIS-based spatial analysis for preliminary groundwater assessment, spatial interpretation, and regional water resource planning, particularly in areas with limited field data. However, the findings remain interpretative because the study relied primarily on secondary datasets and GIS-based analysis without direct hydrogeological validation or field measurements

CONCLUSIONS

1. Soil type alone is not a definitive indicator of groundwater potential. Although clay loam and silt loam are frequently associated with productive aquifers due to their balanced permeability and water retention properties, these soil types are also present in less productive zones, indicating that other factors are also associated with groundwater distribution.
2. Productive groundwater classes were generally associated with lower elevations. Areas with lower elevation, particularly plains generally corresponded with more productive groundwater classes, while higher elevation areas tend to exhibit limited groundwater availability.
3. Proximity showed an apparent relationship with groundwater classes. Productive aquifers are more commonly located near rivers and drainage systems, suggesting possible spatial association between stream proximity and groundwater occurrence.
4. Groundwater potential appeared related to the combined influence of multiple factors. Soil type, elevation, and stream proximity collectively appear associated with groundwater availability, with no single variable being sufficient to fully explain its distribution.
5. GIS-based spatial analysis is a useful preliminary tool for preliminary groundwater assessment. The integration of multiple spatial datasets allowed for efficient mapping and analysis of groundwater potential, making it suitable for provincial-scale screening and planning.
6. Despite the usefulness of GIS-based analysis, the results remain interpretative. Due to the reliance on secondary data and GIS-based methods, the findings should be supported by field investigations and hydrogeological measurements for more accurate groundwater evaluation.

RECOMMENDATIONS

Based on the findings and conclusion of the study, the following recommendations are proposed:

1. Future studies should incorporate additional hydrogeological factors, such as detailed geology or lithology layer to better capture subsurface characteristics, as these are critical factors controlling groundwater occurrence and storage.
2. Actual well yield data, groundwater levels, and pumping test results should be collected and used to validate GIS-based findings and strengthen the interpretation and reliability of groundwater potential zones.
3. Additional environmental variables, such as rainfall distribution and land use patterns, should be integrated into the analysis to provide a more comprehensive assessment of groundwater recharge processes.
4. A more localized analysis at the municipal level is recommended to provide site-specific insights that can support water resource planning and management.
5. Advanced spatial modeling techniques, such as the Analytical Hierarchy Process (AHP) or weighted overlay analysis, should be applied to determine the relative importance of each factor and to develop more accurate groundwater potential models.

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