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Geospatial Application on Mapping Groundwater Potential Zones in Samsun, Türkiye

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Abstract— ***Groundwater is a vital resource for sustaining human life and ecosystems, especially in arid and semi-arid regions. However, its availability is highly dependent on various factors such as climate, topography, and soil characteristics. Understanding the distribution and potential of groundwater is crucial for effective management and sustainable use of this resource. In this study, an interdisciplinary approach combining analytical hierarchical process, multiple influencing factor analysis, and geospatial techniques was used to evaluate groundwater potential in Samsun, Türkiye.***

The study area covers approximately 16,721km2 and is characterized by varying topography, soil types, and land use patterns. To determine the groundwater potential, we considered several influencing factors, including precipitation, slope, soil type, and drainage density. These factors were weighted using the analytical hierarchical process, which assigns values to each factor based on its relative importance in influencing groundwater potential. The multi-influencing factor analysis was then used to combine the weighted factors and generate a groundwater potential index, which was further classified into five zones: poor, moderate, high, very high, and extremely high.

The results show that the central and southern parts of the study area have the highest groundwater potential zones, attributed to their abundant precipitation and brown forest. This method can be useful for identifying recharge zones and managing water resources in different climate conditions.

Index Terms— ***AHP, GIS, Groundwater Potential Zone, Remote Sensing Thematic Layers, Samsun, Türkiye***

I. INTRODUCTION

Experts, strategists, and policymakers face significant challenges when it comes to monitoring groundwater reserves in densely populated areas dealing with water scarcity, particularly because of the impact of climate change on the quality of both surface and groundwater. The declining groundwater levels in various regions are causing a shortage of freshwater for agricultural and irrigation purposes, ultimately resulting in lower crop yields. Different approaches, such as statistical methods, expert assessments, and deterministic methods, can be utilized to determine groundwater potential zones. A widely adopted and trustworthy technique for delineating these zones is the groundwater potential index method (Al-Bakri et al., 2013; Agarwal et al., 2016; Rao, 2017; Gupta et al., 2018; Zanini et al., 2019; Gauthier et al., 2019; Ghosh et al., 2019; Ray, 2019; Gebrie and Getachew, 2019). Over the past few years, the significance of groundwater resources has heightened because of the escalating threat of climate change on water supplies. Climate change has become a prominent phenomenon in the modern world and has noticeably impacted various regions across the globe since the beginning of the twenty-first century. The Intergovernmental Panel on Climate Change (IPCC) reported in 2018 that global warming has risen by 1°C since pre-industrial times due to human activities, with projections indicating a potential increase to 1.5°C between 2030 and 2052. The potential impacts of climate change are a cause for concern, given the pivotal role of climate in regulating the hydrologic cycle, river flow rates, groundwater systems, freshwater availability, and the interconnected aspects of human life, migration patterns, and socio-economic conditions. Numerous studies have indicated a significant decrease in the flow of rivers in several regions globally, coinciding with a rising population that is placing greater strain on freshwater supplies. Regions at risk of water scarcity in the present and upcoming years will increasingly rely on existing groundwater reservoirs to meet their water needs (Bao et al., 2012; Givati et al., 2019)

Recognizing and assessing groundwater resources is crucial for increasing awareness at a local level and reducing potential losses resulting from water scarcity. Identifying areas with high groundwater potential has emerged as a critical focus globally and regionally. The exploration and assessment of groundwater quality typically involves costly methods such as geophysical surveys and borehole data analysis, which also demand significant time and human resources. To streamline this process and minimize expenses, geographical information systems (GIS) and remote sensing (RS) technologies are increasingly being utilized to integrate geographic data and facilitate the identification of groundwater potential zones (Patra et al., 2018; Şener et al., 2018; Murmu et al., 2019; Achu et al., 2020; Ajay Kumar et al., 2020; Lentswe and Molwalefhe, 2020).

Recent research utilizing a combination of GIS and RS technologies alongside multi-criteria decision-making (MCDM) methods has yielded highly positive outcomes in assessing groundwater potential in newly conducted studies (Arulbalaji et al., 2019; Qadir et al., 2020; Roy et al., 2020; Ahmad et al., 2020). The analytic hierarchy process (AHP) is commonly employed and widely regarded for its reliability in the assessment of groundwater potential (Adiat et al., 2012; Mohammadi-Behzad et al., 2019; Diaz-Alcaide and Martinez-Santos, 2019). Hence, the main goal of this study is to create a digital database and thematic maps that take into account a wide range of factors, including slope, lineament density, lithology, fault density, geomorphology, soil composition, land use, precipitation, and drainage density, all of which are known to impact groundwater potential. By integrating GIS and AHP methodologies, the study aims to identify and delineate groundwater potential zones in Samsun, Turkey.

II. METHODOLOGY

A. Study Area

Located on the coast of the Black Sea, Samsun is known for being the delta where the Yeşilırmak and Kızılırmak rivers meet the sea (Figure 1). It is situated between approximately 41°05' - 41°36' north latitude and 35°41' - 36°27' east longitude. The northern coast of Samsun is lined by the Black Sea. The study area experiences a temperate climate with an annual average precipitation ranging from 488 mm to 505 mm. The average temperature throughout the year is 14.6 °C. The aquifers in the study area are unconfined, with well depths ranging from 5 to 20 m, while the soil depth is approximately 1.5 m. Groundwater in the area is primarily utilized for irrigation and drinking purposes (Beden et al, 2023).

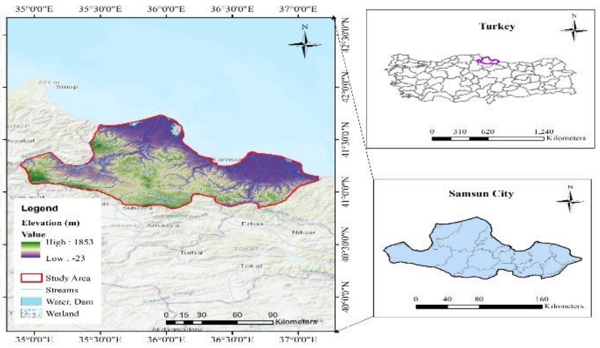

Figure 1. General view and location of the study area

B. Data set and sources for thematic layers

When you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables. The assessment of groundwater potential (GWP) in the research area involved utilizing a blend of RS, GIS and AHP. Various factors such as lithology, lineament density, slope, drainage density, precipitation, land use/land cover, and soil type were integrated for the evaluation. These layers were derived from geological and hydrogeological remote sensing information and processed using ArcMap 10.8.2 for further analysis (Pinto et al., 2017; Patra et al., 2018; Murmu, et al., 2019; Achu et al., 2020; Aykut, 2021; Moodley et al., 2022; Bhadran, et al., 2022; Yadav et al., 2023,).

Experts provided input and considered site-specific conditions to assign weights to the thematic layers and subclasses using the AHP. The methodology outlined by Saaty (1980) was followed to integrate AHP with RS and GIS techniques in this study to delineate Groundwater Potential Zones (GPZ).

Weights were determined by referencing pertinent information from existing literature sources. The GIS analysis incorporated remote sensing data to evaluate factors like precipitation patterns, land use/land cover types, lineament distributions, lithological characteristics, soil textures, lithological formations at the site, drainage density, slope variations, and availability of surface water resources.

These data sets were then contrasted with the current conditions at the study area.

In the process of demarcating GPZ utilizing the AHP, various geo-environmental data were utilized, including land use/land cover, lithology, soil characteristics, slope, lineament density, precipitation patterns, and drainage density. A map depicting land use/land cover types and landforms was generated using Landsat 8 OLI imagery. The land use/land cover types within the study area were obtained through unsupervised classification techniques, which were subsequently verified through ground-truth verification conducted on-site.

Precipitation data for the city of Samsun were acquired from the Turkish State Meteorological Service (MGM) spanning the period from 1967 to 2023. Soil data specific to the study site were sourced from the Ministry of Agriculture and Forestry of the Republic of Turkey.

The lithological map was constructed using the 1/50,000 geological map of Turkey obtained from the Institute of Mineral Research and Exploration (MTA). Through the utilization of a digital elevation model of Samsun city with a spatial resolution of 30 meters derived from the Shuttle Radar Topography Mission (STRM), the slope, Lineament density (LD), and drainage density (DD) maps were generated. The digital elevation models (DEMs) used in the study were sourced from the U.S. Geological Survey (USGS), with detailed information on data sources provided in Table 1. The preparation of thematic layers was carried out using ArcGIS 10.8.2.

Table 1. Detailed source of database.

Thematic layer	Sources
Lithology	Geological survey of Türkiye
Precipitation	MGM (1990-2023)
Soil	Ministry of Agriculture and Forestry of the Republic of Türkiye
Land use/ Landcover	Landsat 8 OLI USGS
Drainage Density	STRM DEM USGS 30 m
Lineament Density	STRM DEM USGS 30 m
Slope	STRM DEM USGS 30 m

C. Analytic Hierarchy Process (AHP)

The use of RS-GIS and AHP techniques in delineating groundwater potential zones in the study area has proven to be beneficial. This approach is particularly advantageous in situations where there is a lack of sufficient and high-quality data for conducting such assessments, and it also presents cost-effective advantages, especially in economically challenged developing nations.

The Saaty scale values (Table 2) consisted of nine points that were assigned to each map according to their individual levels of impact on groundwater potential.

Table 2. Degree of preferences for AHP pair comparison (Saaty, 1980)

Scales	Degree of preferences	Descriptions
1	Equally important	Both factors hold equal significance in terms of their contribution
3	Slightly important	Experiences and judgment show a slight inclination towards a specific factor
5	Quite important	Experiences and judgment significantly lean towards a specific factor
7	Extremely important	Experiences and judgment greatly favor a particular factor
9	Absolutely important	There is ample evidence that decisively supports leaning towards a specific factor
2, 4, 6, 8	Intermediate values	Values situated between two judgments indicate an intermediary stance

Relative importance values are evaluated based on Saaty's 1-9 scale. A rating of 1 on this scale suggests an even impact between thematic maps, while a rating of 9 signifies a strong dominance of one thematic map over the other.

The AHP is commonly utilized in MCDM analysis for tasks such as natural resource management, site selection, suitability analysis, and comparable applications (Das et al., 2019).

To check the consistency and uncertainty of the AHP method it used the consistency index value and consistency ratio for the method if the CR ratio value is less or equal than 0.1 then the process is acceptable otherwise the AHP should be revised. CI and CR can be obtained by following equations.

$$CR = \frac{CI}{RI} \tag{1}$$

where "CR" is the consistency ratio, "CI" is the consistency index, and "RI" is a random index which this value depends on the number of thematic layers. The CI can be calculated by Equation (2) (Saaty, 1988).

$$CI = \frac{\lambda - n}{n-1} \tag{2}$$

where "n" is the number of thematic layers, and λ is the average eigenvalue of the consistency vector. The RI value depends upon the number of thematic layers which involved for GPZ map. According to (Saaty, 1988), the RI value for "n=7" is 1.32. Table 3 shows the RI ratio for n thematic layers.

Table 3. RI values for different number of thematic layers (Saaty, 1980)

N	RI	N	RI	N	RI
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

The connection among the seven thematic layers was established through the MCDM process to calculate the relative importance of each thematic layer for GPZ (Pinto et al., 2017).

By applying these importance values, it generates the pairwise comparison matrices which give us the weight of each thematic layer.

Throughout this procedure, relative weights of individual thematic layers calculated using AHP were linked to corresponding thematic maps within ArcGIS. Cumulative weights for each thematic map were computed, and the map displaying the highest or lowest weight was determined based on field conditions and its influence on groundwater potential. The summary comprised normalized and assigned weights for attributes across various thematic layers, alongside consistency ratios for thematic maps. Combining the seven thematic maps in GIS ArcMap 10.8.2 led to the development of an overall groundwater influencing factor, culminating in the generation of the groundwater potential map (GPM) for the specified study area. These seven thematic layers are precipitation, soil texture, lithology, land use/land cover, lineament density, drainage density, slope.

Table 4. Weight of each thematic layer which given by pairwise comparison matrix

Matrix		P	L	SL	DD	LULC	LD	S	NW
		1	2	3	4	5	6	7	
P	1	1	3	5	3	5	5	9	38.3%
L	2	1/3	1	5	3	3	5	7	25.7%
SL	3	1/5	1/5	1	1	3	1	5	9.6%
DD	4	1/3	1/3	1	1	3	1	5	10.7%
LULC	5	1/5	1/3	1/3	1/3	1	1	3	5.9%
LD	6	1/5	1/5	1	1	1	1	3	7.3%
S	7	1/9	1/7	1/5	1/5	1/3	1/3	1	2.6%
Consistency ratio (CR) 0.06									

D. Thematic Layers

Precipitation

Precipitation influenced the recharge of groundwater storage significantly, as it directed the volume of water available for infiltration into the groundwater storage system. Increased precipitation in a specific area corresponds to greater potential for recharge for groundwater in the area (Machiwal et al., 2011; Murmu, et al., 2019). It is essential to determine the characteristics and volume of precipitation for the calculation of a groundwater potential for and area. Precipitation data for the 1967-2023 period were used for the precipitation distribution on the area by using inverse distance weight (IDW) interpolation method.

Higher groundwater potential is likely when precipitation is numerous in the area, and it reduce with lower precipitation levels. precipitation exhibits variations not only spatially but also temporally. Consequently, assessing and study the impact of precipitation is essential for identifying the GPZ (Patra et al., 2018).

The infiltration rate in each area is impacted by the characteristics of precipitation, including its intensity and duration. Precipitation events characterized by high intensity, but short duration tend to produce increased surface runoff and reduced infiltration, whereas longer-duration precipitation with lower intensity typically encourages greater infiltration over runoff (Biswas et al., 2020).

In the present study in result, the precipitation map was created by implementing the IDW technique for obtaining data in GIS by extracting the annual average precipitation for the study area.

By utilizing data from ten meteorological observation stations, a precipitation map was constructed through interpolation. Annual precipitation in the study region varies between 715.8 mm and 1182 mm. The precipitation map is categorized into five main groups based on annual precipitation levels ranging from 715.8–800, 800.1–900, 900.1–1000, 1000.1–1100, to 1100.1–1182 mm per year. In this research, areas characterized by steeper slopes tend to receive higher annual precipitation amounts compared to those with gentler slopes. The annual precipitation map for the study area is illustrated in Figure 2.

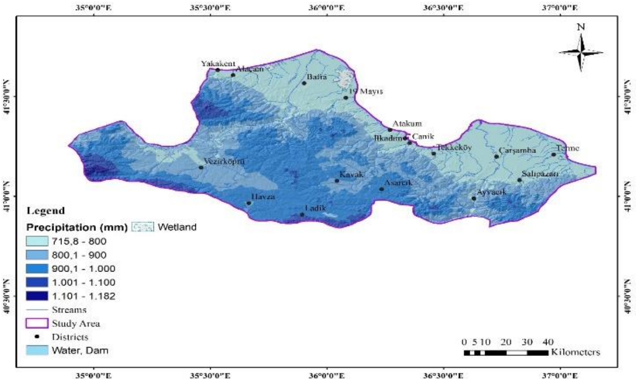

Figure 2. Annual precipitation map for the study area

Soil Texture

The soil composition of a site is pivotal in determining the presence of groundwater, as it directly impacts the rate at which water can infiltrate the ground. Soil texture, which is the uppermost layer of the Earth, has a significant influence on how surface water can penetrate an aquifer system. The specific characteristics of this layer play a crucial role in regulating the amount of recharge water that can seep into the ground, affecting rates of infiltration, percolation, and permeability (Jasrotia et al., 2016).

In the study area, the soil composition consists of a variety of types, including brown forest, podzolic, colluvial, alluvial, and hydromorphic soils, characterized by different pore sizes and formations. These soils are primarily derived from sandy loam, sandy clay loam, and clay loam, each with varying rates of infiltration. In terms of soil type, formation, and slope, hydromorphic soil, with its sandy loam composition and high infiltration rate, was given the highest priority, while brown forest and podzolic soils, with their more sloping formations and composition of clay loam and sandy clay resulting in lower infiltration rates, were assigned lower weights in the analysis among these soil types. In the present study area, most of the area are covered by brown forest and podzolic soils as shown in the Figure 3.

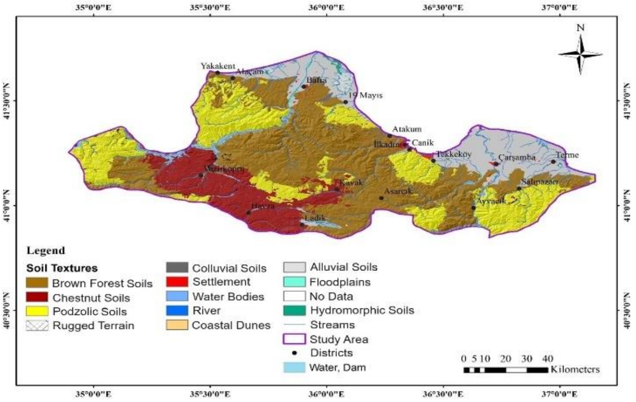

Figure 3. Soil map for the study area

Lithology

The lithological map shows the formation groups of the earth in the study area. Geology impacts groundwater fluxes and is a recommended factor in studies related to GPM (Misi et al., 2018).

The process of water recharge is influenced by various factors such as geology, lithological structure, and rock characteristics at outcrops, as well as topography, slope, and soil composition. The lithological structures within the study area are classified into fourteen different classes, including Sand, Silt, Clay, Admixture sand (alluvium), Andesite-Basalt, Wetland, Limestone, Sand, andesite-basalt, wetland, limestone, water body, volcanic sediment, and Conglomerate Sandstone, each playing a distinct role in the recharge of water resources.

The lithological formation data obtained from the site was transformed into a raster layer utilizing the "feature to raster" tool within ArcMap 10.8.2. This raster layer was then resampled to a cell size of 10 by 10 meters to ensure compatibility and uniformity. The resulting lithological map of the study area can be observed in Figure 4.

Most of the study area site are formed from Conglomerate-Sandstone which located in the center of the city on the other hand the southern east part of the study are has andesite basalt structure, while the northern part of the study area has alluvion lithological structure.

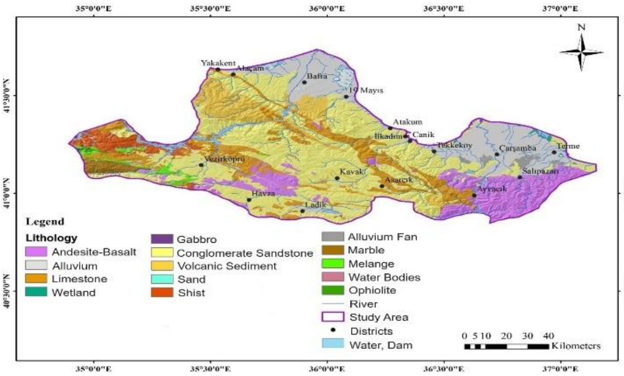

Figure 4. Lithology map of the study area

Land Use/Land Cover

The relationship between land use and land cover plays a vital role in groundwater recharge, affecting factors such as evapotranspiration, surface runoff, and infiltration rates, as highlighted by Misi et al. (2018). According to Martin et al. (2017), the Land Use/Land Cover (LULC) map provides valuable information on the region's topography and various land use categories, offering insights into how they impact the hydrological cycle and groundwater resources.

Within the study area, the predominant land use/land cover types include forested areas, agricultural plantations (such as rice fields, and orchards), natural grasslands, heathlands, seasonal croplands, scrublands, fallow land, built-up areas, waterlogged areas, as well as water bodies. These diverse land cover types contribute to the overall landscape composition and play a significant role in influencing various environmental processes.

Research conducted by Shaban et al. (2019) revealed that vegetation cover plays a crucial role in facilitating groundwater recharge by decomposing roots biologically, thereby creating pathways for water percolation through the loosened rock and soil in a given area. Furthermore, vegetation serves to mitigate direct water evaporation from the soil surface, while plant roots actively absorb water, effectively reducing overall water loss within the ecosystem.

There are fifteen major types of LULC in the study area which, the southern part of the study area is mountains area which covered by forest with high slope and brown forest soil type, with high amount of average annual precipitation. While the northern part of the city consists of agricultural land with built up areas. Table 5 shows the LULC types and categories with their areas and percentage.

Table 5. LULC types and categories with their area and percentage

ID	LULC category and class	Area (km^2)	Percentage
1	Wetland	98.214696	1.03
2	Rugged Terrain	0.25196	0.00
3	Grassland	169.359347	1.77
4	Moor	409.68837	4.30
5	Sand Dunes	26.324971	0.27
6	Mining Zone	4.996339	0.05
7	Pastureland	87.377234	0.91
8	Orchards	620.217979	6.51
9	Forest	3146.058371	33.03
10	Rice Fields	39.067859	0.41
11	Industrial Zone	19.697769	0.20
12	Sparse Vegetation	145.676465	1.52
13	Water Bodies	225.637458	2.36
14	Agricultural Zone	4364.410429	45.82
15	Settlement	167.735374	1.76

For this study, soil characteristic datasets specific to Türkiye were brought into ArcMap 10.8.2 for analysis. The study area was then delineated and segmented into distinct classes based on assigned grid codes. The classification process unveiled that a significant portion of the study area predominantly comprises agricultural plantations, crop lands, and forested areas, as visually represented in Figure 5.

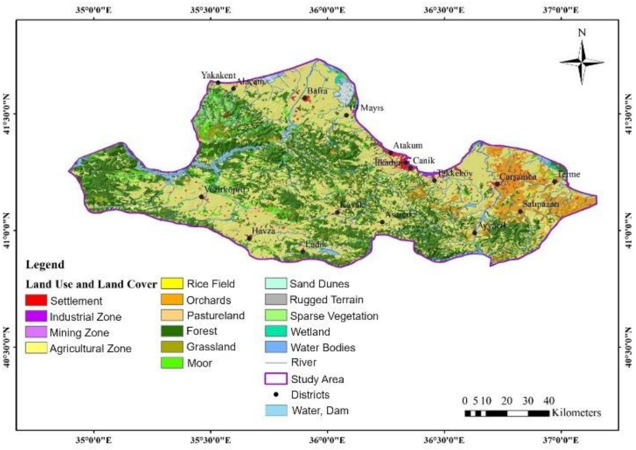

Figure 5. Land use/Land Cover map for the study area

Lineament Density

Lineaments are linear or curvilinear features of the surface of the site that are structurally controlled, discerned in satellite imagery through their distinct linear alignments. They delineate areas of faulting and fracturing, leading to increased secondary porosity and permeability, which establish pathways for groundwater flow and hold significant hydro-geological importance (Sar et al., 2015).

The density of lineaments in a certain region can directly reflect its groundwater potential, as a higher density often indicates the presence of permeable zones. Regions characterized by high lineament density are generally deemed favorable for groundwater potential. Conversely, areas with low lineament density typically exhibit lower groundwater potential (Haridas et al., 1998).

In this study, the LD map was generated using the DEM of the area in the ArcMap 10.8.2 environment. This process involved generating hillside maps of the site at multiple resolutions, including 345-45, 200-50, 100-60, and 90-50. The LD values were then categorized into five density levels, spanning from 0 to 0.378, 0.379 to 0.757, 0.758 to 1.136, 1.137 to 1.514, and finally 1.515 to 1.893 km/km², as illustrated in Figure 6.

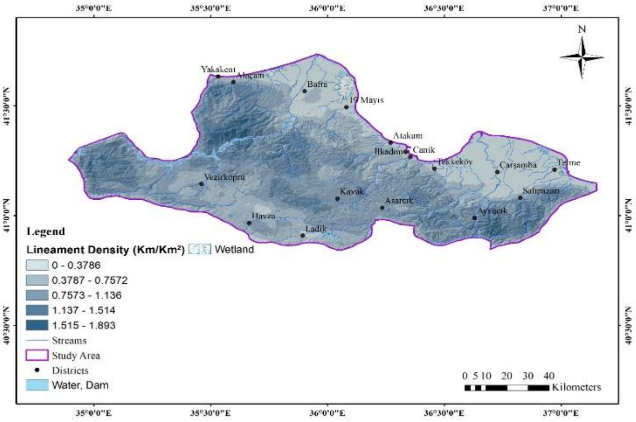

Figure 6. Lineament density map for the study area

Drainage Density

Drainage density, a significant factor of hydrological features, impacts groundwater potential. According to Şener et al. (2018), areas with high drainage density have lower groundwater potential, while those with low DD experience higher GWP. Additionally, Magesh et al. (2012) noted that drainage density has an inverse relationship with water permeability, with less permeable rock leading to less infiltration and higher surface runoff in areas with high drainage density. The calculation of drainage density involves the sum of all streamlines per total area of the study. In the current study, the researchers utilized a DEM and ArcMap's hydrology tools to plot site drainage density, defining it for the study area by analyzing the stream network's line density.

For the present study the DD was classified into five categories as from 16.7- 91.6, 91.7- 167, 168- 241, 242- 316 and 317- 391 Km/Km^2). Figure 7 shows the DD map for the study area.

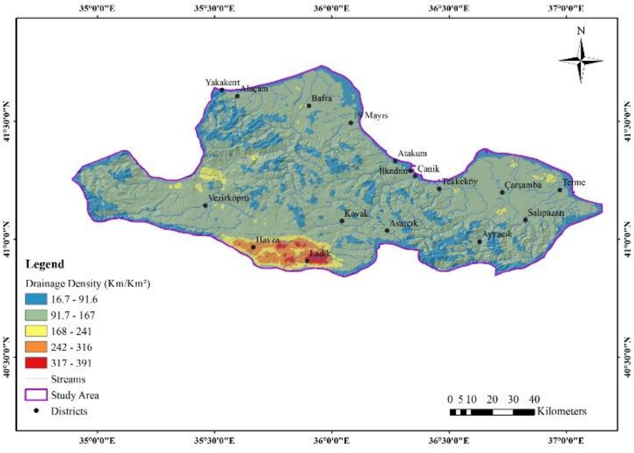

Figure 7. Drainage density map for the study area

Slope

Slope gradient, another critical factor affecting GPZ, plays a crucial role in determining the GPZ of a study area and directly impacts the infiltration rate of surface water into the groundwater. Lower slope angles correspond to flatter terrain, while higher slope values indicate steeper terrain. According to Bera et al. (2020), steep slopes act inversely regarding recharge potential as water flows rapidly downhill, reducing the time for rainwater to soak into the ground. In contrast, lower slope angles allow rainwater to infiltrate and remain on the ground for extended periods, facilitating groundwater recharge.

The study utilized a DEM to create a slope map of the research area. The study area was divided into five slope classes, with the lower-class exhibiting slope angles of 0-5.59 degrees, resulting in high infiltration rates. The highest slope class, with slope angles ranging from 28.92 to 79.26 degrees, contributes to high runoff and low infiltration rates due to the minimal retention time. Figure 8 illustrates the slope map of the study area.

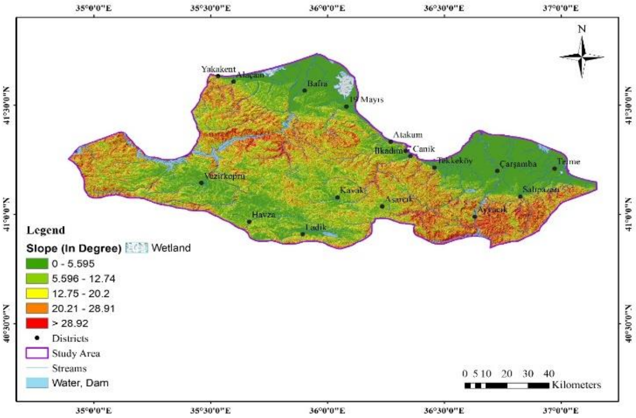

Figure 8. Slope map for the study area

III. FINDINGS AND DISCUSSION

Implementing GPZ for the study area involved using a pairwise comparison matrix based on input thematic layers. Each thematic layer was assessed according to the importance scale proposed by Saaty, ranging from 1 to 9. In this study, annual precipitation emerged as the most critical thematic layer, with a normalized weight of 38.3%. Since precipitation plays a significant role in recharging groundwater, the high annual precipitation in the study area was instrumental in mapping the GPZ.

Following annual precipitation, lithology was identified as the second highest-ranked thematic layer, with a weight of 25.7% impacting the groundwater potential of the study area. The importance of lithology was determined based on its influence on the recharge of precipitation water into the groundwater, as noted by Lentswe and Molwalefhe (2020). In contrast, the soil thematic layer had the lowest weighted influence on the study area, accounting for only 2.6% of the groundwater potential.

Table 6 summarizes the normalized weights for the thematic layers and sub-layers, providing a comprehensive overview of the factors influencing the groundwater potential zones in the study area.

Table 6. Normalized weight of each thematic layer with their sub-classes.

No	Thematic Layer	Normalized Weights	Classes	Rank
1	Precipitation		715.8–800	1
			800.1–900	3
			900.1–1000	5
			1000.1–1100	7
			1100.1–1182	9
2	Land use / Land cover		Settlement	1
			Industrial zone	1
			Mining zone	3
			Agricultural zone	5
			Rice field	9
			Orchard	7
			Pastureland	5
			Forest	7
			Grassland	7
			Moor	5
			Sand Dunes	5
			Rugged Terrain	5
			Sparse Vegetation	3
			Wetlands	3
			Water Bodies	9
3	Lithology		Andesite-Basalt	5
			Alluvium	3
			Limestone	3
			Wetland	3
			Gabbro	5
			Conglomerate Sandstone	1
			Volcanic Sediment	1
			Sand	3
			Shist	1
			Alluvium Fan	3
			Marble	1
			Melange	1
			Water Bodies	7
			Ophiolite	3
4	Lineament density		0–0.378	1
			0.378–0.757	3
			0.0.757–1.136	5
			1.137–1.514	7
			1.514–1.893	9
5	Slope		0–5.595	9
			5.596–12.74	7
			12.75–20.2	5
			20.21–28.91	3
			> 28.92	1
6	Drainage density		16.7–91.6	9
			91.7–167	7
			168–241	5
			242–316	3
			317–391	1
7	Soil type		Brown Forest Soils	7
			Chestnut Soils	5
			Podzolic Soils	3
			Rugged Terrain	5
			Colluvial Soils	3
			Settlement	5
			Water Bodies	9
			River	3
			Sand Dunes	1
			Alluvial Soils	3

Floodplains	3
No Data	1
Hydromorphic Soils	3

Using remote sensing and GIS techniques, a groundwater potential map was created by applying normalized weights to each thematic layer. Through pairwise comparison matrices, each thematic layer was assigned a weight, and the sub-criteria of each layer were also assessed for their importance in determining GPZ for the study site. The cumulative weights of the thematic layers and sub-layers were analyzed using the weighted overlay method within the ArcGIS environment, resulting in the generation of a raster map illustrating the groundwater potential zones of the study area.

The groundwater potential zones were subsequently classified into five distinct categories: poor, moderate, high, very high, and extremely high levels of groundwater potential. The groundwater potential zones map for the study area, displaying these categories, can be observed in Figure 9.

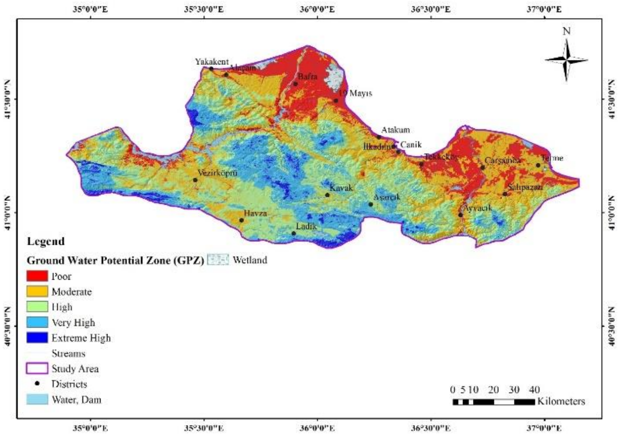

Figure 9. GPZ map for study area

The north part of the study area is designated as the poor GWP, characterized by lower annual precipitation and a loamy soil type with reduced infiltration rates compared to other regions within the study area. In contrast, the central and southern parts exhibit the highest groundwater potential zones, attributed to abundant precipitation and brown forest soil, which significantly impact infiltration rates.

The moderate zone encompasses 5036.34 km^2, representing 30.08% of the total study area, while the high GPZ covers 5145.82 km^2. Additionally, the very high and extremely high zones span 3243.09 km^2 and 519.62 km^2, respectively, of the total study area. The poor GPZ was identified to cover 2796.95 km^2, amounting to 16.70% of the total area.

Overall, the cumulative areas of high, very high, and extremely high GPZ account for 53.23% of the total study area, indicating significant groundwater potential throughout the region. Table 7 provides a detailed classification of the GPZ in the study area, including area coverage and percentage breakdown.

Table 7. Classification of GPZ with the percentage and area of each zone

Groundwater Potential	Percentage Area Coverage (%)	Area (km^2)
Poor	16.70	2796.95
Moderate	30.08	5036.34
High	30.73	5145.82
Very high	19.37	3243.09
Extreme High	3.10	519.62

IV. CONCLUSION

The study aimed to identify the groundwater potential zone in the Samsun city area of Turkey by utilizing various thematic layers, including precipitation, lithology, LULC, DD, LD, soil types, and slope.

The study utilized GIS and RS techniques and applied the AHP method, which was the most effective for identifying GPZ in the study area. This method was shown to help minimize time and costs while facilitating decision-making on groundwater management.

DEM, topographic maps and Landsat imagers were used for mapping the thematic layers for the study area. These thematic layers were assigned and weighted through the AHP method and was integrated in the GIS environment by applying the weighted overlay method for groundwater potential zone map of the study area.

The GPZ map was categorized into five zones from poor to extreme high zone of groundwater potential and from the GPZ map it was indicated that 53.23% of the total area have very good and extreme good potential of groundwater and can be said the overall study area has good GPZ.

This method gives satisfactory information for the GPZ and can be used widely for finding the recharge zone of groundwater and management of water resources for different parts of the world in different climate condition.

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