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HASAN KALYONCU UNIVERSITY  
GRADUATE EDUCATION INSTITUTE  
DEPARTMENT OF CIVIL ENGINEERING**



**USE OF GEOGRAPHICAL INFORMATION SYSTEM FOR THE EVALUATION OF  
SOME GEOTECHNICAL PROPERTIES IN SANLIURFA, TÜRKİYE**

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**M.Sc. THESIS  
IN  
CIVIL ENGINEERING**

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Geotechnical Properties in Sanliurfa, Türkiye**

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**by**

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**GRADUATE EDUCATION INSTITUTE  
MASTER'S THESIS ACCEPTANCE AND APPROVAL FORM**

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Sabira DAG

06.11.2023

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GRADUATE EDUCATION INSTITUTE  
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**Sabira DAG**

**MASTER THESIS**

**Supervisor  
Assist. Prof. Dr. Nurullah AKBULUT**

**ABSTRACT**

Geographic Information Systems (GIS) is a database that offers functions such as analyzing geographic data, querying, statistical analysis, visualization, and spatial analysis. GIS is an important tool for zoning and settlement planning, allowing for more effective examination, research, interpretation, conclusion, and data planning. In this thesis, the goal is to minimize soil-related risks using databases and geotechnical maps created with GIS. The study utilizes geotechnical survey reports, field and laboratory test results obtained from the archives of the Şanlıurfa Municipality Directorate of Planning and Urbanization. Geographical information system methods were used to analyze geological, geophysical, and geotechnical data from 535 drilling points within the borders of Şanlıurfa Central District. Soil properties were examined in different regions of the study area, focusing on rock quality designation (RQD), compression ( $V_p$ ) and shear wave ( $V_s$ ) velocities, poisson ratio ( $\nu$ ), seismic velocity ratio ( $V_p/V_s$ ), unconfined compression strength (UCS), density ( $\rho$ ), maximum shear modulus ( $G_{max}$ ), dynamic elastic modulus ( $E_d$ ), and bulk modulus ( $K$ ). Maps of the study area were created using the Inverse Distance Weighted Method (IDW) and the ArcGIS software, enabling more effective and efficient use of geotechnical data in engineering studies. The study shows that the neighborhoods of Çamlıyayla, Direkli, and Ahmet Yesevi have high rock quality designation, reaching up to 19.71%. The soil density in the central district of Şanlıurfa varies between 1.67 and 2.03 g/cm<sup>3</sup>. The lowest shear wave velocity values are found in the western part of the study area and in Atakent, Çamlıyayla, and Güllübağ neighborhoods, ranging from 469 to 721 m/sec. The  $V_p/V_s$  ratio in the southeastern part of Şanlıurfa's central district, particularly in Direkli and Ahmet Yesevi neighborhoods, ranges from 1.83 to 2.12. Unconfined compression strength throughout the central district of Şanlıurfa varies between 1.66 MPa and 10.29 MPa. The study highlights the high rock strength in the southeastern region, with the eastern region exhibiting very high rock strength.

**Key Words:** Şanlıurfa, geotechnics, shear wave velocity, unconfined compression strength, GIS, mapping.

**HASAN KALYONCU ÜNİVERSİTESİ**  
**LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ**  
**İNŞAAT MÜHENDİSLİĞİ BÖLÜMÜ**

**SANLIURFA'DAKİ ZEMİNLERİN GEOTEKNİK ÖZELLİKLERİNİN**  
**COĞRAFI BİLGİ SİSTEMİ İLE DEĞERLENDİRİLMESİ**

**Sabira DAG**

**YÜKSEK LİSANS TEZİ**

**Danışman**  
**Dr. Öğr. Üyesi Nurullah AKBULUT**

**ÖZET**

Coğrafi Bilgi Sistemleri (CBS), coğrafi veri analizi, sorgulama, istatistiksel analiz, görselleştirme ve mekânsal analiz gibi işlevleri sunan bir veritabanıdır. Zonlama ve yerleşim planlaması için önemli bir araç olan CBS, daha etkili inceleme, araştırma, yorumlama, sonuç çıkarma ve veri planlama imkânı sağlar. Bu tez çalışmasında, CBS kullanılarak oluşturulan veritabanları ve geoteknik haritalar ile zeminle ilişkili riskleri minimize etme amaçlanmıştır. Çalışma, Şanlıurfa Belediyesi Planlama ve Kentsel Dönüşüm Müdürlüğü arşivlerinden elde edilen geoteknik inceleme raporları ile arazi ve laboratuvar deney sonuçları kullanılmıştır. Coğrafi bilgi sistemleri yöntemleri, Şanlıurfa Merkez İlçesi sınırları içinde bulunan 535 sondaj noktasından elde edilen jeolojik, jeofizik ve geoteknik verileri analiz etmek için kullanılmıştır. Çalışma alanının farklı bölgelerinde zemin özellikleri incelenmiş olup, özellikle kaya kalitesi (RQD), basınç (Vp) ve kayma (Vs) dalgası hızları, poisson oranı ( $\nu$ ), sismik hız oranı (Vp/Vs), tek eksenli basınç dayanımı (UCS), yoğunluk ( $\rho$ ), maksimum kayma modülü (Gmax), dinamik elastik modül (Ed) ve hacimsel modül (K) üzerine odaklanılmıştır. Çalışma alanının haritaları, Ters Mesafe Ağırlıklı Yöntem (IDW) ve ArcGIS yazılımı kullanılarak oluşturulmuş, geoteknik verilerin mühendislik çalışmalarında daha etkili ve verimli bir şekilde kullanılmasını sağlamıştır. Araştırma, Çamlıyayla, Direkli ve Ahmet Yesevi mahallelerinin yüksek kaya kalitesine (19,71%) sahip olduğunu göstermektedir. Şanlıurfa Merkez İlçesi'nde zemin yoğunluğu 1,67 ile 2,03 g/cm<sup>3</sup> arasında değişmektedir. Çalışma alanının batı kısmında ve Atakent, Çamlıyayla ve Güllübağ mahallelerinde en düşük kayma hızı değerleri, 469 ile 721 m/sn arasında bulunmaktadır. Şanlıurfa Merkez İlçesi'nin güneydoğusunda, özellikle Direkli ve Ahmet Yesevi mahallelerinde Vp/Vs oranı 1,83 ile 2,12 arasında değişmektedir. Şanlıurfa Merkez İlçesi'nde tek eksenli basınç dayanımı 1,66 MPa ile 10,29 MPa arasında değişmektedir. Araştırma, çalışma alanının güneydoğu bölgesinde yüksek kaya dayanımını vurgularken, doğu bölgesinin ise çok yüksek kaya dayanımına sahip olduğunu göstermektedir.

**Anahtar Kelimeler:** Şanlıurfa, geoteknik, kayma dalgası hızı, tek eksenli basınç dayanımı, CBS, haritalandırma.



*My precious family ....*

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I hope this thesis will serve as a valuable resource for engineers, geotechnical experts and project stakeholders involved in similar projects and help them make informed decisions about soil improvement strategies.

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## ABBREVIATIONS OR SYMBOLS LIST

<b>AASHTO</b>	American Association of State Highway and Transportation Officials
<b>ASTM</b>	American Society for Testing and Materials
<b>Ed</b>	Dynamic Elastic Modulus
<b>FEMA</b>	Federal Emergency Management Agency
<b>G<sub>max</sub></b>	Maximum Shear Modulus
<b>GIS</b>	Geographic Information System
<b>IDW</b>	Inverse Distance Weighting
<b>K</b>	Bulk Modulus
<b>KRDAE</b>	Kandilli Observatory and Earthquake Research Institute
<b>NESEP</b>	National Earthquake Strategy and Action Plan
<b>RQD</b>	Rock Quality Designation
<b>SPT</b>	Standard Penetration Test
<b>SYMAP</b>	Synagraphic Mapping System
<b>UCS</b>	Unconfined Compression Strength
<b>USCS</b>	Unified Soil Classification System
<b>UDAP</b>	National Earthquake Research Programme
<b>V<sub>p</sub></b>	Compression Wave Velocity (m/sec)
<b>V<sub>p</sub>/V<sub>s</sub></b>	Seismic Velocity Ratio
<b>V<sub>s</sub></b>	Shear Wave Velocity (m/sec)
<b>V<sub>s,30</sub></b>	Average Shear Wave Velocity at 30 m Depth
<b>W</b>	Water Content Value
<b>W<sub>s</sub></b>	Shrinkage Limit
<b>M</b>	Poisson Ratio
<b>Σ</b>	Stress (kN/m <sup>2</sup> )

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1. General**

Geotechnical Engineering emphasizes the need for precise identification and appraisal of soil parameters because engineering structures come in direct contact with soil. These parameters play a crucial role in determining the dependability and cost-effectiveness of engineering structures. Although our knowledge about soil is restricted, and we cannot fully govern its behavior. Therefore, accurate evaluation of soil properties is essential to ensure successful construction and design of engineering structures. (Shaik, 2007).

The rise in the world's population has directly impacted the growth of construction activity. This growth has created an urgent necessity for building more structures such as tall buildings, dams, ports, and bridges. This only amplifies how significant it is to identify soil properties and study its behavior, as this is a crucial stage in any construction project.

Soil properties are ascertained through field tests, laboratory tests, and geophysical methods. Each method has its own merits and limitations when it comes to determining soil properties. Thus, there are both advantages and disadvantages associated with using field and laboratory test methods for this purpose. Consequently, the most suitable approach to determining soil parameters is to analyze the results from all three test methods collectively (Íyisan, 1994).

Geotechnical engineering employs a range of techniques in the field to assess soil properties. Disturbed and undisturbed soil samples are taken as part of these methods. Undisturbed samples are collected directly from the field. However, even in the case of undisturbed soil sampling and subsequent laboratory testing, some level of disturbance may still occur. These samples undergo various tests in the laboratory to gather information about soil properties. Sampling in cohesive soils is relatively uncomplicated, whereas sampling in non-cohesive soils can be more expensive since it requires specialized techniques and equipment. Consequently, geophysical methods are also utilized when it is not always feasible to obtain desired samples for every soil type. (Íyisan, 1994).

Geophysical methods are utilized to gather data on the internal composition of soils by measuring their electrical and magnetic properties using field instruments. These methods offer a cost-effective and environmentally friendly alternative, as they provide quick results without requiring soil sampling. However, their sensitivity is lower in comparison to field and laboratory testing methods and can be influenced by field conditions. It is important to note that the accuracy of results obtained through geophysical methods is also lower than those obtained from laboratory-tested soil samples. (İyisan, 1994).

The purpose of this investigation is to demonstrate that soil properties garnered through laboratory tests, field tests, and geotechnical engineering can be utilized more efficiently in soil engineering. Geographic Information System (GIS) aids in visualizing and managing the data collected on soil properties in maps, enhancing comprehension. As a result, quick evaluation of soil properties can be helpful in construction projects, guaranteeing their optimal utilization and efficacy.

As a result, GIS technology provides a considerable advantage in maximizing the effectiveness and efficiency of soil engineering. It enables us to assess soil properties with ease at any location within our workspace, while also seamlessly integrating supplementary data into the maps created. This contributes to time, labor, and cost savings during construction projects. The aim of this research is to build a database by compiling soil properties parameters using GIS technology.

## **1.2. Aim of the Study**

In this study, The Sanliurfa Municipality conducted a study to assess various aspects of soil properties including general information such as geographical location, geological characteristics and seismicity of the study area are also given. The methods included Rock Quality Designation (RQD), Compression ( $V_p$ ) and Shear Wave ( $V_s$ ) Velocity, Poisson's Ratio ( $\nu$ ), Seismic Velocity Ratio ( $V_p/V_s$ ), Unconfined Compression Strength, Density ( $\rho$ ), Maximum Shear Modulus ( $G_{max}$ ), Dynamic Elasticity Module ( $E_d$ ), Bulk Module ( $K$ ). The data obtained from these investigations were transferred to digital format and compiled into a database specific to the study area. This database was then utilized to create digital maps for diverse purposes.

In this context, the utilization of ArcGIS software has facilitated the implementation of geographic information systems in geotechnical engineering. The

objective is to enhance the effectiveness and efficiency of using geotechnical data in engineering studies.

### **1.3. Outline of the Thesis**

**Chapter 1 - Introduction:** This chapter examines the techniques utilized for evaluating soil properties, highlighting the differences and similarities between them. It further delves into the merits, drawbacks, and transferability of results to GIS with regards to the employed soil property evaluation methods.

**Chapter 2 - Literature review:** In this chapter, information about GIS is given and previous studies with GIS system are presented.

**Chapter 3 - Materials and Methods:** In this chapter, the methods used are described in detail. In addition, general information such as geographical location, geological characteristics and seismicity of the study area are also given. The methods included Rock Quality Designation (RQD), Compression ( $V_p$ ) and Shear Wave ( $V_s$ ) Velocity, Poisson's Ratio ( $\nu$ ), Seismic Velocity Ratio ( $V_p/V_s$ ), Unconfined Compression Strength, Density ( $\rho$ ), Maximum Shear Modulus ( $G_{max}$ ), Dynamic Elasticity Module ( $E_d$ ), Bulk Module ( $K$ ).

**Chapter 4 - Results and Discussion:** In this chapter, the maps and graphs created within the scope of the research are evaluated and discussed.

**Chapter 5 - Conclusions and Recommendations:** The thesis is followed by a conclusion and recommendations.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1. General**

This chapter focuses on earlier studies that utilized Geographical Information System (GIS) and outlines the primary traits of the research site, namely its geographical position, geological features, and seismic activity. Moreover, it provides comprehensive information relating to GIS.

#### **2.2. Geographic Information Systems**

##### **2.2.1. Definition of geographical information systems**

The progress in technology has made it possible to store data in digital spaces, which has resulted in the development of data and information management systems known as "information systems." These systems have the task of methodically collecting, processing, and changing data into valuable information. In doing so, their objective is to expedite and simplify the procedure of decision-making. (Yomralioğlu, 2000).

GIS is a computerized information system capable of processing location-based digital data. (Singh & Fiorentino, 2013).

Different fields may have diverse applications and definitions for Geographic Information Systems (GIS). Generally, though, GIS refers to software that facilitates the gathering, examination, modeling, and visualization of geographically linked data. These systems are created to tackle intricate planning and management challenges and have garnered considerable attention across various industries in recent times. (Töreya et al., 2010).

##### **2.2.2. Historical development of the geographical information system**

The development of Geographic Information Systems (GIS) can be traced back to the recognition of people's requirements for visual tools like thematic maps and graphics. In the 18th and 19th centuries, innovative efforts were undertaken in various geographic areas to address distinct issues. These endeavors are regarded as the initial investigations in the realm of GIS.

Illustrative instances encompass the Yorktown Battle Movement Map, created by Louis-Alexandre Bertheir in 1781, the France Population Density and Crime Maps

crafted by Charles Dupin in 1819, and John Snow's 1854 London Cholera Outbreak-Water Source Relationship Map. Similarly, John Snow plotted the positions of cholera fatalities and water pumps in London and made the observation that the majority of cholera-related deaths transpired in households supplied by the Broad Street pump. Taking action, he discontinued the use of the pump, thus preventing the further spread of the cholera epidemic. (Çabuk 2015; Uyguçgil 2011; Vinten-Johansen et al. 2003).

Between the years 1958 and 1961, the groundwork for Geographic Information Systems (GIS) was initiated through a computer-based research program in the Department of Geography, University of Washington, to expedite data retrieval. In 1963, Roger Tomlinson established the Canadian Geographic Information System with two primary goals: firstly, to stockpile and scrutinize Canada's land-based data inventory, and secondly, to produce statistical data applicable in plans for land management. (Çabuk 2015).

The initial mapping program, known as Synagraphic Mapping System (SYMAP), came into existence in a laboratory at Harvard University in 1965. SYMAP gained global popularity and remained widely utilized until the 1990s. Presently, various GIS software programs have been created, with ArcGIS standing out as the most extensively employed. ArcGIS was developed by Environmental Systems Research Institute, a nonprofit organization established in Redlands, California in 1969. (Coppock & Rhind, 1991).

### **2.2.3. Advantages of GIS**

With the progress of computing technology, Geographic Information Systems (GIS) tools have undergone enhancements. Previously time-consuming processes such as layer overlay methods and map production have now become faster and more efficient thanks to computer software. GIS finds applications across various sectors, contributing to decision-making processes and serving as a valuable tool for problem-solving and enhancing different domains. Consequently, GIS is employed not only in planning but also in diverse fields including environmental protection, agriculture, cultural heritage, mapping engineering, geology, earth sciences, sociology, and logistics. (Özcan et al., 2021).

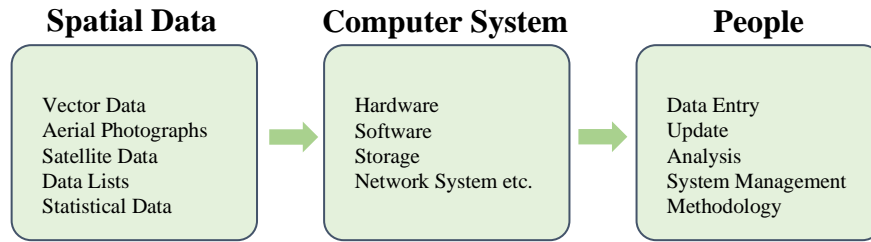
Geographic Information Systems (GIS) provide a wide range of benefits to users across various domains. These benefits encompass the following key features:

1. GIS streamlines the procedures involved in gathering and studying data by easing the task of data collection, storage, analysis, and visualization.

2. GIS aids decision-making by facilitating the analysis and visualization of data, serving as a valuable tool in decision support systems.
3. GIS enables quick and convenient data accessibility, allowing for easy data updates, consequently enhancing overall data accessibility levels.
4. Thanks to the electronic storage and analysis of data, it accelerates workflows by increasing time and cost efficiency.
5. GIS can be adjusted and tailored to suit distinct requirements in various fields, effectively boosting its flexibility.
6. By allowing for data sharing and cooperation, GIS promotes collaboration across multiple departments and organizations.
7. It enables the integration of different data sources and multi-source data analysis.
8. Provides accurate and up-to-date use of geographical data.
9. It provides the ability to create easy-to-understand and impressive reports with map and visualization features.
10. It adapts to the change and development of geographical data over time.
11. It offers multi-user support and optionally provides remote access.
12. It provides the ability to compare and analyze data at different scales and in different geographical regions.

#### **2.2.4. Working methods and components of a GIS**

Geographic Information Systems (GIS) encompasses an information system used for analyzing, storing, updating, and interrogating the geographical positions of vectorial and literary data. In conjunction with geographical data, GIS data facilitates visualization as well as integration with other data, furnishing an analytical overview. The GIS data, encompassing locations defined by a specific coordinate system, are stored as areas, lines, or points. The GIS framework encompasses personnel, software, data, and hardware, allowing secure preservation and archiving of spatial data. (Küpçü et al., 2015). GIS components are presented in Figure 2.1.



**Figure 2.1.** A view of GIS components (Küpçü et al., 2015).

### 2.2.5. Usage areas of GIS

GIS is an information system utilized for the accumulation, retention, scrutiny, exhibition, and administration of geographical data. It finds application in numerous domains, and a few examples of its application areas are provided below:

1. **City Planning:** GIS aids urban planners in the examination of geographical data and enhances their planning endeavors. Within this specific application field, GIS benefits from various data sources like transportation, population statistics, infrastructure, green spaces, and social activities. For instance, in urban planning applications, GIS enables the analysis of factors such as population density, traffic patterns, and availability of green spaces. These data-driven insights provided by GIS inform decision-making processes in urban planning.
2. **Agriculture:** GIS proves to be a valuable approach for collecting, analyzing, and administering data in the healthcare sector. Within this realm of application, GIS encompasses various data sources including land usage, water resources, vegetation coverage, soil analysis, and weather predictions.
3. **Disaster Management:** GIS plays a crucial role in mitigating damage and facilitating emergency response during natural disasters. In this specific application domain, GIS enables risk analysis, emergency planning, and damage assessment through the utilization of geographical data. In the context of crisis management, GIS permits the analysis of factors such as disaster risks, positioning of emergency teams, and locations of healthcare facilities. This analysis aids in the preparation and formulation of emergency plans using GIS.
4. **Health:** GIS is employed for the gathering, examination, and administration of data serving the healthcare industry. Within this application field, GIS incorporates data pertaining to epidemic outbreaks, public health, and disease mapping. Within the healthcare sector, GIS facilitates the analysis of variables such as disease transmission, hospital placements, population density, and the

development of health policies. Such GIS analysis aids in informed decision-making and policy formulation in the healthcare domain.

5. **Geology:** GIS is utilized for the collection, analysis, and management of geological data. Within this specific field of application, GIS encompasses data related to subterranean resources, volcanic occurrences, seismic activity, and categorization of rock types.

Besides these specific areas of application, GIS finds usage in a wide range of fields. For instance, forestry, tourism, the energy industry, the military, and archaeological research are a few examples of the diverse application areas where GIS plays a significant role.

### **2.3. Geotechnical Studies Related with GIS**

Numerous studies in various fields that are associated with GIS have been conducted. Below are a few examples of such studies.

Dai and Lee (2001) created a technique through Geographic Information Systems techniques to identify the likelihood of landslides occurring on Lantau Island. The study involved evaluating terrain characteristics such as lithology, slope direction, elevation, land cover, and proximity to drainage lines to establish the susceptibility to landslides. Suitability analyses were further conducted, in conjunction with real landslide occurrence records, by combining these data sets.

Haşimoğlu and Murat (2004) carried out a study in the settlement region of Yoncalı Thermal Springs, which falls within the jurisdiction of Kütahya Municipality. The study employed satellite imagery and Geographic Information System techniques to digitally map settlement areas, road networks, streams, and culverts as distinct geographic data layers. These maps incorporated multiple layers, including applied zoning plans, geological formations, fault lines, and soil survey data. The primary objective of this study was to develop a comprehensive "Soil Survey Information System" by utilizing all the collected data.

Kunapo et al. (2005) introduced an innovative method that combines Web-GIS with a relational database management system, aiming to provide the construction industry with access to geotechnical data via the Internet. The study presents user-friendly tools that allow data related to specific boreholes to be easily located on a map through

the use of search tools and geotechnical spatial queries. This system grants users the ability to access digital data that is essential for construction project planning.

Orhan (2005) aimed to investigate the geotechnical characteristics of the southern region of Eskisehir Urban Area in a research. Geological, geomorphological, and tectonic data were gathered by performing boreholes in the region and transferred into a computer environment. Using this data, a database and geotechnical engineering map were created in the GIS environment for a specific area within the study boundaries to identify the geotechnical properties of the basic units.

Şişman (2006) conducted an assessment of soil liquefaction potential in the Fethiye settlement area through the utilization of SPT and shear wave velocity data. The study focused on investigating the probability of liquefaction occurring after a hypothetical earthquake in Fethiye district, located in the Muğla city. To accomplish this, liquefaction analyses were carried out by analyzing SPT-N blows and measuring the shear wave velocity. Furthermore, potential liquefaction maps, based on the liquefaction strength risk index, were generated for the area under study.

By utilizing geographic information systems, Karaca (2007) investigated the engineering characteristics of soils surrounding Fethiye and created geotechnical maps that illustrate these properties. The maps provide information on slope, liquefaction potential, depth of groundwater from the surface, groundwater level, vibration period, soil seismic amplification, and elastic wave velocities in different soil layers. Based on these comprehensive maps, the author evaluated the suitability of the study area for settlement purposes.

Kolat (2010) conducted a study to create a geotechnical microzonation model for evaluating the suitability of the Yenişehir (Bursa) settlement center for habitation. The research encompassed an analysis of the soil properties and dynamic behavior of the area. Soil classification, soil amplification, dominant soil period, resonance phenomenon, and liquefaction potential were assessed using borehole data and microtremor measurements. The study evaluated the liquefaction potential both in a two-dimensional planar and a three-dimensional volumetric manner. Based on the findings, geotechnical microzonation maps were generated for the study area in order to determine the suitability of the settlement center for habitation.

Avin (2011) implemented the ArcGIS program to pinpoint geological and geotechnical data necessary for their study. This data comprised soil classifications through EUROCODE-8 standards, groundwater levels and formation status, bearing

capacity, soil safety stresses, and previous settlement values obtained by Balkesir Municipality. To determine the distribution of this information on cadastral maps supplied by the municipality, the researcher employed the ArcGIS program's capabilities.

The study conducted by Wan-Mohamad and Abdul-Ghani (2011) sought to provide essential information for planners, architects, and engineers involved in designing structurally sound and cost-effective buildings in Seri Iskandar, District of Perak Tengah, Perak, Malaysia. To achieve this objective, the authors examined different soil types and conducted field and laboratory tests to determine the Standard Penetration Test (SPT) values at various depths. The findings were then presented as maps, which can serve as a valuable resource for assessing soil conditions in the area. These maps can inform decision-making during the design and construction phases of a project.

Özcan (2012) conducted research to explore the geological-geotechnical properties of the soil in the Selçuklu district of Konya city. To achieve this, the author utilized a variety of data sources including field observations, previous studies, and boreholeing data to prepare a comprehensive geological map of the study area. Soil samples were also collected and subjected to various laboratory tests including sieve analysis, water content, unit weight, and specific gravity tests, to determine the physical properties of the soil in the study area. The results of these tests were used to gain knowledge of the soil properties and characteristics and could be used in planning and designing engineering projects. Additionally, consolidation, triaxial compression, and uniaxial compression tests were conducted to determine mechanical parameters. Based on these tests, soil classes within the study area and geotechnical structure of the soil in the region were analyzed by examining representative soil samples.

In Demir's (2013) research study, a database was established using geological, geophysical, and geotechnical data from 131 geotechnical survey reports in the settlement area of Gürsu (Bursa). Using GIS software, geotechnical maps were created to demonstrate the variation of fundamental soil properties, enabling the quick, economical, reliable, and practical decision-making for land use in the region. The maps generated in the research consist of diversified types of information concerning the study area, such as slope, vegetation depth, groundwater level, elevation, soil classification based on the Unified Soil Classification System, standard penetration test data, shear wave velocity, compression wave velocity, and seismic velocity ratio. By providing a comprehensive understanding of the physical and geotechnical traits in the study area, these maps could

prove advantageous for various uses, including land use planning, engineering design, and disaster mitigation planning.

Cabalar et al. (2019) conducted a study to examine the potential for liquefaction in Kahramanmaraş, a city located in south-central Türkiye on the East Anatolian and Dead Sea fault lines. The research involved geotechnical investigations conducted in both the field and laboratory settings. A total of 238 boreholes were drilled throughout the city, and soil samples obtained from these locations underwent standard penetration tests to determine their physical properties, including sieve analysis, Atterberg limits, and soil classification. The liquefaction potential of the soil was assessed based on the SPT results, considering a hypothetical earthquake scenario with a magnitude of 7.5. The findings indicated that the southern areas of the city had a high potential for liquefaction, while the northern areas generally fell into the non-liquefaction zone. The researchers employed GIS-based computer software to create maps illustrating the results. These GIS maps can be valuable resources for researchers and engineers conducting more advanced studies in land use planning and urban development.

Karabaş (2019) conducted a study analyzing data from geotechnical survey reports carried out at 192 borehole points in the study area using geographic information system analysis. The author performed various analyses, including SPT-N calculation analysis, bearing capacity calculation analysis, groundwater level and water content analysis, liquefaction calculation analysis, soil classification analysis, and earthquake hazard level analysis based on soil amplification calculation. The results of these analyses were presented and interpreted using GIS-based software to generate maps that can aid in land use planning and urban development. These maps provide detailed information on the physical and geotechnical characteristics of the study area, such as soil properties, earthquake hazard levels, and liquefaction potential. Engineers and planners can utilize this information to make informed decisions regarding development and construction projects in the area.

Demirtaş (2022) conducted a study in Elazığ city, where soil index properties, soil classification, and bearing capacity calculations were conducted using data from 210 borehole logs. To further analyze the data, soil classification maps, groundwater maps, water content maps, shear wave velocity maps, compression wave velocity maps, and soil amplification maps were generated using ArcGIS software and the IDW method. According to Demirtaş, these maps can prove valuable for preliminary studies, feasibility

studies, land use policy, urban planning, and design, by accurately and easily illustrating the distribution of various soil properties.

Göksular (2022) conducted a study in Siirt city, utilizing geotechnical data from 178 boreholes. The data was used to create maps of soil classification, bearing capacity, shear wave velocity, soil amplification, and dominant vibration period, employing a geographic information system. Moreover, four different methods based on geophysical and geotechnical approaches were employed to calculate bearing capacity. The study also estimated and compared shear wave velocity values, considering various approaches and formations described in previous literature.



## **CHAPTER 3**

### **MATERIALS AND METHODS**

#### **3.1. Introduction**

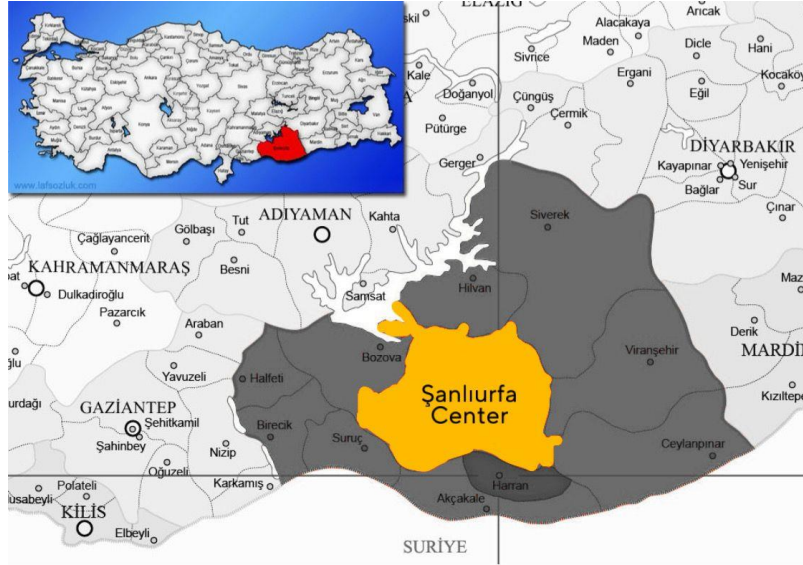
The topography of Şanlıurfa city is made up of mostly flat and gently sloping areas, with a decrease in altitude towards the south and an increase in altitude towards the east, west, and north. The average altitude of Şanlıurfa is 477 meters, and the highest point is Karacadağ at 1,957 meters. The highest points of other mountains are Susuz Mountain (812 m), Tektek Mountain (749 m), Germuş Mountains (800 m), Cudi Mountains (638 m) and Arat Mountain (895 m). The most important plains in the region are the Harran, Suruç, Viranşehir, Hilvan, Ceylanpınar, Bozova and Siverek plains. The study area, which is climatically dry and insufficient in terms of rainfall, provides a large part of its drinking water from the Euphrates River.

The Euphrates River is a lifeline for the Şanlıurfa city. A large part of the Euphrates River basin passes through the Birecik and Halfeti districts of Şanlıurfa. This river, which is seen as the largest water source, has a discharge of 356 m<sup>3</sup>/s. The Euphrates River passes west of Birecik and Halfeti, forming the administrative border with the Gaziantep city. The Atatürk Dam, the largest dam in Türkiye, is located on this river as part of the GAP. Pelicans and gazelles are other natural assets of Şanlıurfa.

#### **3.2. General Characteristics of the Study Area**

The study area was determined as the center of Şanlıurfa. The central district of Şanlıurfa is located in the Southeastern Anatolia region, and Şanlıurfa Central district is a part of Şanlıurfa city. The surface area of Şanlıurfa Central district is 19,242 km<sup>2</sup> and it is the 3rd largest district of Turkey in terms of area. Şanlıurfa Center map location is 37° 10' 2.6544" North and 38° 47' 43.8468" East GPS coordinates.

Geological, geophysical and geotechnical data obtained from a total of 535 boreholes points were used. Figure 3.1. presents the location map showing the study area.



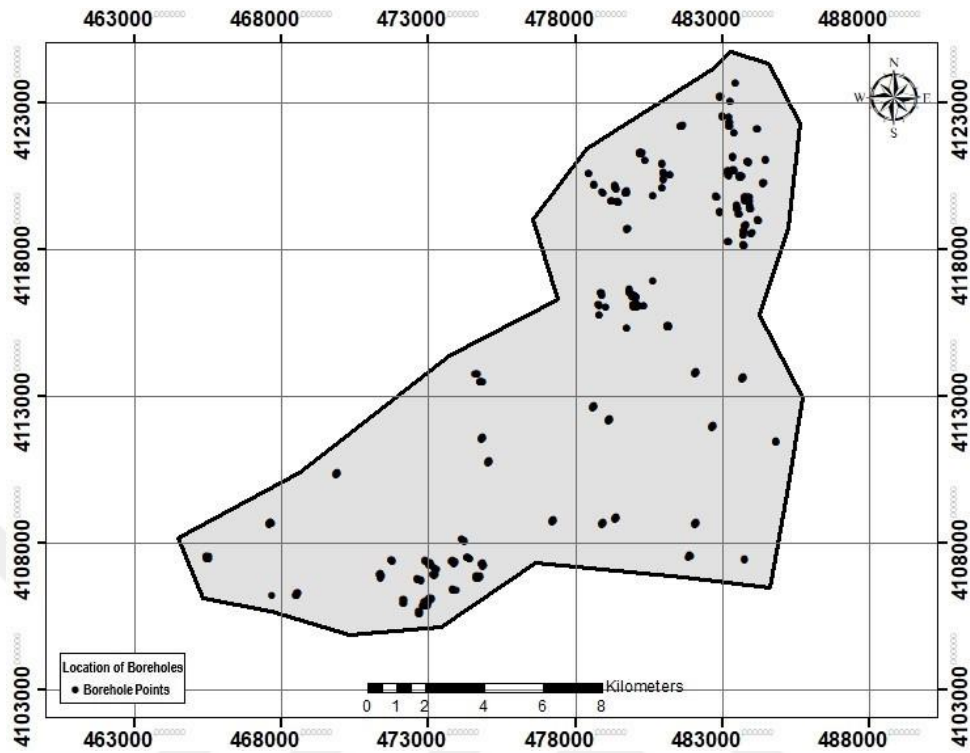
**Figure 3.1.** Location map showing the study area

Figure 3.2. is showing distribution of boreholes points in the neighborhoods of the central district of Şanlıurfa.



**Figure 3.2.** Distribution of boreholes points in the neighborhoods of the central district of Şanlıurfa.

Figure 3.3. presents the location map the borehole points of the study area.



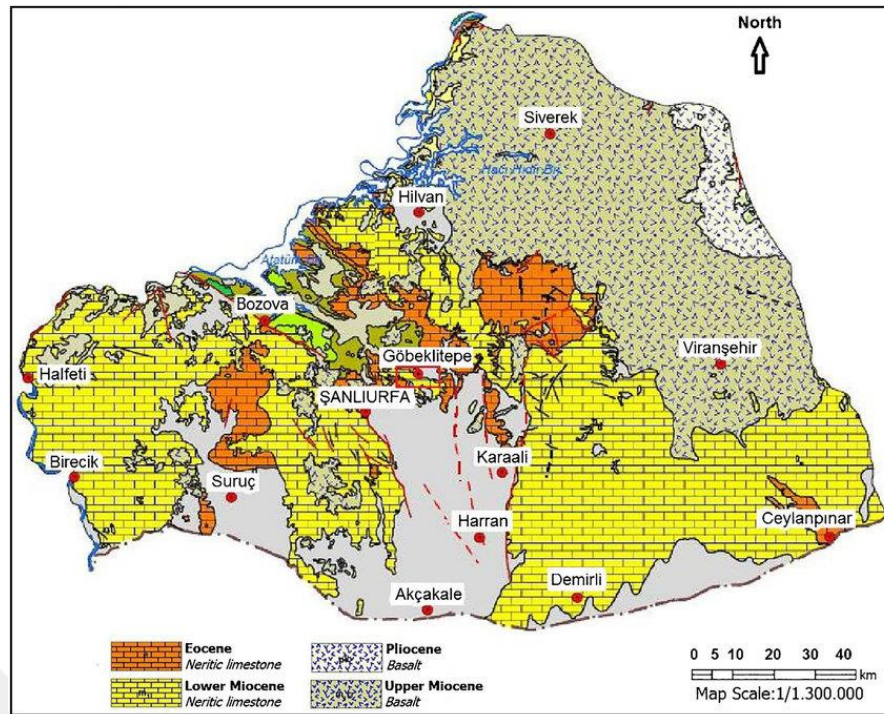
**Figure 3.3.** Location map showing boreholes of the study area

### **3.2.1. Geographical location and morphology**

Şanlıurfa city is mostly made up of rocks from the Tertiary period, with limestone being the most common. Limestone is easy to break, carve, and shape, so it is still used in construction in Şanlıurfa and Birecik today.

The region has a long geological history, with rocks dating back to the Cambrian period. The structural features of Southeastern Anatolia were shaped by tectonic activity at the end of the Cretaceous period.

During the Eocene-Oligocene period, plate-like limestone, marl, shale, sandstone, and silty limestone units were deposited in a shelf environment that deepened towards the north. Figure 3.4. indicates the geology map of Sanliurfa.



**Figure 3.4.** Geology map of Sanliurfa (Akbas-et-al., 2002)

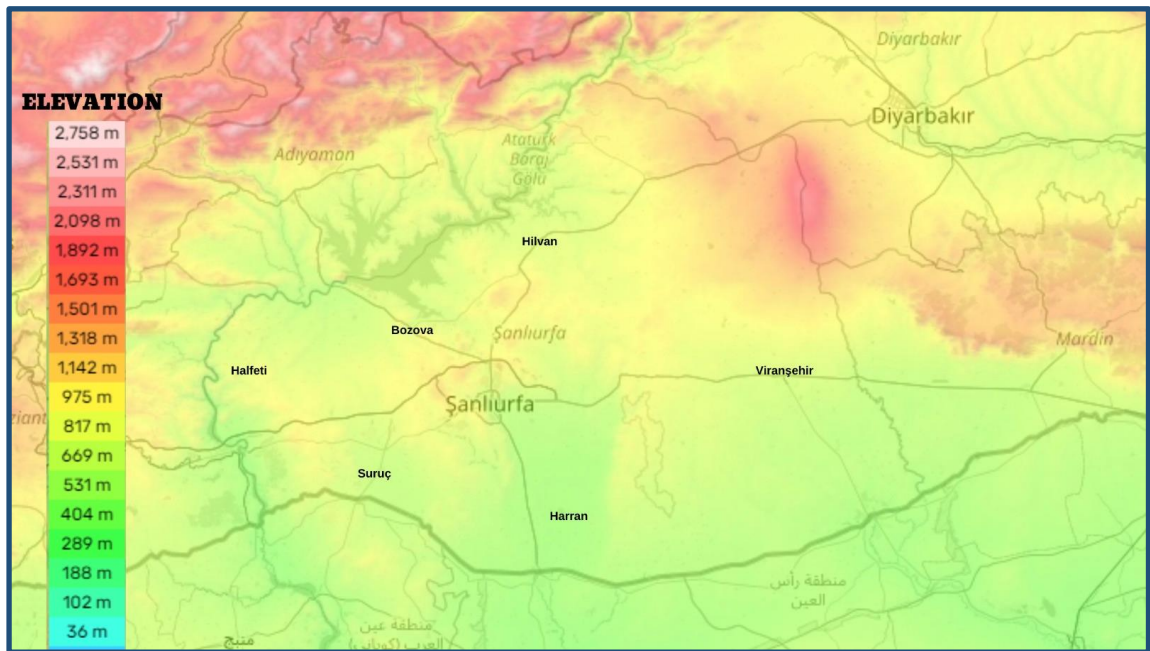
The geology map of Şanlıurfa City shows that the green areas are Cretaceous-Paleocene age clastic and carbonate rocks, the orange areas are Eocene age limestones, the yellow areas are Miocene age limestones, the brown areas (between Siverek and Viranşehir) are Pliocene-Quaternary age basalt rocks, and the gray areas represent alluvium. Of these rock units, alluvium is a permeable, granular aquifer. Groundwater is extracted to the surface by wells. Basalt rocks are non-soluble, rock aquifers, and limestones are soluble, karstic, rock aquifers.

Here is a more detailed explanation of each rock unit:

- Cretaceous-Paleocene age clastic and carbonate rocks: These rocks are made up of a variety of materials, including sandstone, limestone, and shale. They are found in the northern and western parts of the city.
- Eocene age limestones: These rocks are composed of calcium carbonate and are found in the central and southern parts of the city.
- Miocene age limestones: These rocks are similar to Eocene age limestones, but they are slightly younger.

- Pliocene-Quaternary age basalt rocks: These rocks are made up of volcanic rock and are found in the southeastern part of the city.
- Alluvium: This material is made up of sediment that has been deposited by rivers, streams, and other bodies of water. It is found in the valleys and floodplains of the city.

Figure 3.5. highlights the physical map of Şanlıurfa city.

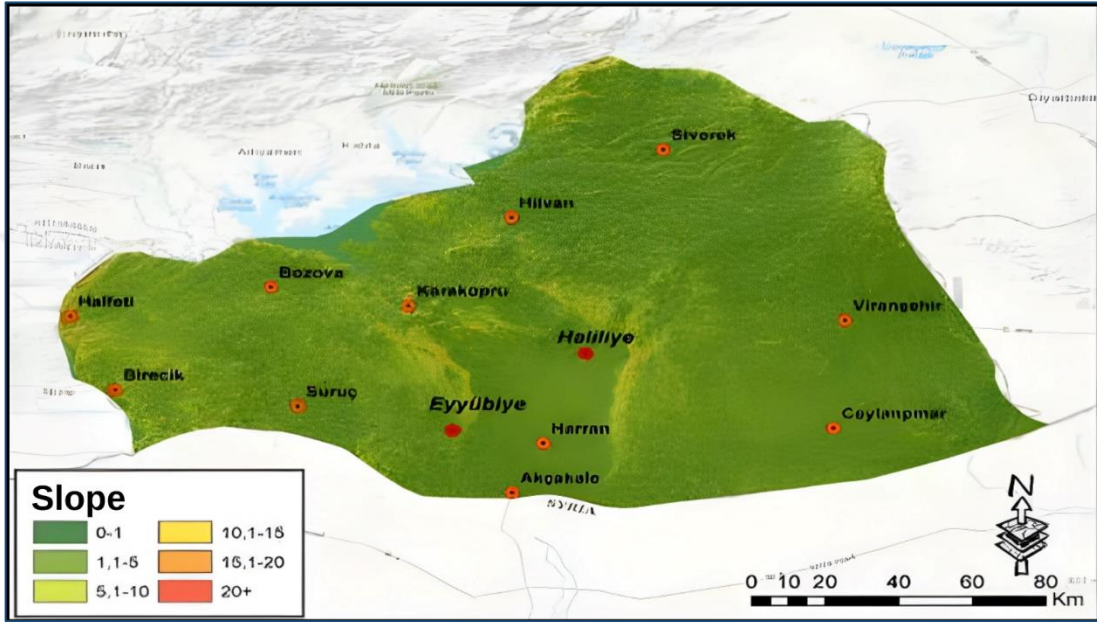


**Figure 3.5.** The physical map of Şanlıurfa city (URL-1)

When the geomorphological structure of Şanlıurfa City is examined, it is seen that it has a simple appearance and includes the main landforms of mountains, plateaus, and plains (Güzel, 2020). The highest point in the city is Karacadağ, which is located on the border with Diyarbakır city and has an elevation of 1957 m. Apart from this, the elevation of the areas located in the north and west of the city does not reach 1000 m.

The morphological unit that covers the widest area in Şanlıurfa city is plateaus. Since the study area is a Quaternary terrain, the degree of erosion is not at a sufficient level. In parallel, bedrock is visible in places due to deep erosion due to the high discharge of the Euphrates River. As can be seen in Figure 3.5., the elevation of Şanlıurfa city decreases from east to west and from north to south. Alluvial deposits formed by rivers

are found in the southern part of the city. In this area, the elevation is around 700 meters on average and is suitable for agriculture. The traces of the Euphrates River, the largest water source in Şanlıurfa, are seen to the north. The Euphrates River, which has a high discharge, erodes the slopes and especially the ground of the bed it flows through. In the western part of Şanlıurfa, the elevation increases around Birecik and Halfeti. Figure 3.6. is showing the map the slope of Şanlıurfa city.



**Figure 3.6.** Map showing the slope of Şanlıurfa city (Yurddas, 2022)

When the map in Figure 3.6. is examined, it is seen that the slope of the land is quite high in the east of Karaköprü, along a line from the west of the city to the south, around the Tektek Mountains to the east of the University campus and Harran Plain, around Halfeti and Karacadağ compared to Harran Plain. It is observed that the velocity of the river and the erosion effect are high in the areas with high slope where the Euphrates River passes.

### 3.2.2. Climate, temperature, rainfall, and vegetation

One of the most important factors that determine the climate of the study area is its location. The pressure conditions of the subtropical air mass that dominates the region change seasonally. This situation causes winters to be mild and rainy, and summers to be hot and dry in general in Şanlıurfa city. The distribution of precipitation in the study area can be explained by the wandering low cyclones in Türkiye. The cyclones that affect the

region in winter cause precipitation to occur in Şanlıurfa and its surroundings, also affected by the relief. The Mediterranean depression, which affects the southern and partly southeastern parts of Türkiye via the Mediterranean in the autumn and winter seasons, is the main cause of these precipitations (Sözer, 1984). In the summer, temperatures in the region rise sharply with the expansion of the low pressure center of Basra. The wind pressure conditions of Şanlıurfa City also affect the direction of the wind, depending on the continentality (continentality) and marine characteristics of the area. Continentality reveals the temperature difference between day and night in the area. There are large temperature differences between day and night in the study area, which is far from marine influence. Table 3.1 is showing the average temperature and rainfall values for Sanliurfa city between 1929-2022.

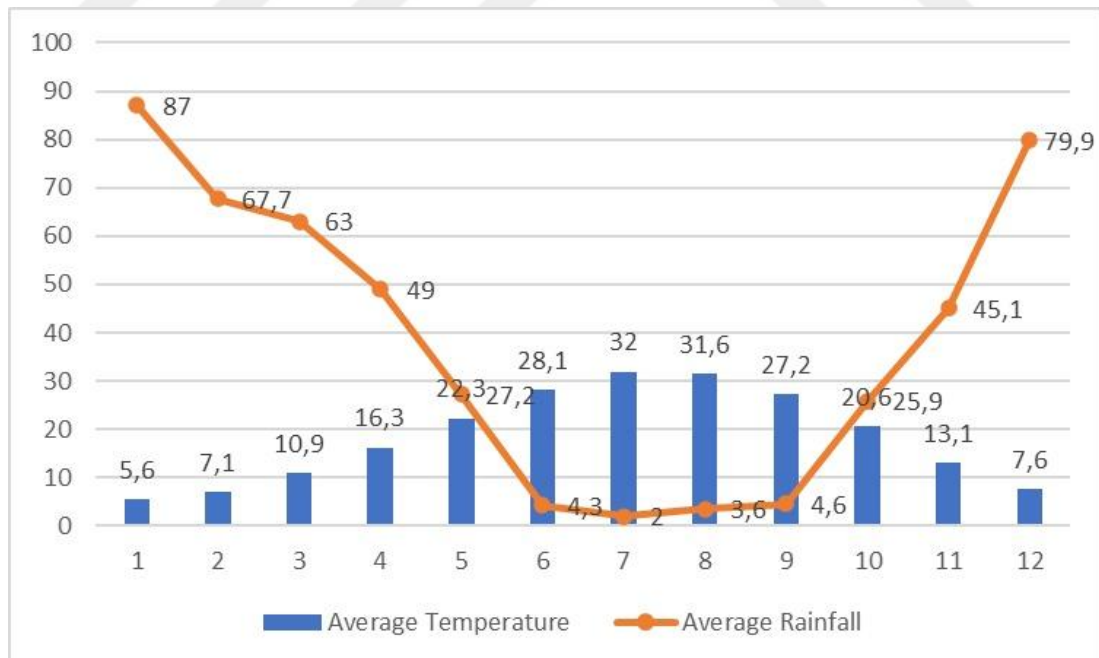
**Table 3.1.** The average temperature and rainfall values for Sanliurfa city between 1929-2022 (MGM, 2023).

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
<b>Average Temperature (°C)</b>	5.6	7.1	10.9	16.3	22.3	28.1	32.0	31.6	27.2	20.6	13.1	7.6	18.5
<b>Average Highest Temperature (°C)</b>	9.9	12.0	16.4	22.4	28.8	34.7	38.8	38.4	34.0	27.1	18.8	12.1	24.5
<b>Average Lowest Temperature (°C)</b>	2.1	3.0	5.8	10.3	15.3	20.5	24.3	24.0	20.0	14.6	8.5	4.0	12.7
<b>Average Sunshine Duration (hour)</b>	4.1	5.1	6.4	7.8	10.0	12.1	12.3	11.3	10.0	7.9	5.8	4.0	8.1
<b>Average Number of Rainy Days</b>	11.90	10.39	10.46	8.77	6.08	1.37	0.30	0.23	0.79	4.73	7.46	10.70	73.2
<b>Average Monthly Total Rainfall (mm)</b>	87.0	67.7	63.0	49.0	27.2	4.3	2.0	3.6	4.6	25.9	45.1	79.9	459.3
<b>Highest Temperature (°C)</b>	21.6	25.5	29.5	36.4	40.4	44.1	46.8	46.2	43.9	37.8	30.8	26.0	46.8
<b>Lowest Temperature (°C)</b>	-10.6	-12.4	-7.3	-3.2	2.5	8.3	15.0	16.0	10.0	1.9	-6.0	-6.4	-12.4

When Table 3.1, which shows the monthly temperature data for Şanlıurfa city, is examined, it is seen that the average temperature does not fall below 0 °C in any month of the year. The average temperature is 5.6 °C in the coldest month of January, and rises

to 7.1 °C in February. The temperature exceeds 22.3 °C from May and reaches its highest value of 32 °C in July, after which it starts to decrease from August (Figure 3.7). The average temperature value for September is 27.2 °C, while this value falls to 7.6 °C in December. In other words, the average temperature values in Şanlıurfa are high in the summer months (Güzel, Settlements of Şanlıurfa City, 2005). The highest temperature value in the city was reached in July at 46.8 °C, and the lowest temperature value was reached in February at -12.4 °C.

When the average rainfall values between 1929 and 2022 are examined, Şanlıurfa receives the most rainfall in January with 87.0 mm. On the other hand, the month with the least rainfall is July with 2.0 mm. In general, the annual rainfall amount in Şanlıurfa City is low. In addition, severe droughts occur along with high temperatures in the summer season. The average annual rainfall of 459.3 mm, the temperatures that reach negative values in winter, and the high temperatures seen in the summer season are the reflections of the continental climate. The distribution of temperature and rainfall by months forms a contrast. The month with the highest average temperature value, July, is also the month with the lowest rainfall value (Figure 3.7).



**Figure 3.7.** Average temperature of Şanlıurfa city by month (URL-2)

Şanlıurfa city, located in the Southeastern Anatolia Region, is in the Iranian-Turan flora, like the rest of the region, and has a steppe climate. Therefore, it is very poor in

terms of forest resources. This situation is summarized by the average annual rainfall of 463.3 mm, which has led people to the Euphrates River, which they see as their largest water source. Even though a part of the city is irrigated with the Southeastern Anatolia Project (SAP), in the Birecik district of Şanlıurfa, which is outside the project scope, pistachio trees are irrigated with water drawn from the Euphrates River with their own means due to the insufficient rainfall in the winter months.

After touching on the water problem of Şanlıurfa city, we can mention the plant communities it hosts; olive, oak, pistachio, and wild pear trees that have become cultural plants today. The finding of an old olive tree on an erosional hill (Göbeklitepe) on the southern side of the Çaykuyu plateau of the study area, which is not suitable for agriculture and is relatively sheltered from its surroundings, shows that the presence of olive in the city dates back to a very long time ago (Güzel, Natural Geographical Features of Şanlıurfa city, 2020). The olive plant continued to exist in Şanlıurfa city until the 1990s, but was abandoned due to its low economic return. The agricultural fields that were vacated from olive trees were eventually replaced by pistachio. Pistachio is seen in large numbers in the Birecik district of Şanlıurfa city. Although pistachio does not grow naturally, it has adapted to the region and has provided production that meets the needs of the country and even exports.

### **3.2.3. General geological characteristics of the region**

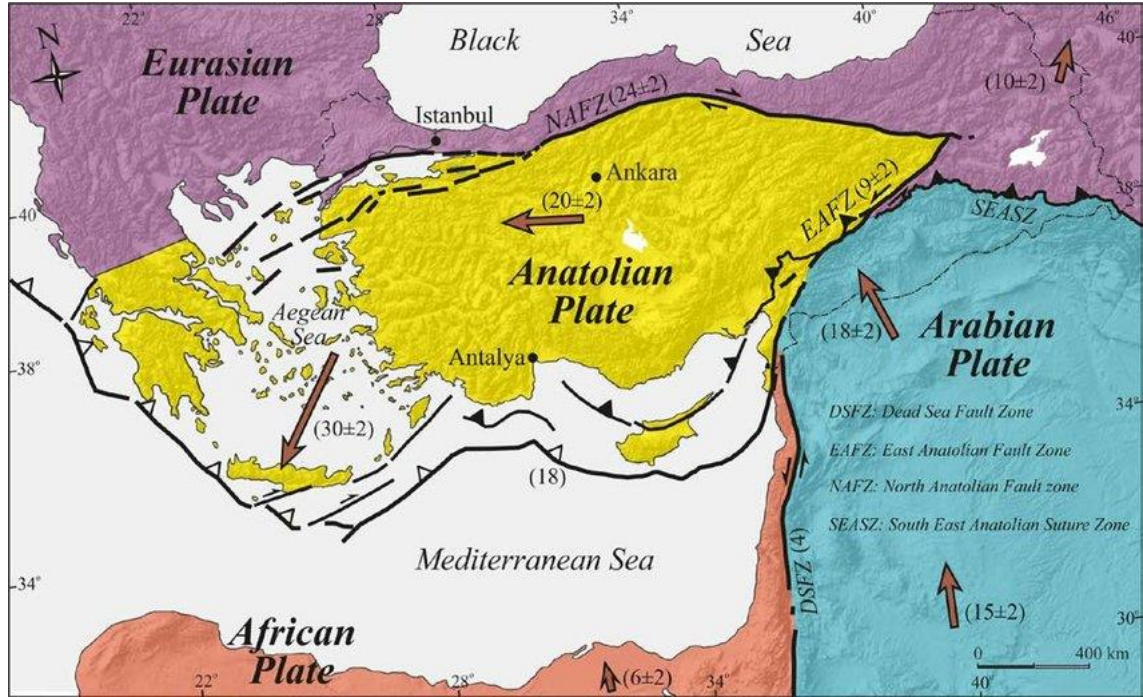
In order to understand the geological structure of the study area and the tectonic features of the region, it is necessary to know the development of the historical period between the Anatolian and Arabian plates.

The Southeast Anatolian Region was formed by the collision of Arabian and Eurasian Plates along the Bitlis - Zagros Rim Belt (or Southeast Anatolian Thrust) after the Tethys Sea had closed as a consequence of the north-south convergent of the Arabian - Eurasian Plates in the late Mesozoic (Şengör, 1980).

North-south trending compression, north-trending thrust faults and folds appeared before the Pliocene. In the Late Pliocene, however, these compressions could no longer be accommodated by thrust faults and folds, and strike-slip faults came to the fore. As of today, hundreds of large earthquakes have occurred in the southeast Anatolian region due to movement along thrust faults. These include the Eastern Anatolian Fault, its

conjugates, Lice Fault Zone, and Bozova Fault, which are all part of the Bitlis - Zagros Rim Belt (İmamoğlu and Çetin, 2007)

The tectonic map of Türkiye showing the plates and their directions of movement is presented in Figure 3.8.

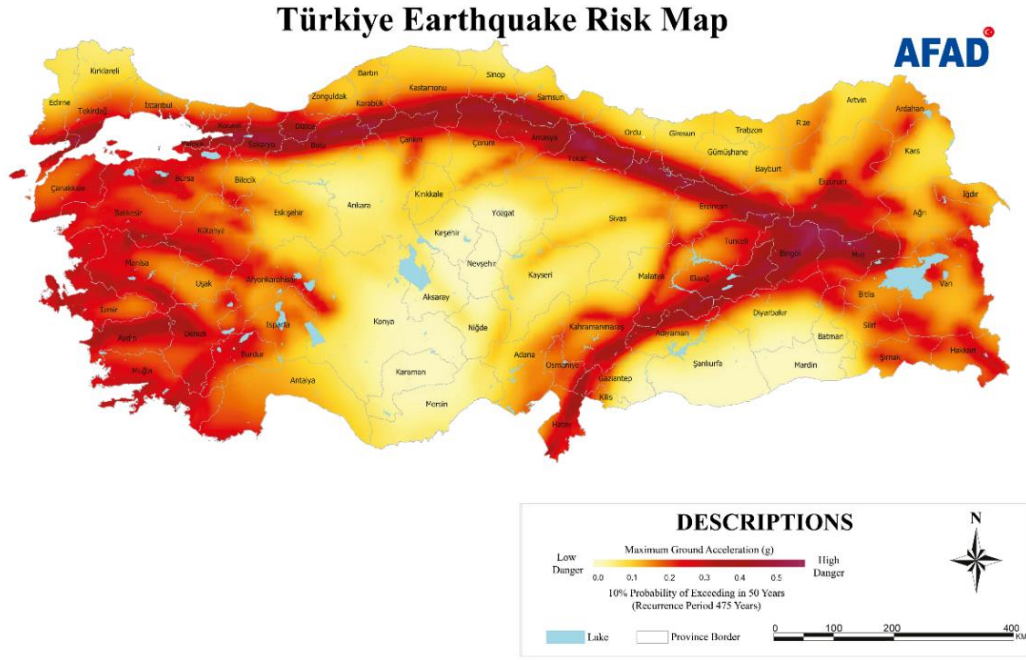


**Figure 3.8.** Tectonic map of Türkiye showing the plates and their direction of movement (Isik et al., 2014)

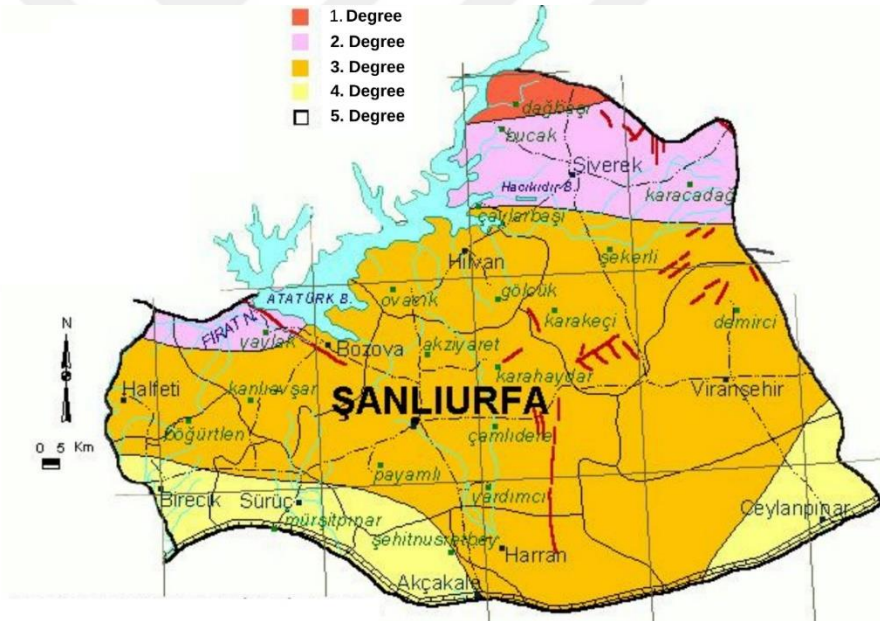
### 3.2.3.1. Seismicity of the study area

Türkiye is part of the Alpine-Himalayan earthquake belt. Türkiye experiences significant earthquakes as a result of compression between the Eurasian plate in the north and the African and Arabian plates. The Anatolian plate of Türkiye moves westward along the North and East Anatolian fault zones. In the east, the Bitlis-Zagros Rim Belt (Bitlis Thrust Zone) forms the boundary between the Arabian Plate and eastern Anatolia. The compression caused by the past northward movement of the Arabian Plate along this belt led to the formation of the mountain range known today as the Southeastern Taurus Mountains.

The Türkiye Earthquake Hazard Map came into force on January 1, 2019, with the project supported by the National Earthquake Strategy and Action Plan (NESEP-2023) and the National Earthquake Research Programme of the Presidency for Disaster and Emergency Management. The map showing the earthquake hazard status of Sanliurfa City is presented in Figure 3.10., and the earthquake hazard status of Sanliurfa City according to the Türkiye Earthquake Hazard Map is presented in Figure 3.9.



**Figure 3.9.** Map of earthquake zones of Türkiye (AFAD, 2023).



**Figure 3.10.** Earthquake hazard levels of Şanlıurfa city according to Türkiye earthquake hazard map (Şanlıurfa Provincial Disaster and Emergency Directorate, 2022).

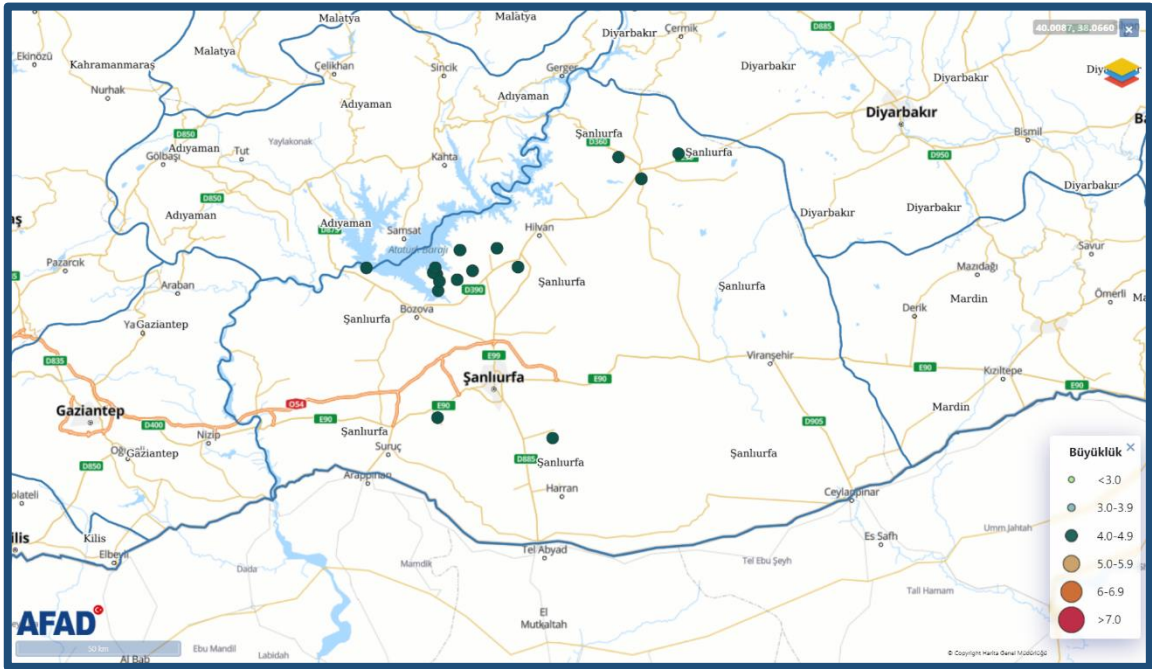
When the earthquake risk map is examined, it shows that the risks are higher in the north. The fact that the Atatürk Dam is located in the second-degree earthquake zone increases the likelihood of it being affected by possible earthquakes. Although Şanlıurfa is not in an earthquake zone, earthquakes that occur in neighboring cities such as Kahramanmaraş, Adıyaman, Bingöl, Malatya, and Elazığ affect the region. According to data from the Kandilli Observatory and Earthquake Research Institute (KRDAE) of

Boğaziçi University, the number of earthquakes in Şanlıurfa has been increasing in recent years (KRDAE, 2021). In addition, the weak geological soil structure of Şanlıurfa, the fact that new settlements such as sırım have clay-like soil, and the fact that most of the buildings are old and not earthquake-resistant also increase the destructive effect of possible earthquakes in Şanlıurfa (Gümüştü et al., 2004: 41-52). In areas where earthquakes occur, the planning of settlements and the construction of buildings in a way that is resistant to earthquakes are also important in terms of reducing the destructive effects of earthquakes. The fact that the public goes out into the streets in panic when an earthquake occurs and goes left and right uncontrollably makes it difficult for authorized units to intervene in events at the time of the earthquake. In this respect, the crisis desk to be established at certain points in the city will contribute to the healthy management of the process in the event of a possible disaster. Earthquakes greater than  $M_w=4$  occurred in Sanliurfa city between 2000 and 2023 are presented in Table 3.2.

**Table 3.2.** Earthquakes greater than  $M_w=4$  occurred in Sanliurfa city between 2000 and 2023 (AFAD, 2023).

Date	Location	Longitude	Latitude	Depth	Type	Magnitude
06-02-2023 06:21:22	Karaköprü (Şanlıurfa)	37.057	38.598	7	ML	4.0
17-06-2020 08:47:13	Hilvan (Şanlıurfa)	37.5228	38.6763	4.02	Mw	4.1
21-05-2018 01:09:24	Karaköprü (Şanlıurfa)	37.4565	38.595	9.67	Mw	4.0
17-04-2015 11:49:56	Hilvan (Şanlıurfa)	37.528	38.8056	10.94	Mw	4.0
01-12-2012 03:51:42	Atatürk Barajı - [02.26 km] Bozova (Şanlıurfa)	37.4735	38.3485	17.86	MI	4.1
12-02-2012 04:49:07	Karaköprü (Şanlıurfa)	37.4407	38.6665	23.16	MI	4.1
30-04-2010 17:02:59	Hilvan (Şanlıurfa)	37.4757	38.8793	22.41	MI	4.1
29-09-2008 20:54:55	Atatürk Barajı - [02.43 km] Karaköprü (Şanlıurfa)	37.474	38.59	24.04	MI	4.4
04-09-2008 22:54:31	Karaköprü (Şanlıurfa)	37.4605	38.5825	23.8	MI	4.8
03-09-2008 02:22:46	Karaköprü (Şanlıurfa)	37.4363	38.6043	24.04	MI	4.9
24-07-2006 23:04:58	Karaköprü (Şanlıurfa)	37.4655	38.7202	7.5	Md	4.0
27-11-2001 08:53:31	Siverek (Şanlıurfa)	37.72	39.31	10.7	Md	4.2

Figure 3.11. present that distribution of earthquakes that occurred in Sanliurfa between 2000 and 2023.

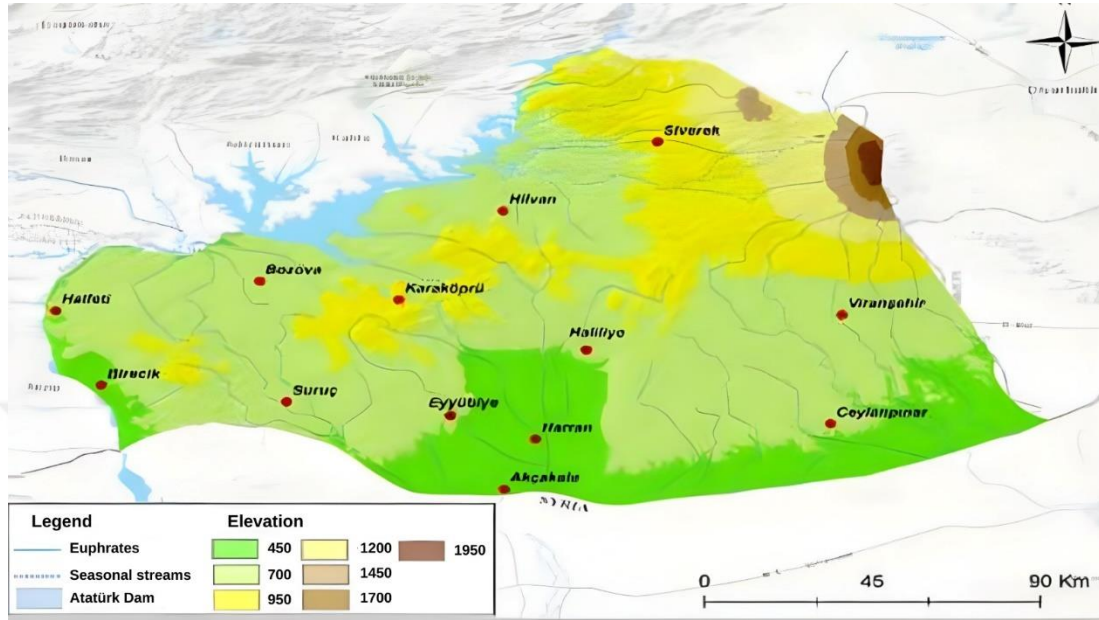


**Figure 3.11.** Distribution of earthquakes that occurred in Sanliurfa between 2000 and 2023 (AFAD, 2023).

### 3.2.3.2. Hydrography Features

When the terminological meaning of the name "Urfa" is examined; According to various sources, it means "near water-abundant in water". Even the depiction of Urfa on coins with puddles during the Roman period shows that the association of the city with water dates back to ancient times (Segal, 2002). Taking this into consideration, considering the location of Şanlıurfa city; Although it is poor in terms of climatic characteristics (rainfall value), people have established various settlements in this area due to the passing of the Euphrates River near it and the presence of some water sources in the region, such as the city center. The Euphrates River is a major river that is important for both Şanlıurfa and Türkiye, with a length of 1263 km within Türkiye, a water catchment basin exceeding 70,000 km<sup>2</sup>, and an annual water transportation capacity of 30 billion m<sup>3</sup>. When the hydrography map of Şanlıurfa, which is located in Figure 3.12, is examined, it is seen that a large part of the city's water source is formed by the Euphrates River and its tributaries.

The opening and closing of the gates of dams on the Euphrates River causes the water reserves (aquifers) of many rivers that flow into the Euphrates to decrease or increase. Hydrography map of Şanlıurfa city is in Figure 3.12.



**Figure 3.12.** Hydrography map of Şanlıurfa city (Yurddas, 2022)

### 3.3. Rock Quality Designation

RQD is a widely used input in rock mass descriptions and was first developed by Deere (1964). RQD (%) is defined as the ratio of the total length of sound core pieces that are at least 10 cm long to the total length of the core run. The RQD-based rock quality classification is given on Table 3.3.

**Table 3.3.** The classification of RQD-based rock quality (Deere, 1964)

RQD (%)	Quality	Description
0-25	Very Poor	Very weak and unstable rock. Not suitable for construction.
25-50	Poor	Weak and unstable rock. Suitable for construction with caution.
50-75	Fair	Moderately weak and stable rock. Suitable for construction with some precautions.
75-90	Good	Moderately strong and stable rock. Suitable for construction without major precautions.
90-100	Excellent	Strong and stable rock. Ideal for construction.

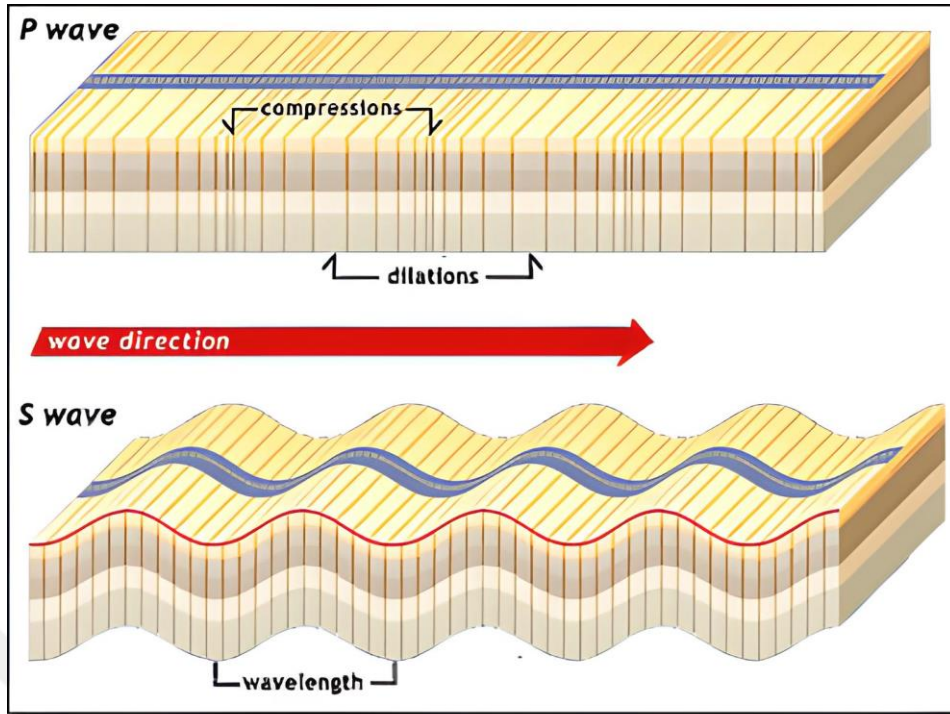
It effectively divides rock quality into five categories: Very Poor, Poor, Fair, Good, and Excellent. The descriptions provided for each category accurately reflect the suitability of the rock for construction purposes:

Rock with an RQD of less than 25% is considered very weak and unstable. It is not suitable for construction due to its high susceptibility to weathering, erosion, and landslides. Rock with an RQD of 25-50% is considered weak and unstable. It can be used for construction with caution, but extra precautions are necessary to ensure the stability of structures built on this type of rock. Rock with an RQD of 50-75% is considered moderately weak and stable. It can be used for construction with some precautions. However, careful assessment of the rock's properties and appropriate mitigation measures are essential. Rock with an RQD of 75-90% is considered moderately strong and stable. It is suitable for construction without major precautions and is a good choice for foundations, tunnels, and other structures. Rock with an RQD of 90-100% is considered strong and stable. It is ideal for construction and the most suitable type for large and complex structures.

### **3.4. Compression and Shear Wave Velocity**

Earthquakes are significant natural calamities that can cause widespread destruction and loss of life. They generate vibrations called earthquake waves, which propagate in different directions on and within the Earth's surface, as energy from the earthquake source spreads. These waves are comprised of two types: P-waves and S-waves.

P-waves and S-waves can be analyzed to assess the mechanical properties of the soil. P-waves travel in the same direction as their vibrations, while S-waves travel perpendicular to their vibration direction (i.e., perpendicular to the displacement of soil particles). Understanding these two types of waves is crucial for comprehending how soil responds under stress and can provide valuable information for geotechnical engineering applications. Figure 3.13. is showing the propagation of P and S waves



**Figure 3.13.** Propagation of P and S waves (URL-3)

As P-waves are the fastest waves in a medium, they are recorded first in earthquake records. The velocity of the P-wave;

$$V_P = \sqrt{\frac{\lambda + 2\mu}{\rho}} = \sqrt{\frac{E(1-\sigma)}{\rho(1+\mu)(1-2\mu)}} \quad (3.7)$$

$\lambda =$

$\sigma =$  Stress

$G =$  Shear Modulus

$D =$  Density

$\mu =$  Poisson Ratio

$E =$  Modulus of Elasticity

The velocity of the S-wave  $V_S$  is calculated using the following formula;

$$V_S = \sqrt{\frac{G}{\rho}} = \sqrt{\frac{E}{2\rho(1+\mu)}} \quad (3.8)$$

### 3.5. Poisson's Ratio

The Poisson's ratio of rocks is calculated based on their velocities ( $V_f$  and  $V_s$ ) only, regardless of their densities. Poisson's ratio is inversely proportional to porosity. It increases with increasing depth and water saturation. It is the ratio of the longitudinal strain to the lateral strain of a structure under stresses. It is dimensionless and is found

using the  $V_p$  and  $V_s$  velocities. It indicates the degree of porosity and intergranular pore pressure.

It is calculated using the following relationship:

$$\nu = \frac{V_p^2 - 2 * V_s^2}{2 * (V_p^2 - V_s^2)}$$

The Poisson's ratio values obtained by seismic methods for each measurement were evaluated according to the following soil condition table.

Poisson's ratio is an important measurement for evaluating the mechanical properties of a material. For example, materials with a high Poisson's ratio are more likely to bend under stress. Therefore, the use of these materials should be carefully evaluated in cases where they will be exposed to bending forces.

Poisson's ratio is also an important tool for evaluating the properties of rocks. As mentioned above, Poisson's ratio reflects the degree of porosity and fracturing of the rock. Poisson's ratio is high in porous and water-saturated rocks. These rocks, when subjected to a longitudinal extension, also experience a lateral contraction. This is due to the compression of the pores and water in the rock.

In hard rocks, however, Poisson's ratio is lower. These rocks, when subjected to a longitudinal extension, do not experience a lateral contraction. This is due to the low porosity and water content of the rock.

Poisson's ratio can be used to determine the strength, brittleness, and permeability of rocks. For example, rocks with a high Poisson's ratio are more likely to be less strong and more brittle. Additionally, their permeability is also more likely to be higher. Soil conditions according to Poisson's ratio is shown on Table 3.4.

**Table 3.4.** Soil conditions according to Poisson's ratio (Ercan,2001).

<b>Poisson's Ratio</b>	<b>Soil/Rock Density</b>
<b>0.5 or greater</b>	Liquid-Fluid
<b>0.4 to 0.5</b>	Very Loose
<b>0.3 to 0.39</b>	Loose
<b>0.2 to 0.29</b>	Dense-Solid
<b>0.1 to 0.19</b>	Solid
<b>0.0 to 0.09</b>	Strong

### 3.6. Seismic Velocity Ratio

The seismic velocity ratio ( $V_p/V_s$ ) is a measure of soil compaction. It provides information about the liquefaction potential of the soil. For loose, saturated silty sand and sand environments, a ratio of 2.49 or greater indicates that the soil has the potential to liquefy, depending on the magnitude and duration of the earthquake and the impact area.

The  $V_p/V_s$  ratio indicates the soil's density and saturation in alluvium. It is an expression of the soil's compactness and rigidity. It is interpreted differently in clay, sand, and alluvium. It indicates many parameters, such as fractures in rock, liquefaction in sand, and deformation in clay.

The seismic velocity ratio values of the layers obtained by seismic methods were evaluated according to the soil condition table. Soil condition according to the  $V_p/V_s$  ratio are presented on Table 3.5.

**Table 3.5.** Soil conditions according to the  $V_p/V_s$  ratio (Ercan, 2001).

<b>Soil/Rock Density</b>	<b><math>V_p/V_s</math> Ratio</b>
<b>Very Loose</b>	Infinite-2.49
<b>Loose</b>	2.49-1.87
<b>Dense-Solid</b>	1.87-1.71
<b>Solid</b>	1.71-1.50

The seismic velocity ratio ( $V_p/V_s$ ) is a ratio that characterizes the vibration properties of a rock or soil. This ratio is the ratio of the elastic moduli of a rock or soil, namely  $V_p$  (P-wave velocity) and  $V_s$  (S-wave velocity).

The seismic velocity ratio is an important parameter used in earthquake engineering and geophysical applications. It is important because it considers factors such as whether the soil is compact or not, especially the liquefaction potential, when evaluating the behavior of a soil during earthquakes. Therefore, the  $V_p/V_s$  ratio can be used as an indicator to predict the liquefaction potential of the soil.

### **3.7. Unconfined Compression Strength**

Unconfined compression strength refers to the ability of a rock or soil to resist shear stress at its culvert. This strength depends on the composition, density, porosity, etc. of the rock or soil. Varies depending on various factors such as. Unconfined compression strength is an important parameter that shows the strength of rocks. Unconfined compression strength is defined as the maximum load per unit area of a rock sample under a stress applied in the axial direction.

Unconfined compression strength affects the properties of rocks such as strength, shear potential, permeability and bearing capacity. Unconfined compression strength varies depending on the rock type, the internal structure of the rock, and the environmental conditions in which the rock is found.

In general, rocks with higher unconfined compression strength are considered stronger with higher strength. Therefore, these types of rocks are preferred in the construction of structures such as foundations, tunnels and slopes. Rocks with lower unconfined compression strength are considered less strong. Therefore, such rocks should be carefully considered in the construction of structures.

Unconfined compression strength can also affect the shear potential of rocks. In rocks with high unconfined compression strength, cracks and crevices within the rock are less open. Therefore, slipping is less likely on such rocks. Unconfined compression strength can also affect the permeability of rocks. In rocks with high unconfined compression strength, cracks and crevices within the rock are less open. Therefore, such rocks are less permeable.

Unconfined compression strength can also affect the bearing capacity of rocks. Rocks with high unconfined compression strength can carry more load. Therefore, such

rocks may be preferred for larger structures. The table below shows the strength of rocks according to their unconfined compression strength values.

The unconfined compression strength values used in the equations depend on the  $V_s$  velocity;

$$q_u = 0,443 \sqrt{V_s} / 134$$

**Table 3.6.** Strength of rocks according to their unconfined compression strength (American Society for Testing and Materials (ASTM),2002)

Unconfined Compression Strength (MPa)	Rock Strength
>200	Very high
100-200	High
50-100	Medium
20-50	Low
<20	Very low

### 3.8. Density

The density values used in the equations depend on the  $V_p$  velocity;

$$\rho = 0.31 * V_p^{0.25}$$

It is calculated using the equation. Its unit is  $g/cm^3$ . The density values obtained by seismic methods for each measurement were evaluated according to the density classification table which is given on Table 3.7.

**Table.3.7.** Density classification (Keçeli,1990).

Density ( $g/cm^3$ )	Definition
<1.20	Very Low
1.20-1.40	Low
1.40-1.90	Medium
1.90-2.20	High
>2.20	Very High

### 3.9. Maximum Shear Modulus

$V_s$  is found by knowing the wave velocity and density. It is an indicator of stiffness and resistance to shear. Shear modulus is the most obvious indicator of the possible deformation of the soil for an earthquake. It is an important parameter for detecting soil and earthquake-related damages. It is also an indicator of the resistance ability of the soil under lateral forces.

$$G = \frac{\rho * V_s^2}{100}$$

It is calculated using the equation. The maximum shear modulus values obtained by seismic methods were evaluated according to the soil property table which is shown on Table 3.8.

**Table 3.8.** Soil property definitions according to maximum shear modulus (Bowles, 1988).

Gmax (kg/cm <sup>2</sup> )	Soil Property
0-600	Loose Soils
600-3000	Moderately Dense Soils
3000-10000	Dense Soils
>10000	Very Dense Soils

### 3.10. Dynamic Elasticity Module

$V_p$  is determined using  $V_s$  velocities and density. It is an indicator of the hardness and cementation degree of the soil.

$$E_d = \frac{G * V_s^2 * (3 * V_p^2 - 4 * V_s^2)}{V_p^2 - V_s^2}$$

It is calculated using the equation. Dynamic elasticity modulus values obtained by seismic methods were evaluated according to the soil property table which is presented on Table 3.9.

**Table.3.9.** Soil property definitions according to dynamic modulus of elasticity (Bowles, 1988).

<b>Ed (kg/cm<sup>2</sup>)</b>	<b>Soil Property</b>
<b>0-2000</b>	Loose Soils
<b>2000-10000</b>	Moderately Dense Soils
<b>10000-30000</b>	Dense Soils
<b>&gt;30000</b>	Very Dense Soils

### 3.11. Bulk Module

It shows the soil's resistance to compression. It is determined with the help of density and seismic velocities.

$$K = \frac{\rho * [V_p^2 - \left(\frac{4}{3 * V_s^2}\right)]}{100}$$

It is calculated using the equation. Bulk modulus values obtained by seismic methods were evaluated according to the soil conditions which is given on Table 3.10.

**Table 3.10.** Soil condition according to bulk modulus (ASTM,1978).

<b>K (kg/cm<sup>2</sup>)</b>	<b>Compressibility</b>
<b>&lt;400</b>	Very Low
<b>400-10000</b>	Low
<b>10000-40000</b>	Medium
<b>40000-100000</b>	High
<b>&gt;100000</b>	Very High

## **CHAPTER 4**

### **RESULT AND DISCUSSION**

#### **4.1. Introduction**

The study examined various parameters, including Rock Quality Designation (RQD), Compression ( $V_p$ ) and Shear Wave ( $V_s$ ) Velocity, Poisson's Ratio ( $\nu$ ), Seismic Velocity Ratio ( $V_p/V_s$ ), Unconfined Compression Strength, Density ( $\rho$ ), Maximum Shear Modulus ( $G_{max}$ ), Dynamic Elasticity Module ( $E_d$ ), and Bulk Module ( $K$ ).

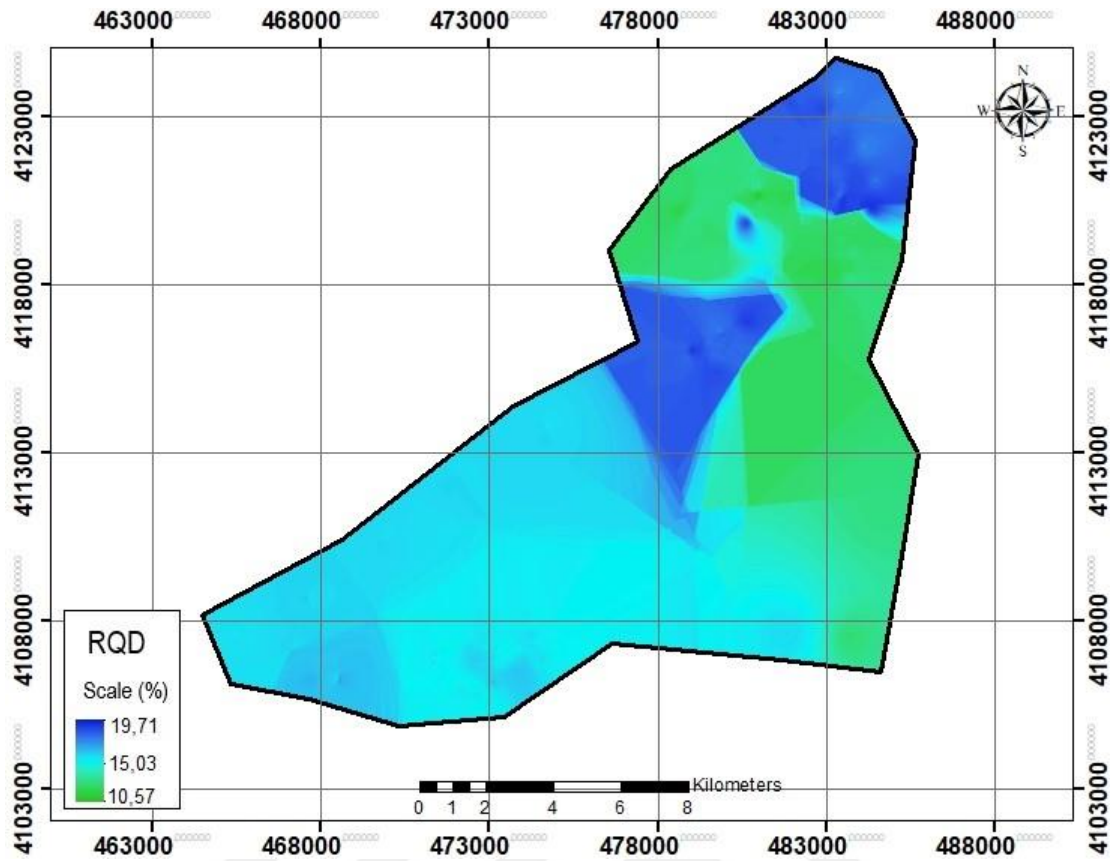
To conduct the evaluations, Geographic Information System (GIS) maps were utilized. These maps were created using ArcGIS, a widely used software for analyzing geographic data, mapping, and geographic information systems. In addition, the IDW method was employed to generate these maps. The IDW method is an interpolation technique that estimates values for non-point locations by considering the relationship between nearby data points. It calculates the estimated value for a point by giving more weight to the values of neighboring points while reducing the influence of more distant points.

#### **4.2. Analysis of Rock Quality Designation Map**

The Rock Quality Designation (RQD) refers to the proportion of solid rock within a sample. It is expressed as a percentage and can range from 0 to 100. A higher RQD value indicates a stronger rock.

The RQD is a significant parameter used to assess the characteristics of a rock mass. It helps determine the rock's strength, stability, and permeability. Consequently, it finds applications in construction, mining, and various geotechnical fields.

To calculate the RQD, data obtained from boreholes, which are pipes used to extract rock samples, is utilized. By measuring the length of solid rock present in the core of the sample, the RQD value can be determined. Map of rock quality designation analysis is given Figure 4.1.



**Figure 4.1.** Map of rock quality designation analysis

The distribution map of Rock Quality Designation (RQD) reveals that the neighborhoods of Batıkent, İpekyol, Eyyüpnebi, and Kendirci exhibit the lowest rock quality grades. In these areas, the rock quality designation ranges from 10.57% to 15.03%.

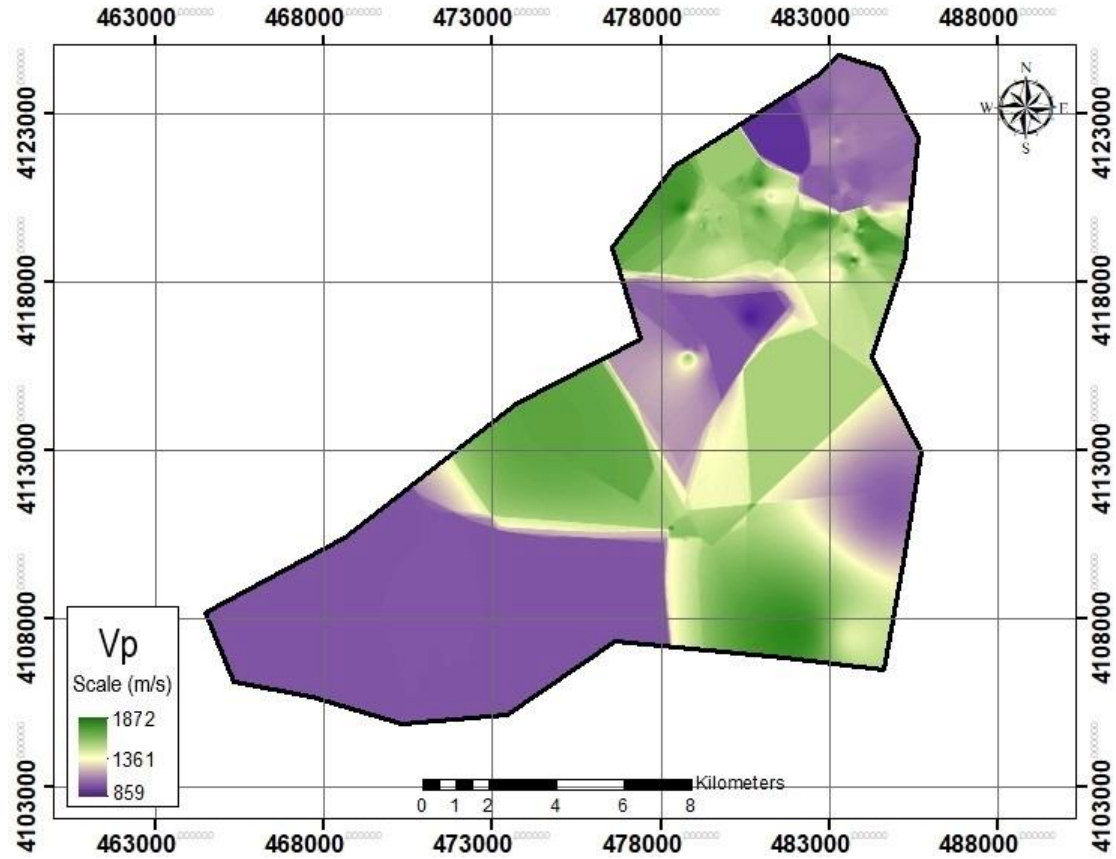
Conversely, neighborhoods like Çamlıyayla, Direkli, and Ahmet Yesevi generally demonstrate higher rock quality grades, with values reaching up to 19.71%.

### 4.3. Analysis of Compression and Shear Wave Velocity Maps

Compression and shear wave velocities are important parameters in geotechnical engineering. These velocities are used to evaluate the mechanical properties of soil, such as strength and hardness.

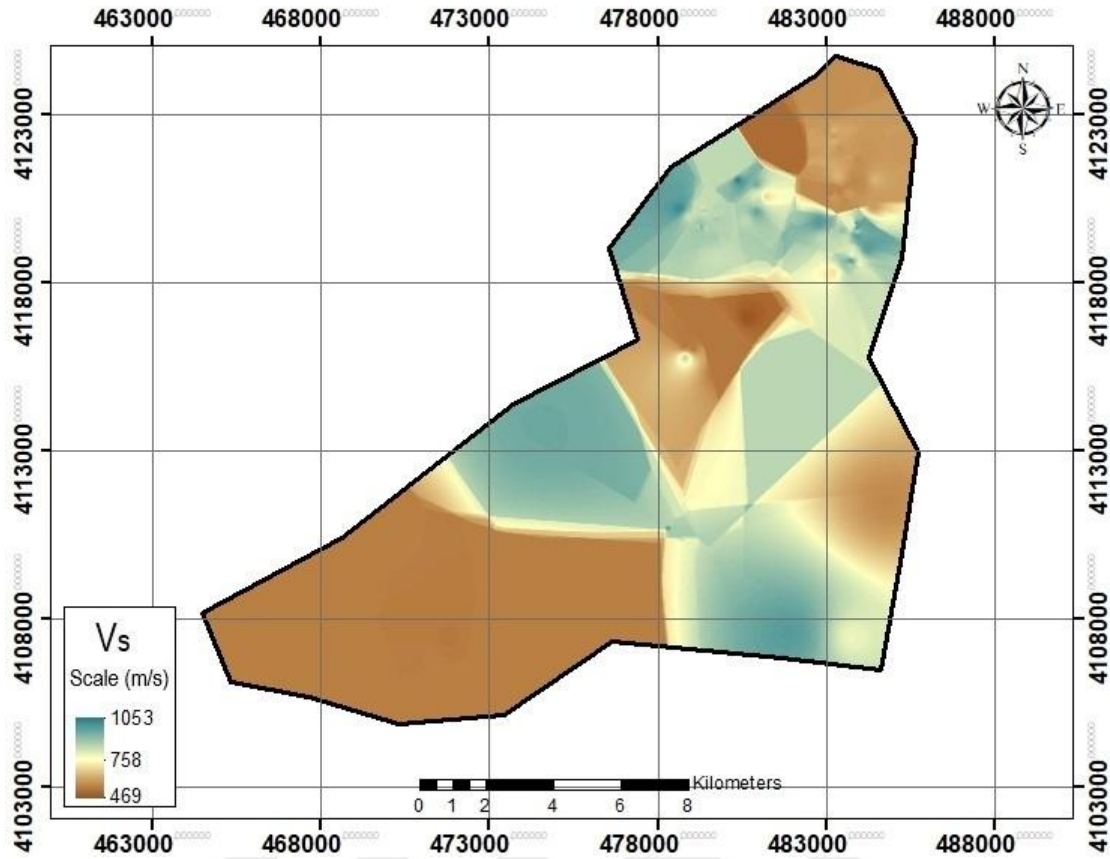
Shear wave velocity is a particularly important parameter in earthquake engineering. It is used to determine soil class, calculate shear modulus and modulus of elasticity at low deformation levels, and evaluate liquefaction potential.

Shear wave velocity is also used to calculate the increase in soil motion caused by soil conditions. Figure 4.2. presents that map of compression (vp) wave velocity analysis.



**Figure 4.2.** Map of compression (vp) wave velocity analysis

According to the compression wave velocity distribution map, the compression wave velocity throughout the study area varies between 859 - 1872 m/sec. Compression wave velocity values around the Ahmet Yesevi, Çalışkanlar and Atakent neighborhoods of the study area are in the range of 859 - 1361 m/sec. Map of shear ( $v_s$ ) wave velocity analysis is given Figure 4.3.



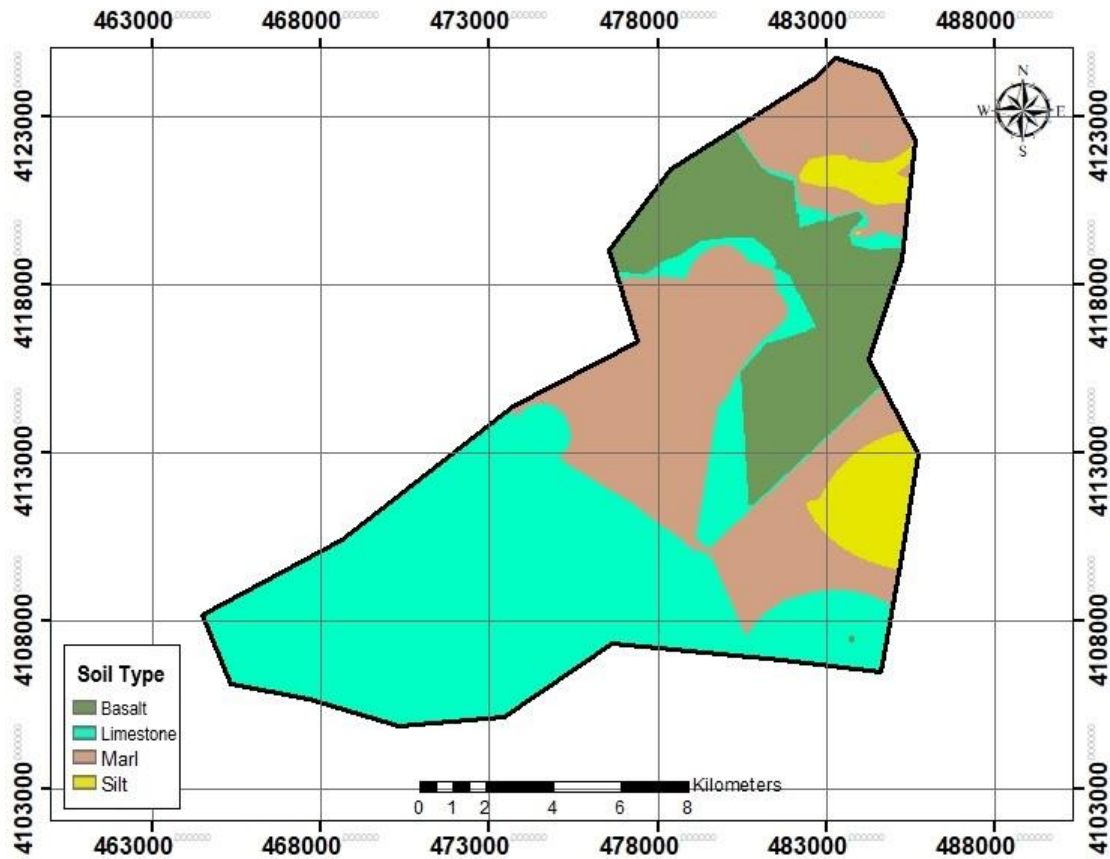
**Figure 4.3.** Map of shear (vs) wave velocity analysis

According to the shear wave velocity distribution map, the lowest shear wave velocity values are seen in the west of the study area and in a large part of Atakent, Çamlıyayla and Güllübağ neighborhoods. In these regions, shear wave velocity varies between 469 and 721 m/sec.

Similar to this study, Karaca, in his study in 2007, investigated the engineering properties of the soils around Fethiye using GIS and created geotechnical maps showing these properties. Likewise, based on the soil seismic amplification map, he evaluated the suitability of the study area for settlement purposes.

#### **4.4. Analysis of Soil Type Map**

Based on the soil map of the central district of Şanlıurfa, a significant portion of the city is comprised of fertile lands. The presence of these fertile lands contributes to the city's status as an important agricultural center. Figure 4.4. is showing map of soil type analysis.



**Figure 4.4.** Map of soil type analysis

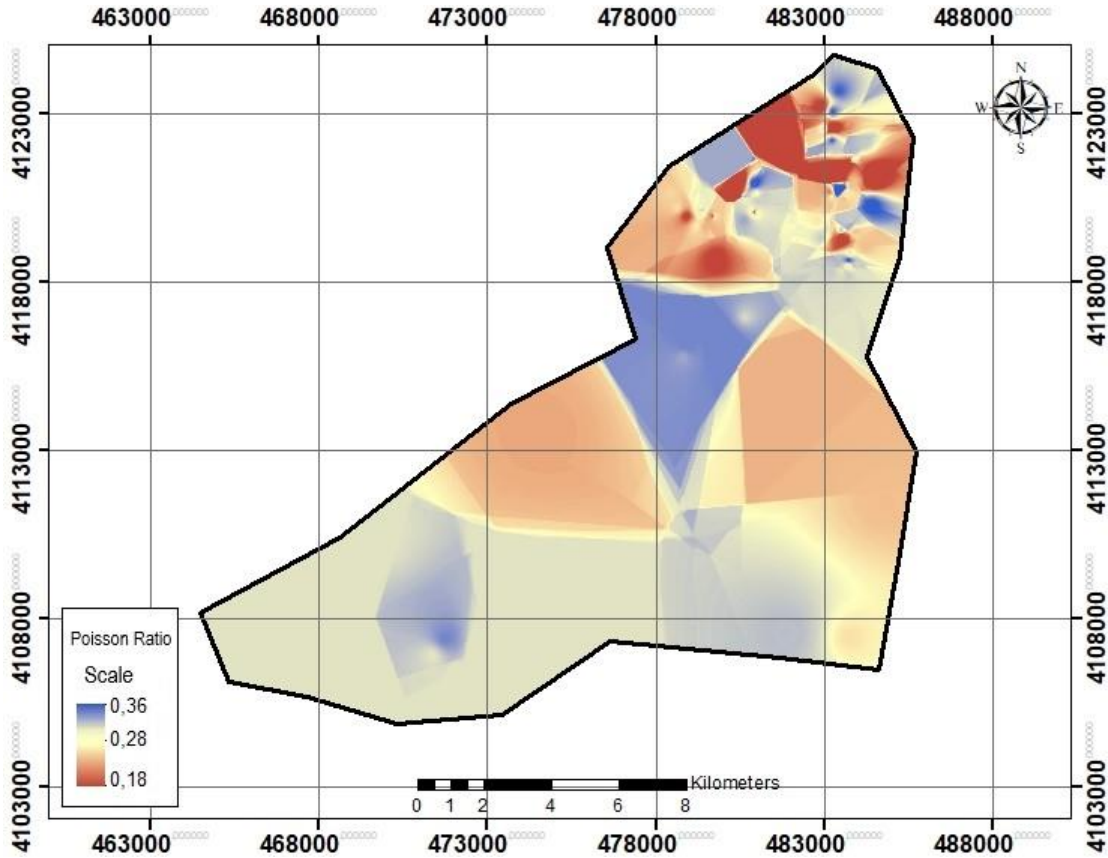
According to the map, rocks such as basalt, limestone, and marl are commonly found in the northern and eastern parts of the city. These types of rocks are known for their mineral richness, which in turn promotes the development of fertile soils. As a result, a diverse range of crops including grains, legumes, vegetables, and fruits are cultivated in these regions.

In the southern part of the city, silt soils are predominant. Although silt soils are generally less fertile, they possess a high capacity for retaining water. Consequently, irrigated agriculture is commonly practiced in these areas.

The soil map of the central district of Şanlıurfa serves as a valuable resource in assessing the agricultural potential of the city. The information provided can be utilized to effectively develop agricultural areas and enhance overall agricultural production.

#### 4.5. Analysis of Poisson Ratio Map

Poisson's ratio is the ratio between the deformation of a material in a unit area and the deformation of the material in a unit volume. It typically ranges from 0 to 0.5. As the Poisson's ratio approaches 0, the material becomes less elastic, and as it approaches 0.5, it becomes more elastic. Figure 4.5. indicates that map of poisson ratio analysis.



**Figure 4.5.** Map of poisson ratio analysis

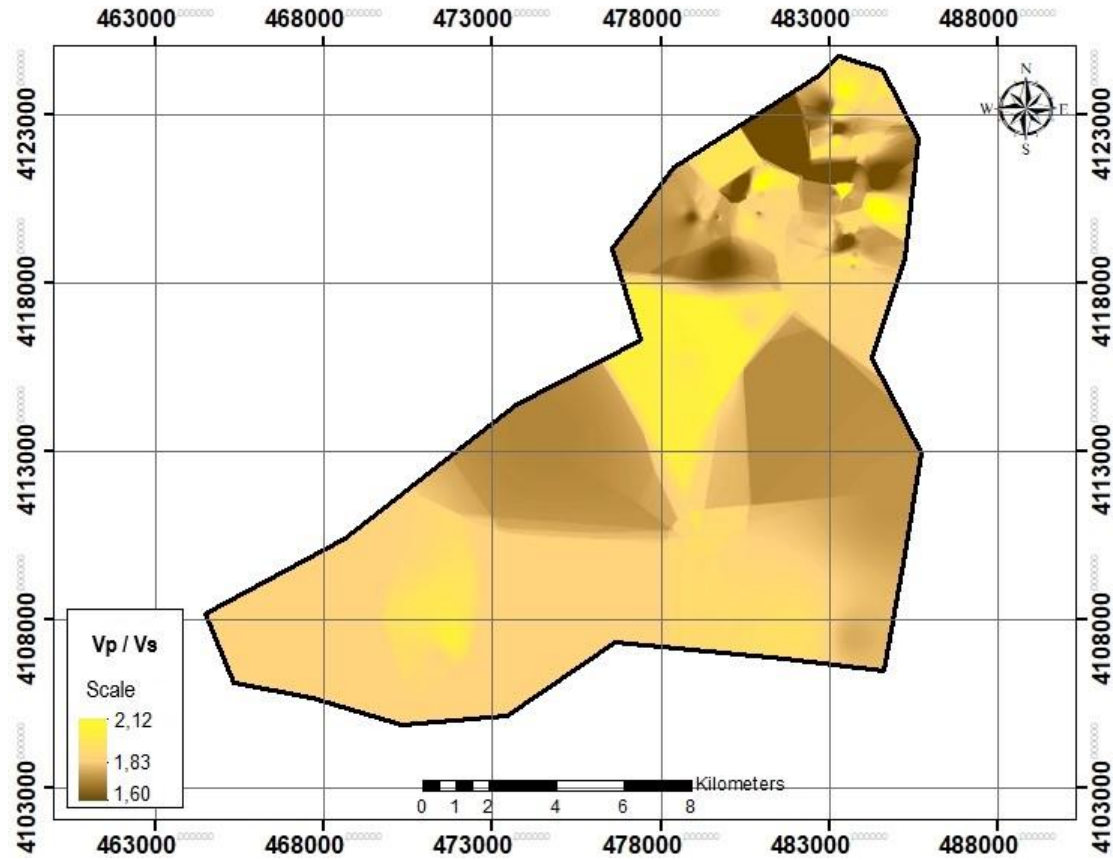
In the central district of Şanlıurfa, the Poisson's ratio varies between 0.2 and 0.4.

According to the Poisson ratio distribution map, the Poisson ratio in the central district of Şanlıurfa varies between 0.2 and 0.4. It is observed that the soil/rock density of Çalışkanlar, Koçören and surrounding neighborhoods is tight-solid, while Direkli and surrounding neighborhoods are very loose.

Çalışkanlar, Koçören and surrounding neighborhoods are compared to other areas of the study area. It has harder rocks than In Direkli and surrounding neighborhoods, the rock density is loose and less strong and more fragile than other regions.

#### 4.6. Analysis of Seismic Velocity Ratio Map

The  $V_p/V_s$  ratio is a significant parameter that indicates the density and strength of soils. Generally, as the  $V_p/V_s$  ratio increases, the soil becomes denser with a higher strength. Map of seismic velocity ratio analysis is given on Figure 4.6.



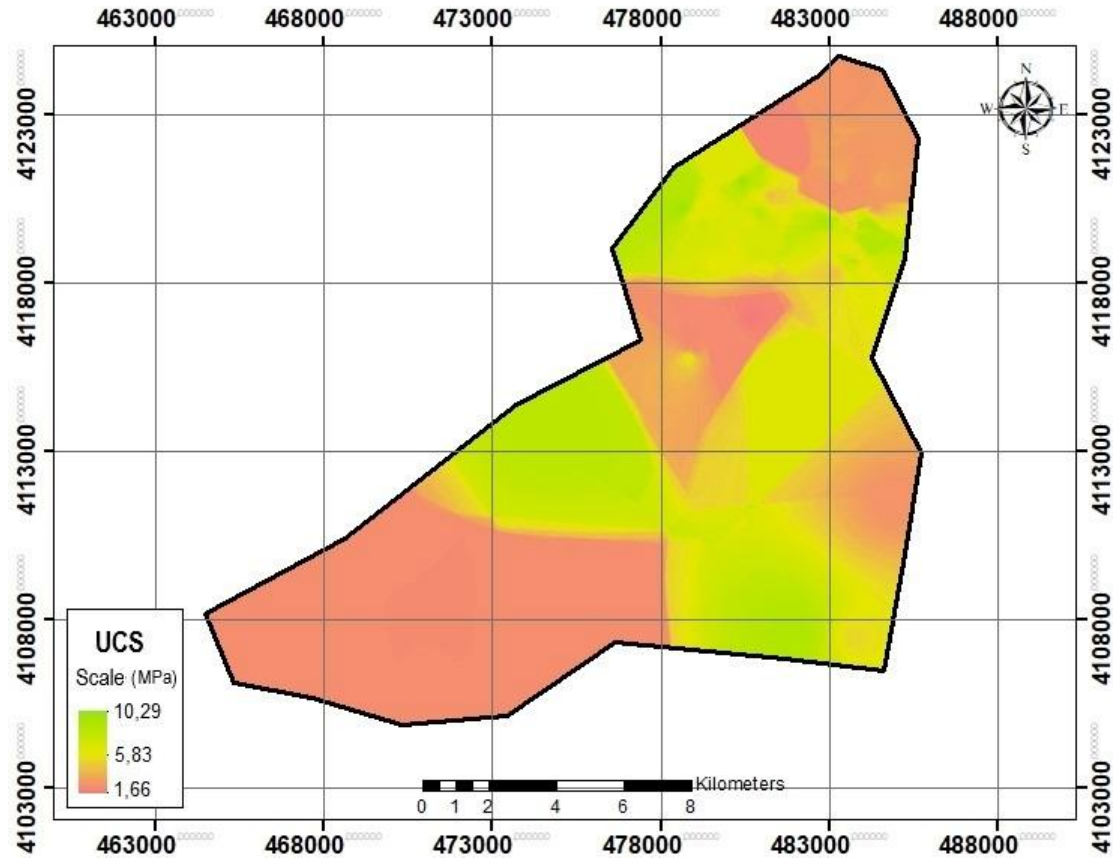
**Figure 4.6.** Map of seismic velocity ratio analysis

In the central district of Şanlıurfa, the seismic velocity ratio varies between 1.60 and 2.12.

According to the seismic velocity ratio map of the central district, the Direkli and Ahmet Yesevi neighborhoods in the southeastern part of Şanlıurfa exhibit a  $V_p/V_s$  ratio ranging from 1.83 to 2.12. This indicates that these regions have a dense and solid soil. In a significant portion of the Batıkent Kurtuluş and Onikiler neighborhoods within the central district of Şanlıurfa, the  $V_p/V_s$  ratio is between 1.60 and 1.83.

#### 4.7. Analysis of Unconfined Compression Strength Map

Unconfined compression strength refers to the ability of a rock or soil to resist shear stress at its culvert. Figure 4.7. is showing the map of unconfined compression strength analysis.



**Figure 4.7.** Map of unconfined compression strength analysis

According to the unconfined compression strength distribution map, unconfined compression strength throughout Şanlıurfa central district, varies between 1.66 and 10.29 MPa. It is observed that the rock strength in the Southeastern region is high, and the rock strength is very high in the Eastern region. Rocks in the southeastern region with high unconfined compression strength are considered more rigid and strong. Therefore, these types of rocks are preferred in the construction of structures such as foundations, tunnels and slopes.

The highest unconfined compression strength is seen in Hacibayram, Kendirci, Tepe neighborhoods. In these neighborhoods, unconfined compression strength varies between 5.83 and 10.29 MPa.

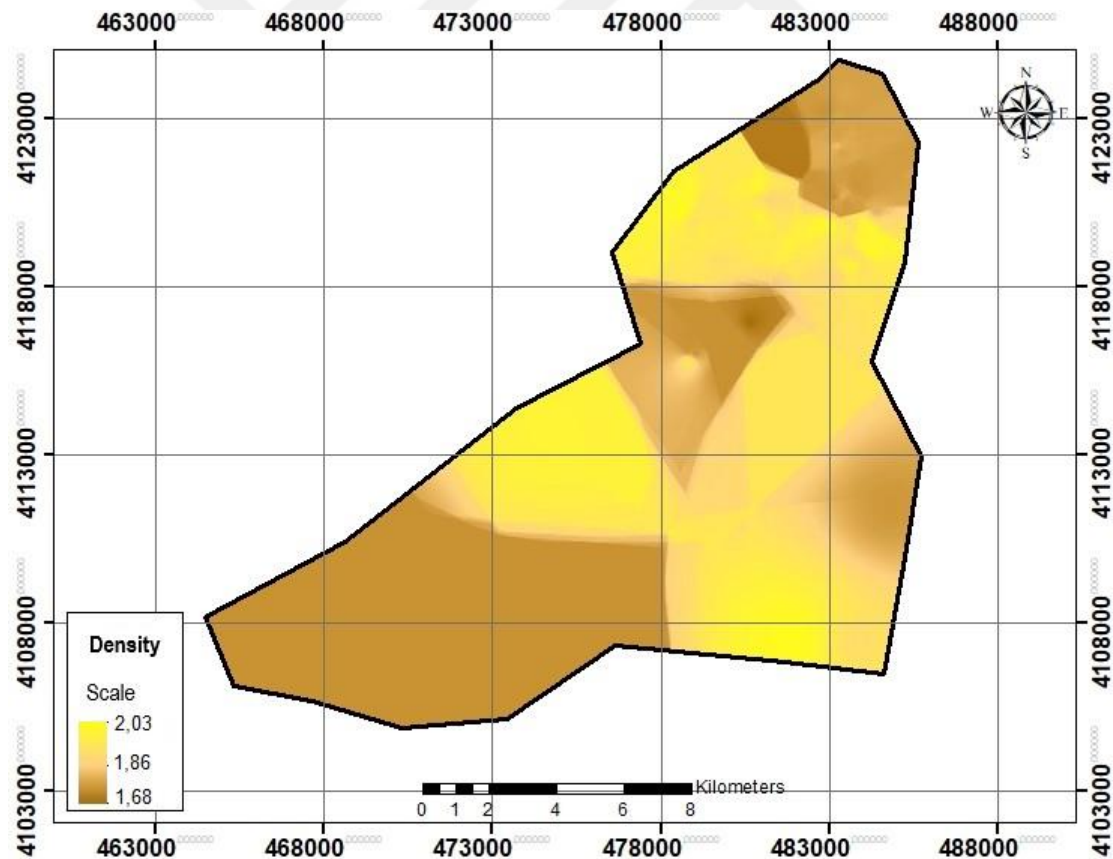
#### 4.7. Analysis of Soil Density Map

Soil density is a measurement of the mass per unit volume of a soil sample, typically expressed in  $\text{g/cm}^3$ ,  $\text{kg/m}^3$  or  $\text{Mg/m}^3$ .

A higher soil density indicates that the unit volume of the soil is heavier, while a lower soil density indicates that the unit volume of the soil is lighter.

The bearing capacity of the soil is directly influenced by its density. Soils with higher density have greater bearing capacity, making them more suitable for supporting structures such as building foundations.

Conversely, soils with lower density have lower bearing capacity and are less suitable for supporting structures. For example, high soil density is important for road construction. Map of soil density analysis is shown in Figure 4.7.



**Figure 4.7.** Map of soil density analysis

According to the density distribution map, the soil density in Şanlıurfa ranges from 1.67 to 2.03 g/cm<sup>3</sup>. The analysis results show that the soil density is at a medium level in areas such as Çalışkanlar, the northern parts of Keberli, the northern parts of Doğukent, and the northeast of the Eyyübiye neighborhood. On the other hand, Batıkent, Türkmevdanı, and Batıkent-Karaköprü neighborhoods exhibit high soil density.

Based on these values, the soil in Batıkent, Türkmevdanı, and Batıkent-Karaköprü neighborhoods has a higher strength, and the regional carrying capacity is higher compared to other areas. These regions are better suited for construction purposes.

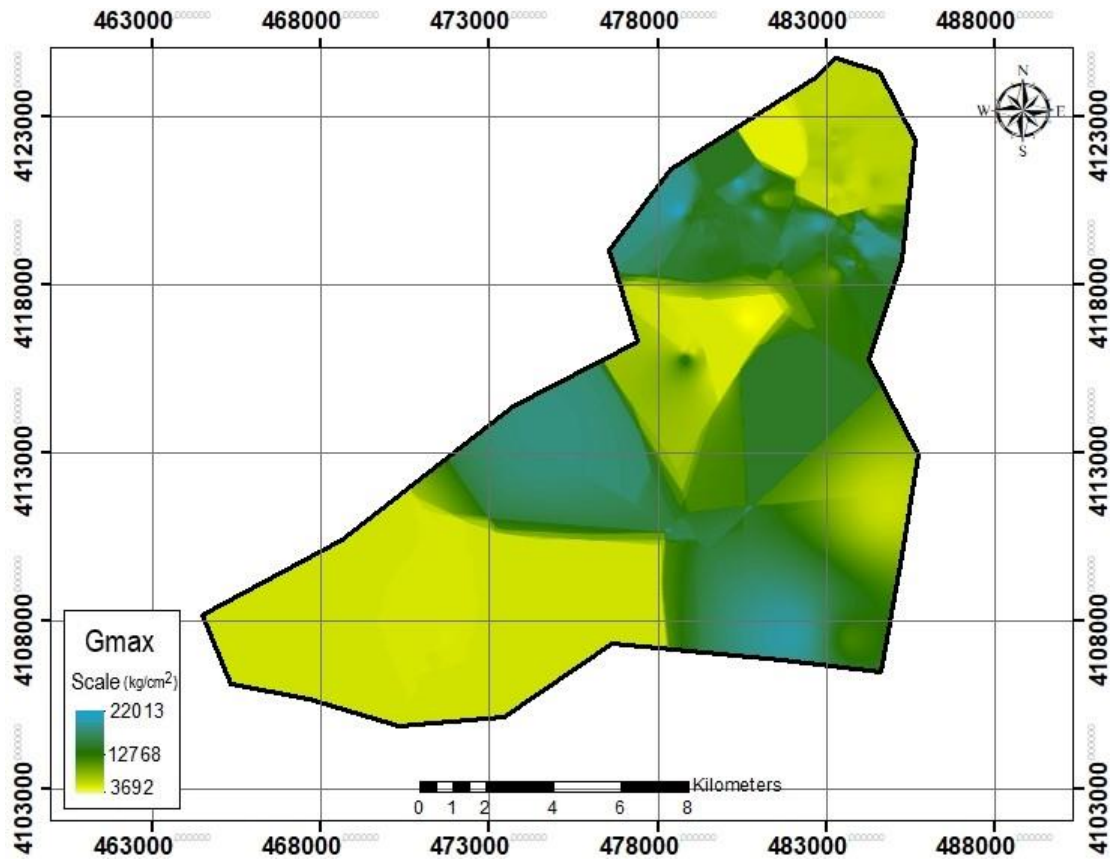
#### **4.8. Analysis of Maximum Shear Modulus Map**

The Maximum shear modulus (G<sub>max</sub>) is a property of soil materials that indicates their resistance to shear stress.

The shear modulus serves as a significant indicator of potential soil deformation during earthquakes. It is a critical parameter for identifying soil and earthquake-induced damages.

Soils with high shear modulus values experience less deformation during earthquakes, while those with low shear modulus values undergo more deformation.

Figure 4.8. is showing the map of soil density analysis.



**Figure 4.8.** Map of maximum shear modulus analysis

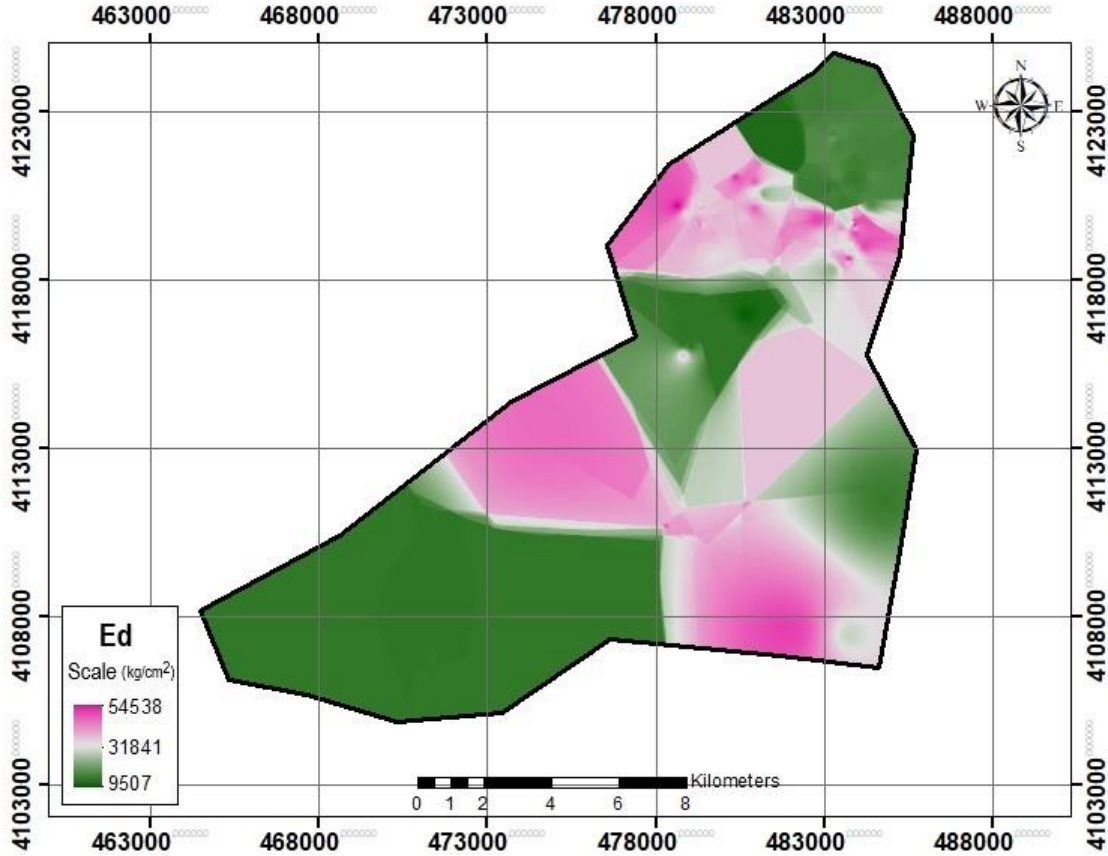
The Maximum shear modulus values in Şanlıurfa vary significantly. The Kadıkendi neighborhood in the southeast of the city central district, as well as the Batıkent and Selçuklu neighborhoods, exhibit higher maximum shear modulus values compared to other areas. This is likely due to the presence of clayey soil in these regions, while other areas have sandy soil.

In the Central district of Şanlıurfa, the Çalışkanlar, Direkli, and Çamlıyayla neighborhoods demonstrate maximum shear modulus values ranging from 3692 to 12768 kg/cm<sup>2</sup>. Based on these values, the bearing capacity and seismic resistance of the soils in these central district areas are relatively low.

On the other hand, the maximum shear modulus values for Batıkent, Eyyübiye, Akbayır, and surrounding neighborhoods located in the southern part of the Şanlıurfa Central district range from 12768 to 22013 kg/cm<sup>2</sup>. The soils in these regions show higher bearing capacity and seismic resistance compared to other neighborhoods.

#### 4.9. Analysis of Dynamic Modulus of Elasticity Map

The Dynamic Modulus of Elasticity ( $E_d$ ) is an indicator of the soil's hardness and level of cementation. Soils with higher  $E_d$  values are harder and more cemented, which means they are more resistant to earthquakes. Map of dynamic modulus of elasticity analysis is shown in Figure 4.9.



**Figure 4.9.** Map of dynamic modulus of elasticity analysis

Throughout Şanlıurfa, the Dynamic Modulus of Elasticity varies from 9507 to 54538 kg/cm<sup>2</sup>, indicating the presence of different soil types in the region, ranging from hard and cemented to soft and less cemented soils.

The areas around Koçören, Çalışkanlar, Keberli, Direkli, and Atakent exhibit a moderate level of solidity. On the other hand, the regions of Doğukent, Selçuklu, and Batıkent display a very solid soil. The soils in these regions are harder and more cemented compared to other areas.

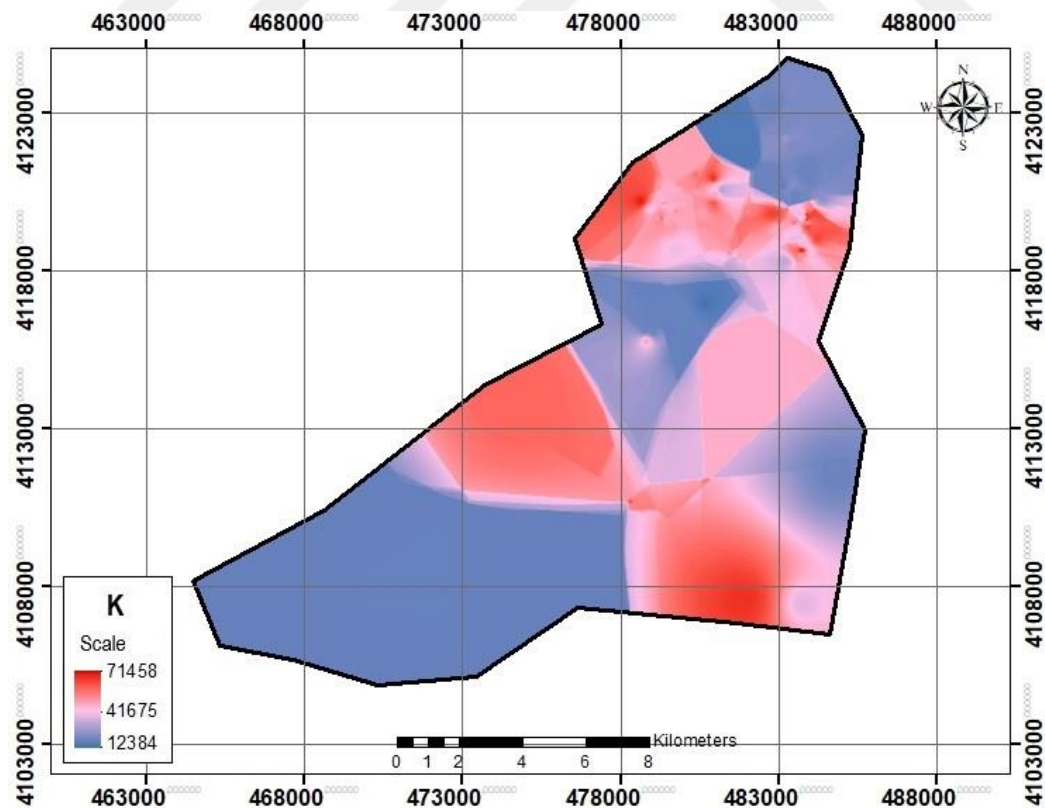
The neighborhoods in Koçören, Çalışkanlar, Keberli, Direkli, and Atakent are generally situated on moderately solid soils, which correspond to a medium level of earthquake risk. In contrast, the neighborhoods in Doğukent, Selçuklu, and Batıkent are generally located on very solid lands, resulting in a lower risk of earthquakes.

Similarly, Kolat, in his study in 2010, created a geotechnical microzonation model to evaluate the suitability of Yenişehir (Bursa) settlement center for settlement. The research involved analysis of the dynamic behavior of the field.

#### 4.10. Analysis of Bulk Module Map

The bulk modulus, which is determined by density and seismic velocities, indicates the soil's resistance to compression. Soils with higher bulk modulus values have greater resistance to compression.

In construction and infrastructure projects, soils with high compression resistance are preferred. These soils are more suitable for building foundations and other structures. Map of bulk module analysis is shown in Figure 4.10.



**Figure 4.10.** Map of bulk module analysis

According to the Bulk Module (K) distribution map, the Bulk Module (K) in the central district of Şanlıurfa ranges from 12384 to 71458 kg/cm<sup>2</sup>. In Şanlıurfa Central district, the neighborhoods of Şenevler, Güllübağ, Eyyübiye, and Çalışkanlar mostly have medium compression resistance, while other neighborhoods show high compression resistance. Soils with high bulk modulus values are more suitable for constructing foundations and other structures.



## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

In this study, a database was created using the data obtained from the geotechnical survey reports in the archives of Şanlıurfa Municipality Planning and Urbanization Directorate. This database allows various analyzes to be made using geotechnical data in the study area located within the borders of Şanlıurfa central district. Analysis Rock Quality Definition (RQD), Compression ( $V_p$ ) and Shear Wave ( $V_s$ ) Velocity, Poisson Ratio ( $\nu$ ), Seismic Velocity Ratio ( $V_p/V_s$ ), Unconfined Compressive Strength, Density ( $\rho$ ), Maximum Shear Modulus ( $G_{max}$ ) It includes Dynamic Elasticity Module ( $E_d$ ) and Bulk Module ( $K$ ) analyses.

The maps produced as a result of these analyzes were designed to make the geotechnical data in the study area more effective and efficient. Maps provide a visual representation of soil properties, seismic hazards, carrying capacity and other important factors. This is an important tool for improving decision-making processes and optimizing planning and design efforts. The results of the research are summarized below:

- a. The geological units seen throughout Şanlıurfa province consist of alluviums, basalts, clayey limestones and marls, from young to old.
- b. RQD values were calculated using data obtained from drilling cores in the study area.
- c. According to the values stated in the maps produced as a result of rock quality analyses, the fact that the RQD in Şanlıurfa is below 25% indicates that it has a weak and unstable rock structure.
- d. According to the rock quality designation distribution map, the lowest rock quality designation values are seen in Batikent, İpekyol, Eyyüpnebi, Kendirci neighborhoods. In Çamlıyayla, Direkli, Ahmet Yesevi neighborhoods, the rock quality designation reaches up to 19.71%.

- e. Maps showing S-wave velocity and P compressional wave velocity show a similar pattern to RQD maps. In a limited part of the study area, compression wave velocity values are in the range of 859 - 1294 m/sec. Shear wave speed varies between 469 and 721 m/sec in the west of the study area and in a large part of Atakent, Çamlıyayla and Güllübağ neighborhoods.
- f. According to the values specified in the maps created as a result of the Soil Type analysis, it is seen that the soil has different properties in different parts of the study area. According to the map, rocks such as basalt, limestone and marl are common in the north and east of the district. Silty soils are seen in the south of the city.
- g. Şanlıurfa Central district, poisson's ratio varies between 0.2 and 0.4 according to the distribution map. The soil and rock density of Çalışkanlar, Koçören and surrounding neighborhoods are solid, while Direkli and surrounding neighborhoods are very loose. Çalışkanlar, Koçören and the surrounding areas have harder rocks compared to other parts of the study area. Since the Direkli region and the rock nearby are loose, it is more fragile and not strong than other regions.
- h. According to the central district seismic velocity rate map, Direkli and Ahmet Yesevi neighborhoods in the southeastern part of Şanlıurfa exhibit a  $V_p/V_s$  ratio varying between 1.83 and 2.12. This shows that these regions have dense and solid soil. The  $V_p/V_s$  ratio is between 1.60 and 1.83 in a significant part of the Batıkent Kurtuluş and Onikiler neighborhoods of the central district of Şanlıurfa.  $V_p/V_s$  ratios are an important parameter that shows the density and strength of soils. In general, as the  $V_p/V_s$  ratio increases, the soil is denser and have a higher strength. Direkli and Ahmet Yesevi neighborhoods in the central district of Şanlıurfa have a higher strength of soil.
- i. The Şanlıurfa central district's unconfined compression strength exhibits spatial variability, ranging from 1.66 to 10.29 MPa. Notably, the rock strength is high in the southeast and very high in the east. Rocks with high unconfined compression strength, indicating superior rigidity and strength, are favored for infrastructure

construction such as foundations, tunnels, and slopes. Hacıbayram, Kendirci, and Tepe neighborhoods demonstrate the highest unconfined compression strength values, ranging from 5.83 to 10.29 MPa.

- j. Based on the density distribution map, the soil density in Şanlıurfa varies from 1.67 to 2.03 g/cm<sup>3</sup>. The analysis indicates that areas like Çalışkanlar, the northern parts of Keberli, the northern parts of Doğukent, and the northeast of the Eyyübiye neighborhood have a moderate soil density. However, the Batikent, Türkmevdanı, and Batikent-Karaköprü neighborhoods have a high soil density. These findings suggest that the soil in Batikent, Türkmevdanı, and Batikent-Karaköprü neighborhoods is more resilient and capable of bearing heavier weights compared to other areas. Therefore, these regions are better suited for construction purposes and have a higher regional carrying capacity.
- k. The maximum shear modulus values of the central districts and neighborhoods located in the north of Şanlıurfa city vary between 3692 and 12768 MPa.
- l. The Kadıkendi neighborhood in the southeast of the city center district, as well as the Batikent and Selçuklu neighborhoods, show higher maximum shear modulus values compared to other areas. This difference can be attributed to the presence of clayey soil in these regions, while other areas have sandy soil. In the Central district of Şanlıurfa, specifically the Çalışkanlar, Direkli, and Çamlıyayla neighborhoods, the maximum shear modulus values range from 3692 to 12768 MPa. Based on these values, it can be inferred that the bearing capacity and seismic resistance of the soils in these central district areas are relatively low.
- m. Dynamic Elasticity Modulus (Ed) throughout Şanlıurfa varies between 9507-54538 kg/cm<sup>2</sup>. This shows that there are various soil types in Şanlıurfa, from hard and cemented soil to soft and less cemented soil.
- n. According to the distribution map of the Bulk Module, K values in the central district of Şanlıurfa vary from 12384 to 71458 kg/cm<sup>2</sup>. In the central district of Şanlıurfa, neighborhoods such as Şenevler, Güllübağ, Eyyübiye, and Çalışkanlar predominantly exhibit medium compression resistance, whereas other neighborhoods demonstrate high compression resistance. Soils with higher values

of Bulk Module are more suitable for constructing foundations and other structures.

- o. This study shows that Türkiye should take precautions against natural disasters, apply appropriate building standards and develop disaster management strategies based on the reality of earthquakes. For this purpose, it is very important to evaluate the soil characteristics of residential areas, reduce disaster damages and determine whether residential areas are safe. GIS analysis can be used to visualize this data on a map and perform more detailed analysis.
- p. Relevant institutions and local governments should support studies on the creation of earthquake hazard maps of residential areas within the scope of the 2012-2023 National Seismic Strategy and Action Plan targets. Dissemination of these studies will allow more research and examination in earthquake risk areas.
- q. The support of local governments is very important to determine the earthquake risk and ensure the safety of settlements. Thanks to these studies, it is possible to understand the soil characteristics of the region, update seismic risk maps and take necessary precautions. As a result, supported studies make an important contribution to reducing disaster damages and understanding earthquake risk.
- r. This study will provide information on soil properties by analyzing the collected data.
- s. The maps created by the study may help us better understand other research in the region. Maps, together with the visual representation of soil features, make it significantly easier to understand soil conditions and inspire future research. It is expected to provide ideas to practitioners and planners during the planning phase. However, considering the variability of geological units and the variability caused by anisotropy, comprehensive point-by-point surveys should also be carried out. In this way, more accurate information can be obtained through more comprehensive and detailed studies about the soil properties of the region

## CHAPTER 6

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