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

Harun TANYERİ

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Supervisor

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by

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Harun TANYERİ

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MASTER THESIS

Supervisor
Assist. Prof. Dr. Nurullah AKBULUT

ABSTRACT

Geographic Information Systems (GIS) is a collection of data that offers features such as analyzing geographical data, querying, visualization, statistical analysis, and spatial analysis. Within the scope of construction areas and urban planning, GIS is used in digital mapping studies, allowing for more effective examination, interpretation, conclusion, and planning of data. This study aims to minimize risks emerging from geotechnical problems, specifically seismic site effects and soft soil properties. Soil survey reports, field and laboratory test results obtained from the archives of Batman Municipality's Directorate of Zoning and Urbanization were used during the study. Geological, geophysical, and geotechnical data obtained from 253 borehole logs within a region of approximately 54 km² of the Central District of Batman Province were analyzed using GIS Inverse Distance Weighting (IDW) method. Engineering properties of soils were examined according to various depths (1.5, 3.0, 4.5, 7.5, 9.0 and 15.0) in the study area. The study included a standard penetration test (SPT), bearing capacity, groundwater level, consistency limits, shear wave velocity (V_S), site dominant vibration period (T_0), and soil classification analyses according NEHRP, EUROCODE-8 and TDBY2018 earthquake regulations. The blow number of the standard penetration test (SPT-N) range from 4 to 50. A total of 1398 soil samples are classified into nine different groups (CH, CL, GC, GM, GW, GW-GM, SC, SM and SW-SM) over a large area. The soil classification clearly indicates that clayey soil samples make up 89% of the study area, demonstrating their dominance. The analysis of shear wave velocity data at a depth of 30 meters revealed that the soil classes in the study area can be categorized as C and B according to the NEHRP and TBDY2018 classification or B and A according to EUROCODE-8. These soil classes are important for evaluating the seismic characteristics of the soil in the study area. Furthermore, the soil in the northern region of Batman is typically loosely packed, while other areas have medium to dense soil. Also, the proximity to the Batman River results in increased groundwater levels and low bearing capacity. In addition, water level beneath the ground ranges from 3.0 to 15 meters, but the highest percentage of water content is found at a depth of 1.5 meters, with a percentage reaching up to 41%. Finally, certain areas in Batman have alluvial soils and a high groundwater level, which increases the risk of liquefaction during earthquakes and for further studies it is crucial to identify and map these areas in the region.
Keywords: Batman, GIS, geotechnics, mapping.

HASAN KALYONCU ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ
İNŞAAT MÜHENDİSLİĞİ BÖLÜMÜ

BATMAN'DAKİ ZEMİNLERİN GEOTEKNİK ÖZELLİKLERİNİN COĞRAFİ BİLGİ SİSTEMİ İLE DEĞERLENDİRİLMESİ

Harun TANYERİ

YÜKSEK LİSANS TEZİ

Danışman
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ÖZET

Coğrafi Bilgi Sistemleri (CBS), coğrafi verileri analiz etme, sorgulama, görselleştirme, istatistiksel analiz ve mekansal analiz gibi özellikler sunan bir veri kümesidir. İmara yeni açılacak alanlar ve kentsel planlama öncesinde, CBS verilerin daha etkili bir şekilde incelenmesine, yorumlanmasına, sonuç çıkarılmasına ve planlanmasına olanak tanır. Bu çalışma, sismik zemin etkileri ve yumuşak zemin özellikleri konusunda geoteknik sorunlardan kaynaklanan riskleri en aza indirmeyi amaçlamaktadır. Tez çalışmasında Batman Belediyesi İmar ve Şehircilik Dairesi'nin arşivlerinden elde edilen zemin etüd raporları, saha ve laboratuvar deney sonuçları kullanılmıştır. Batman İli Merkez İlçesi yaklaşık 54 km² lik bir bölgeden elde edilen 253 sondaj verisinden jeolojik, jeofizik ve geoteknik veriler, CBS Ters Mesafe Ağırlıklı Enterpolasyon (IDW) yöntemi kullanılarak analiz edilmiştir. Zeminin mühendislik özellikleri çalışma alanındaki çeşitli derinliklere (1,5, 3,0, 4,5, 7,5, 9,0 ve 15,0) göre incelenmiştir. Tez çalışması, standart penetrasyon deneyi (SPT), taşıma kapasitesi, yeraltı su seviyesi, kıvam limitleri, kayma dalgası hızı (V_S), hâkim titreşim periyodu (T_0) ve NEHRP, EUROCODE-8 ve TDBY2018 deprem yönetmeliklerine göre zemin sınıflandırma analizlerini içermektedir. Standart penetrasyon deneyi vuruş sayısı (SPT-N), 4 ile 50 arasında değişmektedir. Toplamda 1398 zemin numunesi incelenmiş olup, dokuz farklı gruba (CH, CL, GC, GM, GW, GW-GM, SC, SM ve SW-SM) ayrılmıştır. Ancak zeminlerin sınıflandırılması, kil içeren zemin örneklerinin yaklaşık %89 olduğunu ve çalışma alanında kil zemin yapısının baskın bir özellik olduğunu göstermektedir. 30 metre derinlikteki kayma dalgası hızı verilerinin analizi, çalışma alanındaki zemin sınıflarının NEHRP ve TDBY2018'e göre sınıflandırmasına göre C ve B veya EUROCODE-8'a göre B ve A olarak kategorize edilebileceğini ortaya koymuştur. Bu zemin sınıfları, çalışma alanındaki zeminin sismik özelliklerini değerlendirmek için önemlidir. Ayrıca Batman'ın kuzeyindeki zeminler genellikle gevşek yapıda olup diğer alanlarda ise orta sıkı ile sıkı zeminler bulunmaktadır. Batman Nehri'ne yakınlık, yeraltı su seviyesini artırırken taşıma kapasitesini düşürmektedir. Yeraltı su seviyesi 3,0 ile 15 metre arasında değişmektedir, ancak en yüksek zemin numunesi su içeriği %41 ile 1,5 metre derinlikte bulunmaktadır. Batman'daki bazı bölgeler alüvyal zeminlere ve yüksek yeraltı su seviyelerine sahiptir, bu da depremler sırasında sıvılaşma riskini artırır. Bu alanları bölgede belirlemek ve haritalamak için ileri çalışmalar yapmak oldukça önemlidir.

Anahtar Kelimeler: Batman, CBS, geoteknik, haritalandırma.

My precious family …..

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ABBREVIATIONS OR SYMBOLS LIST

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BSSC	Building Seismic Safety Council
E	Modulus of Elasticity
FEMA	Federal Emergency Management Agency
G	Shear Modulus
g	Gravitational acceleration (cm/s^2)
GIS	Geographic Information System
IDW	Inverse Distance Weighting
JRC	Joint Research Centre
Md	Dry mass of sample
Mw	Wet mass of sample
NEHRP	National Earthquake Hazard Reduction Program
P_I	Plasticity index
q_a	Bearing capacity for allowable bearing capacity (kN/m^2)
q_u	Ultimate Bearing capacity (kN/m^2)
SPT	Standard Penetration Test
To	Soil dominant vibration period (sec)
USCS	Unified Soil Classification System
Vp	Compression wave velocity (m/sec)
Vs	Shear wave velocity (m/sec)
$V_{S,30}$	Average shear wave velocity at 30 m depth
w	Water content value
W_L	Liquid limit
W_P	Plastic limit
W_S	Shrinkage limit
w_w	Water mass value
γ	Unit weight (kN/m^3)
μ	Poisson Ratio
σ	Stress (kN/m^2)

CHAPTER 1

INTRODUCTION

1.1. General

From the perspective of Geotechnical Engineering, the accurate determination and investigation of soil parameters are of great importance due to the direct contact of engineering structures with the soil. These parameters are significant factors that determine the reliability and cost of engineering structures. However, our knowledge about soil is limited, and we do not have the ability to fully control soil behavior. This is why accurate soil property determination plays a key role in the construction and design process of engineering structure. (Shaik, 2007).

The increasing population today has also increased the rate of construction. This situation leads to the need for more structures including high-rises, dams and ports, as well as bridges. These needs further emphasize the importance of determining soil properties and investigating soil behavior, which is the most critical stage of construction work.

Soil properties are determined using field test methods, laboratory test methods and geophysical methods. Each method of determining soil properties has its own advantages as well as limitations. Therefore, there are various disadvantages as well as advantages of field and laboratory test methods in determining soil properties. In this context, examining the results of all three test methods together will be the most appropriate approach to determining soil parameters (İyisan, 1994).

In geotechnical engineering, various methods are used in the field to determine soil properties. These methods include taking disturbed and undisturbed soil samples. Undisturbed samples are soil samples taken directly from the field. However, even in the case of undisturbed soil sampling and laboratory testing, these samples may still experience some degree of disturbance. These samples are subjected to various tests in the laboratory to obtain information about soil properties. Sampling in cohesive soils is relatively straightforward, whereas in non-cohesive soils it is more expensive as it requires special techniques and equipment. Therefore, geophysical methods are also used when the desired samples cannot always be obtained for each soil type (İyisan, 1994).

Geophysical methods aim at obtaining information about the internal structures of soils through the measurement of their electrical and magnetic properties using various instruments on the field. These methods are relatively economical and environmentally friendly as they provide rapid results without the need for soil sampling, but their sensitivity is lower compared to field and laboratory testing methods and can vary depending on field conditions. Results from geophysical methods are also less accurate than those obtained from samples tested under laboratory conditions (İyisan, 1994).

The aim of this study is to show that the soil properties determined by laboratory tests, field tests and geotechnical engineering can be used more effectively in soil engineering. GIS allows the collected data on soil properties to be visualised and managed on maps, making it easier to understand. As a result, rapid assessment of soil properties can be beneficial in construction works, ensuring that they are used effectively and efficiently.

As a result, the use of GIS is a significant convenience for the more effective and efficient application of soil properties in the field of engineering. GIS allows us to easily evaluate the soil properties at any point within our work area, while seamlessly incorporating additional information into maps created, which results in time, labour, and cost savings when performing construction works. This study seeks to create a database by compiling parameters related to soil properties using GIS technology.

1.2. Aim of the Study

In this study, Batman Municipality conducted research to determine the bearing capacity, liquefaction potential, shear wave velocity ($V_{S(30)}$), Standard Penetration Tests (SPT), groundwater level, consistency limits, natural water content, and sieve analysis results of the soil. Soil classification analyses were also carried out according to NEHRP (USA) Earthquake Regulation and EUROCODE-8, and local soil class analyses were conducted based on earthquake hazard level analyses according to soil amplification calculation. The data from these studies was transferred to digital media and a database for the study area created. This database was used to create digital maps for various purposes.

In this context, ArcGIS software has been used for the application of geographic information systems in geotechnical engineering. It is thus aimed at using geotechnical information more effectively and efficiently in engineering studies.

1.3. Outline of the Thesis

Chapter 1 - Introduction: This chapter compares and contrasts the methods used to determine soil properties. It discusses the advantages of the methods used to determine soil properties, their limitations and the ease with which the results of these methods can be transferred to GIS.

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 Standard Penetration Test (SPT), Bearing Strength Analysis, Compression wave Velocity (Vp), Shear Wave Velocity (Vs) Analysis, Sieve Analysis, Soil Amplification Calculations, Soil Prevailing Shifting Period, ($V_{S(30)}$) Shear Wave Velocity and NEHRP, EUROCODE-8 and TBDY Analysis, Consistency Limits, Unified Soil Classification System (USCS), Water Content and Groundwater Levels.

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 highlights previous Geographical Information System (GIS) studies and describes general characteristics of the study area such as its geographical location, geology and seismicity as well as providing details regarding GIS.

2.2. Geographic Information Systems

2.2.1. Definition of geographical information systems

Technological advances have facilitated the storage of data in digital environments, leading to the need for systems based on data and information management, which can be referred to as "information systems". The purpose of these systems is to systematically collect, process and transform data into meaningful information. As a result, they aim to accelerate and facilitate the process of decision-making. (Yomralıoğlu, 2000).

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

GIS can be used and defined in different ways by different disciplines. In general, however, it is a software that enables the collection, analysis, modelling and visualisation of data related to a specific location. These systems are designed to address complex planning and management issues and have attracted considerable interest across a range of sectors in recent years. (Töreyen et al., 2010).

2.2.2. Historical development of the geographical ınformation system

GIS originated with the emergence of people's needs for visual elements such as thematic maps and graphical schemes. During the 18th and 19th centuries, pioneering work was carried out in different geographical regions to solve different problems. These works are considered to be the first studies in the field of GIS. Examples include Louis-Alexandre Bertheir's 1781 Yorktown Battle Movement Map, Charles Dupin's 1819 France Population Density and Crime Maps, and John Snow's 1854 London Cholera Outbreak-Water Source Relationship Map. Similarly, John Snow mapped the locations of cholera deaths and water pumps in London and realised that most cholera deaths occurred in houses that received water from the Broad Street pump. He stopped using the pump, preventing the cholera outbreak from spreading (Çabuk 2015; Uyguçgil 2011; Vinten-Johansen et al. 2003).

The foundation GIS were laid between 1958 and 1961 in the Department of Geography, University of Washington through a computer-based study aimed at accelerating data access. In 1963, Roger Tomlinson founded GIS under the name Canadian Geographic Information System with two main objectives: first, to store and analyse Canada's inventory of land data, and second, to generate statistical data for use in land management plans (Çabuk 2015).

The first known mapping program, developed in a Harvard University laboratory in 1965 and called Synagraphic Mapping System (SYMAP), was widely used worldwide until the 1990s. Today, many GIS software programs have been developed, of which ArcGIS is the most widely used. ArcGIS developed by Environmental Systems Research Institute in Redlands (California), a nonprofit organization founded 1969. (Coppock & Rhind, 1991).

2.2.3. Advantages of GIS

As computing technology has advanced, GIS tools have evolved, and layer overlay methods, map production processes, and other processes that used to take days in the past have now become faster and easier thanks to computer software. GIS is used in many different sectors based on decision-making processes and is an important tool for solving different problems and improving areas. For this reason, GIS is used not only in the field of planning but also in many other fields such as environmental protection, agriculture, cultural heritage, mapping engineering, geology, earth sciences, sociology, and logistics (Özcan et al., 2021).

GIS offers many advantages to its users in many different areas. The facilities provided by Geographic Information Systems can be summarized as follows:

1. It simplifies the process of data collection and analysis by making it easier to collect, store, analyse and visualise data.
2. It provides support in decision-making processes with the analysis and visualization of data and can be used as a decision support system.
3. It provides fast and easy access to data and makes it possible to update data easily, thus increasing data accessibility.

4. Thanks to the electronic storage and analysis of data, it accelerates workflows by increasing time and cost efficiency.

5. GIS is adaptable and customizable to meet different needs in different areas, thus increasing its adaptability.

6. GIS increases collaboration between different departments and organizations by facilitating the sharing of data and facilitating collaboration.

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

GIS is an information system created for analyzing, storing, updating, and querying the geographical locations of literary and vectorial data. It visualizes GIS data on the map and provides the opportunity to analyze it by combining geographical data with other data. GIS data are stored as points, lines, or areas whose geographical locations are defined by a specific coordinate system. This system consists of software, hardware, data, and personnel and provides secure storage and archiving of spatial data (Küpçü et al., 2015). GIS components are presented in Figure 2.1.

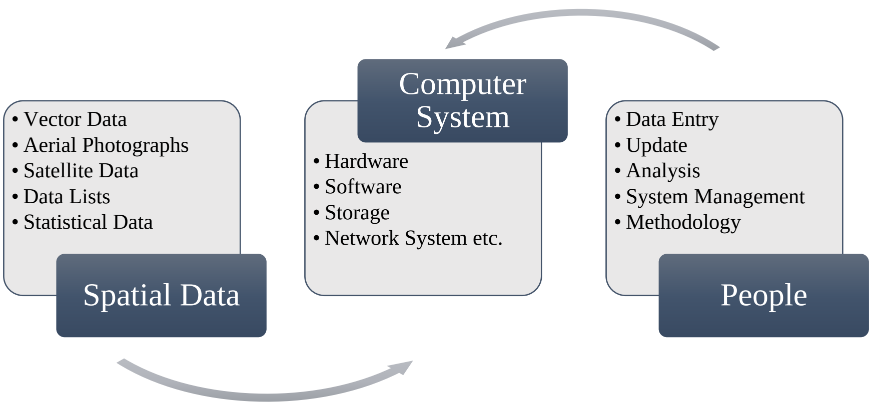


Figure 2.1. A view of CBS components (Küpçü et al., 2015).

2.2.5. Usage areas of GIS

GIS an information system, is used to collect and store geographical data, as well as analyze, manage, present, and manage it. GIS is used in many areas. Some application areas are as follows:

1. City Planning: GIS helps urban planners analyze geographical data and improve their planning. In this application area, GIS benefits from many data sources, such as transport, population, infrastructure, green areas, and social activities. For example, in urban planning applications, it is possible to analyze factors such as population density, traffic flow, and green areas using GIS and make urban planning decisions based on these data.
2. Agriculture: GIS is a useful method to collect, analyse and manage data for the health sector. In this application area, GIS includes data such as land use, water resources, vegetation cover, soil analysis, and weather forecasting.
3. Disaster Management: GIS helps in damage reduction and emergency response in natural disasters. In this application area, GIS performs risk analysis, emergency planning, and damage assessment using geographical data. In crisis management applications, it is possible to analyze factors such as disaster risks, locations of emergency teams, and locations of health facilities and prepare emergency plans using GIS.
4. Health: GIS is used for the collection, analysis, and management of data used in the health sector. In this application area, GIS includes data such as the spread of epidemics, population health, and disease maps. In the health sector, it is possible to analyze factors such as the spread of diseases, the layout of hospitals, population density, and the creation of health policies using GIS.
5. Geology: GIS is used to collect, analyse and manage geological data. In this application area, GIS includes data such as underground resources, volcanic activity, seismic activity and rock types.

In addition to these application areas, GIS is used in many different fields. For example, forestry, tourism, the energy sector, the military, and archaeological research are just a few of these application areas.

2.3. Geotechnical Studies Related with GIS

Many studies have been carried out in different fields related to GIS. Some examples of these are presented below.

Dai and Lee, (2001) developed a method to determine landslide susceptibility on Lantau Island by using geographic information systems techniques. To establish the landslide susceptibility within the scope of this study, several variables including lithology, slope direction, elevation, land cover and distance from drainage lines - commonly referred to as terrain characteristics - were evaluated. A series of suitability analyses was then carried out combining this data with actual landslide event records.

Haşimoğlu and Murat, (2004), conducted a study in the settlement area of Yoncalı Thermal Springs, located within the boundaries of Kütahya Municipality, where satellite imagery and Geographic Information System techniques were used to digitize settlement areas, roads, streams, and culverts as separate geographic data layers and create maps. These maps incorporate various layers, such as applied zoning plans, geological formations and fault lines as well as soil survey data. This study sought to create a "Soil Survey Information System" using all of the data obtained through this investigation.

Kunapo vd., (2005) developed a novel approach that integrates Web-GIS with relational database management system for the potential use of geotechnical data by the construction industry via the Internet. The study offers easy-to-use tools to locate data on the map related to boreholes that are of interest using search tools and geotechnical space queries. This system gives users access to digital data which is crucial for the planning of construction projects.

Orhan, (2005) attempted to determine in a research the geotechnical property of the southern portion of the Eskisehir Urban Area. Geological, geomorphological, and tectonic data related to the area were collected and transferred to a computer environment as a result of borehole logs carried out in the region. These data were used to determine the geotechnical properties of the basic units in a limited area within the boundaries of the study area by creating a database and geotechnical engineering map in GIS environment.

Şişman, (2006) evaluated the liquefaction potential of soils in the Fethiye settlement area using SPT and shear wave velocity data. In this study, the liquefaction potential after a scenario earthquake was investigated in the settlement area of Fethiye district, Muğla province. Liquefaction analyses were performed by measuring SPT-N blows and the shear wave speed. Potential liquefaction maps based upon the liquefaction strength risk index were also prepared.

Karaca, (2007) determined engineering properties of soils around Fethiye using geographic information systems and produced geotechnical mapping showing these properties. These maps show slope, liquefaction potential, depth of groundwater from the surface, groundwater level, vibration period, ground seismic amplification, and elastic wave velocities in soil layers. Based on these maps, the author assessed the suitability of the study area for settlement.

Kolat, (2010) conducted a study to develop a geotechnical microzonation model for assessing the suitability of the Yenişehir (Bursa) settlement center for settlement. The study involved investigating the soil properties and dynamic behavior of the area, as well as evaluating soil classification, soil amplification, dominant soil period, resonance phenomenon, and liquefaction potential using borehole data and microtremor measurements. The liquefaction potential of the study area was evaluated both in a two-dimensional planar and a three-dimensional volumetric manner. Based on the findings, geotechnical microzonation maps were created for the study area to assess the suitability of the settlement center for settlement.

Avin, (2011) used the ArcGIS program to locate geological and geotechnical data, including soil classifications according to EUROCODE-8, groundwater levels and formation status, bearing capacity, soil safety stresses, and settlement values obtained in previous studies conducted by Balkesir Municipality, on cadastral maps provided by the municipality. The distribution of the data on the cadastral map was determined using the ArcGIS program.

The study by Wan-Mohamad and Abdul-Ghani, (2011) aimed to provide valuable information for planners, architects, and engineers in designing safer and more cost-effective structures in Seri Iskandar, District of Perak Tengah, Perak, Malaysia. To achieve this, the authors analyzed soil types and Standard Penetration Test (SPT) values at various depths through field and laboratory tests and presented the results in the form of maps. The maps can be used as a reference to determine the soil conditions in the area, which can aid in making informed decisions during the design and construction phases of a project.

Özcan, (2012) investigated the geological-geotechnical properties of the soil in the Selçuklu district of Konya province. In the study, the author prepared a geological map of the study area by integrating various sources of data, including field observations, previous studies, and borehole logs data. To determine the physical properties of the soil in the study area, soil samples were collected and subjected to various laboratory tests, including sieve analysis, water content, unit weight, and specific gravity tests. The results of these tests were used to gain a better understanding of the soil properties and characteristics in the study area, which can be useful for planning and designing various engineering projects. In addition, consolidation, triaxial compression, and uniaxial compression tests were carried out to determine mechanical parameters. Based on these tests, the soil classes in the study area and the geotechnical structure of the soil in the region were analyzed by examining representative soil samples.

Demir, (2013) created a database using geological, geophysical, and geotechnical data from 131 soil survey reports in the settlement area of Gürsu (Bursa). Geotechnical maps were created using GIS software to show the variation of basic soil properties and to make quick, economical, reliable, and applicable decisions for land use in the area. The maps produced in the study consist of various types of information related to the study area, including slope, vegetation depth, groundwater level and elevation, soil type based on the Unified Soil Classification System, standard penetration test data, shear wave velocity, compression wave velocity, and seismic velocity ratio. These maps provide a comprehensive understanding of the physical and geotechnical characteristics of the study area, which can be useful for various applications such as land use planning, engineering design, and disaster mitigation planning.

Cabalar et al., (2019) conducted a study to investigate the liquefaction potential in the city of Kahramanmaraş, located in south-central Turkey on the East Anatolian and Dead Sea fault lines. The study involved geotechnical investigations that were carried out both in the field and in the laboratory. A total of 238 boreholes were boreholeed in the city, and soil samples obtained from these boreholes were subjected to standard penetration tests to determine their physical properties, including sieve analysis, Atterberg limits, and soil classification. The liquefaction potential of the soil was evaluated based on the SPT results and a hypothetical earthquake scenario with a magnitude of 7.5. The results of the study revealed that the southern parts of the city have a high liquefaction potential, whereas the northern parts are generally in the non-liquefaction zone. The authors used Geographical Information System-based computer software to map the results, and these GIS maps can be effectively used by researchers and engineers for advanced studies in land use planning and urban development.

In the study conducted by Karabaş, (2019), data obtained from soil survey reports conducted at 192 borehole logs points in the study area were analyzed using geographic information system analysis. The study conducted by the author involved several 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 create maps that can be used for land use planning and urban development. These maps provide detailed information about the physical and geotechnical characteristics of the study area, including soil properties, earthquake hazard levels, and liquefaction potential, which can be useful for engineers and planners in making informed decisions about development and construction projects in the area.

In the study conducted by Demirtaş (2022), soil index properties, soil classification, and bearing capacity calculations were performed using 210 borehole logs in Elazığ province. In addition, soil classification maps, groundwater, water content, shear wave velocity, compression wave velocity, and soil amplification maps were produced using ArcGIS software with the IDW method. Demirtaş said these maps could be useful for preliminary studies, feasibility studies, land use policy, urban planning, and design, and could accurately and easily show the distribution of different soil properties.

In the study carried out by Göksular, (2022), geotechnical data obtained from 178 boreholes in the city of Siirt was used to produce maps of soil classification, bearing capacity, shear wave velocity, soil amplification, and dominant vibration period using a geographic information system. In addition, bearing capacity calculations were performed using four different methods based on geophysical and geotechnical approaches. The study also calculated and compared shear wave velocity values, taking into account different approaches and formations in the literature.

CHAPTER 3
MATERIALS AND METHODS

3.1. Introduction

In order to assess the suitability of the approximately 54 km² area within the borders of the Central District of Batman Province for settlement, the studies carried out within the framework of the geological survey reports prepared on the basis of 253 geological-geotechnical borehole logs were used within the framework of this thesis study.

This chapter provides a detailed description of the methods used. General information such as the geographical location, geological characteristics, and seismicity of the study area is also given. Standard penetration tests, liquefaction potential, natural water content, consistency limits, sieve analysis, groundwater level, Unified Soil Classification System (USCS) soil classification, bearing capacity, and shear wave velocity were investigated at depths of 1.5 m, 3 m, 4.5 m, 7.5 m, 9 m, and 15 m in the study area. In addition, shear wave velocity (Vs30), soil classification according to the National Earthquake Hazard Reduction Programme (NEHRP) and the European Union Earthquake Code (EUROCODE-8), seismic hazard level according to soil amplification, and local soil class according to predominant vibration period were investigated.

GIS maps were produced using the ArcGIS programme and 10m square maps were produced using the IDW method.

3.2. General Characteristics of the Study Area

3.2.1. Geographical location and morphology

Until 1990, Batman was a district of Siirt province. On May 16, 1990, with Decree No. 3647, it became the 72nd province of Türkiye by including the districts of Hasankeyf and Gercüş from Mardin province, and Beşiri, Kozluk, and Sason from Siirt province. It covers an area of 4,694 km² in the Dicle region of the Southeastern Anatolia Region of Türkiye, which corresponds to 0.6% of the total area of Türkiye. Batman Province is located between 38º 40' - 37º 50' north latitudes and 41º 10' - 41º

40' east longitudes. It has six districts, which are Merkez, Kozluk, Sason, Hasankeyf, Gercüş, and Beşiri (ÇSB, 2017).

Batman is surrounded by Muş, 218 km to the north, Diyarbakır, 100 km to the west, Bitlis, 135 km to the east and Mardin, 149 km to the south (KGM, 2023).

The basin located between Kıra and Raman Mountains appears as a plain between elevations of 650-800 meters. This area corresponds to a narrow valley within the Diyarbakır Basin and was formerly called the Tilmis Plain. Today it is known as the "Batman Plain (Tonbul & Sunkar, 2008).

While the north and northeast of Batman Province are high, steep, and mountainous, the south has a more rugged topography. The Tigris River flows through the province from west to east, and important rivers such as the Batman, Sason, Kayser, Garzan, and Pisiyar streams also flow through the province (ÇSB, 2017).

The location map showing the study area is given in Figure 3.1.

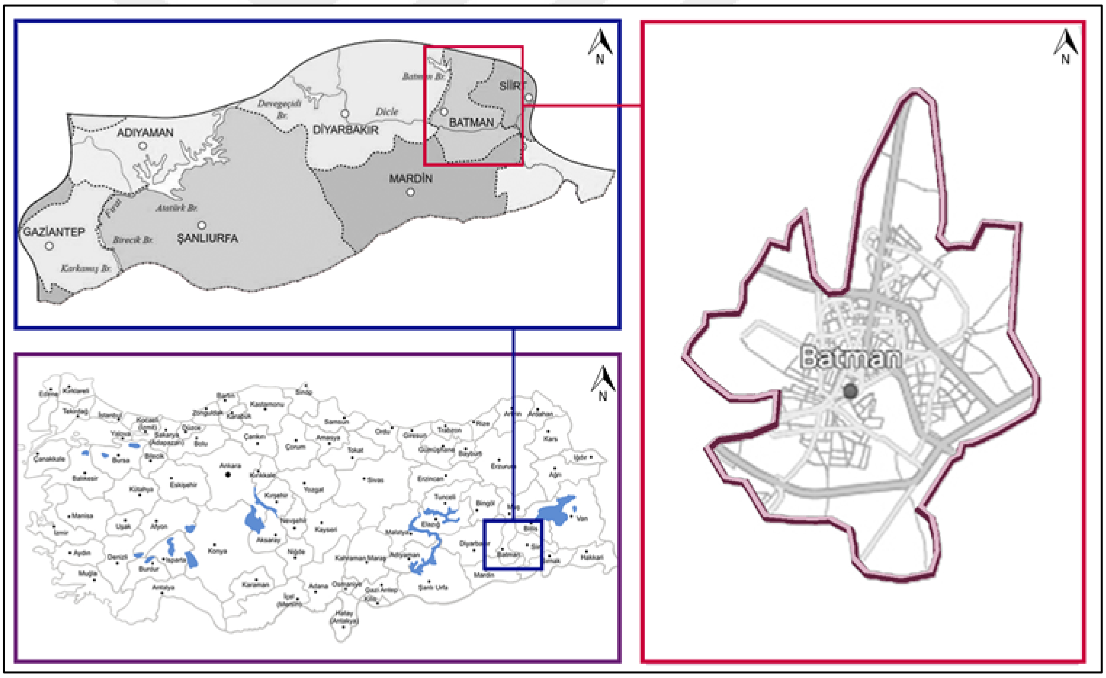


Figure 3.1. The location map of the study area

3.2.2. Climate, temperature, rainfall, and vegetation

The Southeastern Anatolia Region has a climate characteristic shaped by the influence of the Mediterranean and Eastern Anatolia Regions and the arid tropical region in the south (Odabaşı & Boydak, 1984). The region experiences a long summer period due to high spring temperatures. The winter period is considered to be a short and distinct one as the temperatures are not very low. The average temperature is above

20°C for 4-5 months of the year, and temperatures do not fall below 0°C in winter. Since the temperature difference between the hottest and coldest months is close to 30°C, this thermal regime effective in the Southeastern Anatolia Region is defined as the Terrestrial Mediterranean Thermal Regime (Koçman, 1993).

The climate of Batman Province is continental and is located in one of the hottest regions of Türkiye. The pattern of temperature and rainfall in the region varies significantly between seasons. The winter months are cold and rainy, but the summer months are hot and dry. Snow and rain are common in winter, and rain and snow in spring and autumn. Figure 3.2 presents the relationship between monthly total precipitation in Batman and average temperature values. (ÇSB, 2017).

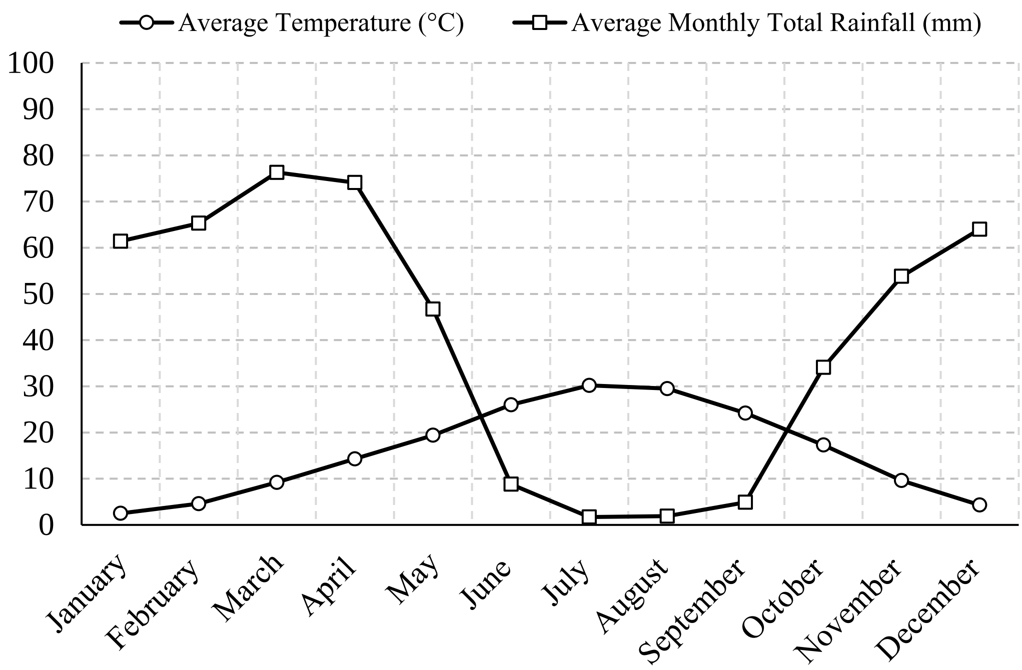


Figure 3.2. A graph of Batman province showing the annual temperature and precipitation (MGM, 2023).

The average annual temperature is over 15ºC. In January, which is considered the coldest month of the year 2.5 ºC, and in July , the hottest one, there is an average temperature of 30.20 ºC. Average temperature values for Batman province between 1959-2021 are presented in Hata! Başvuru kaynağı bulunamadı..

In Batman and its surroundings, in contrast to the characteristic Mediterranean rainfall regime, the precipitation caused by terrestrial effects is more intense in the spring period, and therefore the Delayed Mediterranean Rainfall Regime dominates in the region(Koçman, 1993). The average number of rainy days per year in Batman is

76.9, and the average annual rainfall is 493 mm. The highest average rainfall is in March with 76.30 mm, and the lowest average rainfall is in July with 1.70 mm. The prevailing wind direction in the province is east. Annual average temperature and precipitation maps of Batman are presented in Figure 3.3. (ÇSB, 2017; MGM, 2023).

Temperature data from the General Directorate of Meteorology between 1959 and 2021 are shown in Table 3.1, and the average of the highest and lowest values are shown in Table 3.2.

Table 3.1. The average temperature values for Batman province between 1959-2021 (MGM, 2023).

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Average Temperature (°C)	2,50	4,60	9,20	14,30	19,40	26,00	30,20	29,50	24,20	17,30	9,60	4,30	15,90
Average Highest Temperature (°C)	7,70	10,70	15,90	21,70	27,80	35,00	39,50	39,40	34,50	26,70	17,00	9,70	23,80
Average Lowest Temperature (°C)	-1,40	0,00	3,60	7,90	11,50	15,90	20,30	19,70	15,00	10,00	4,10	0,50	8,90
Average Sunshine Duration (hour)	3,30	4,60	5,60	7,40	9,20	11,60	12,00	11,30	9,80	7,10	5,20	3,00	7,50
Average Number of Rainy Days	9,92	9,69	10,69	9,15	9,31	1,54	0,77	0,62	1,08	6,08	6,85	11,23	76,90
Average Monthly Total Rainfall (mm)	61,40	65,30	76,30	74,10	46,70	8,80	1,70	1,90	4,90	34,10	53,80	64,00	493,00

Table 3.2. The highest and lowest temperature values for Batman province between 1959-2021 (MGM, 2023).

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Highest Temperature (°C)	18.6	24.6	30.6	35.8	42.0	45.1	48.8	46.2	43.8	37.0	28.6	22.6	48.8
Lowest Temperature (°C)	-24.0	-22.2	-17.0	-9.0	0.9	0.0	11.8	11.5	4.4	-3.0	-7.6	-23.0	-24.0

A significant part of Batman province is steppe. The most important product in terms of agricultural activity for this region is wheat. Because the groundwater is close to the surface, plants that can adapt to the climatic conditions can grow easily.

However, there is very little forest cover in the region as most of the existing forests have been destroyed. Ongoing deforestation in the mountainous regions has resulted in the loss of forest characteristics and the creation of heath areas. Increasing population movements are also putting pressure on the natural vegetation and, if this continues, the green area per capita will fall below the national average in square metres (Polat, 2019).

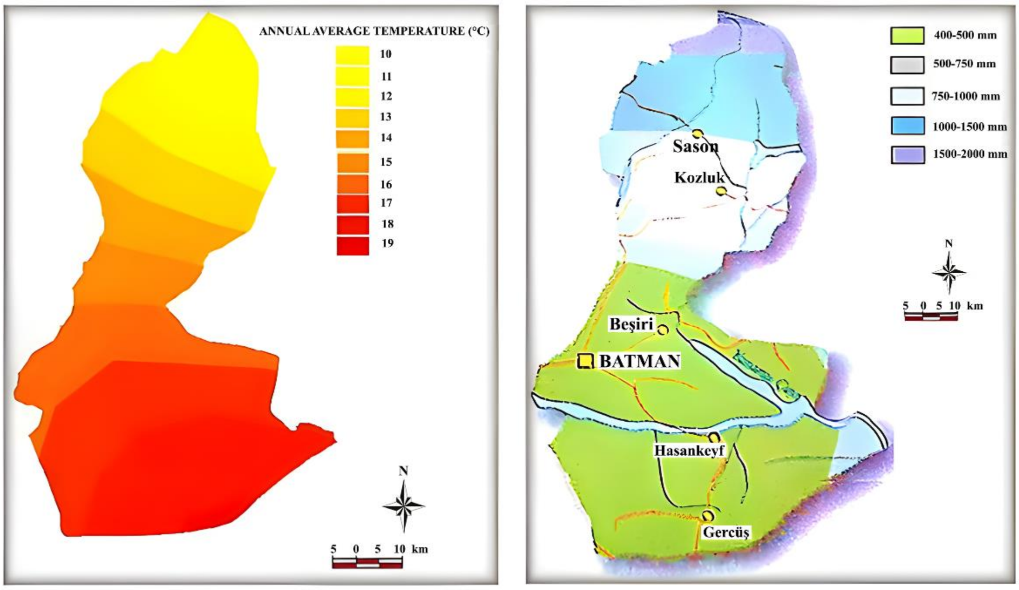


Figure 3.3. Annual average temperature and precipitation maps of Batman province (Batman Provincial Disaster and Emergency Directorate,2022).

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 Turkey showing the plates and their directions of movement is presented in Figure 3.4.

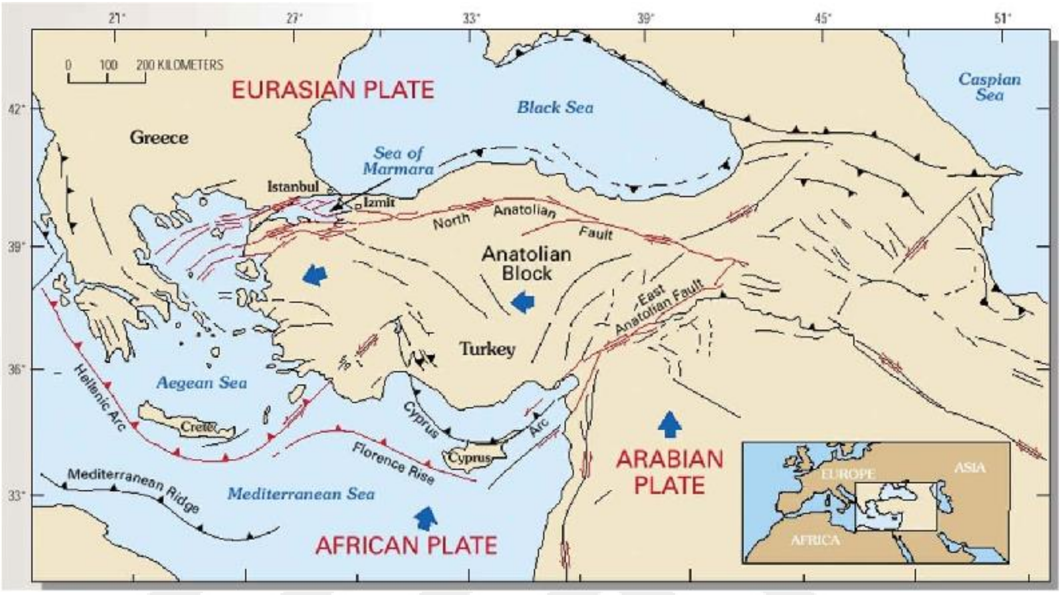


Figure 3.4. Tectonic map of Türkiye showing the plates and their direction of movement (Barka, 1992; Rockwell et al., 2001).

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 province of Batman is under the influence of the aforementioned Bitlis-Zagros Rim Belt (BZKK), and the faults associated with this belt have produced significant destructive earthquakes in the past. For example, the 1670 Muş, 1866 Kulp, 1884 Pervari, and 1975 Lice earthquakes (M=6.7) are the largest and most destructive (Batman Provincial Disaster and Emergency Directorate, 2022).

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 (UDAP) of the Presidency for Disaster and Emergency Management. The map showing the earthquake hazard status of Batman Province is presented in Figure 3.5, and the earthquake hazard status of Batman Province according to the Türkiye Earthquake Hazard Map is presented in Figure 3.6.

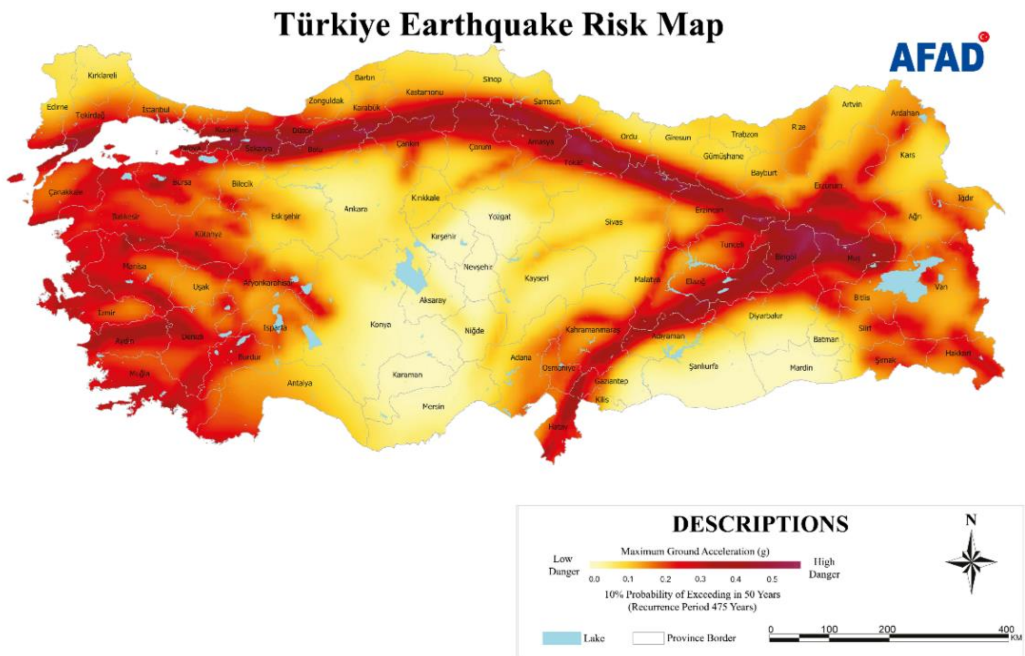
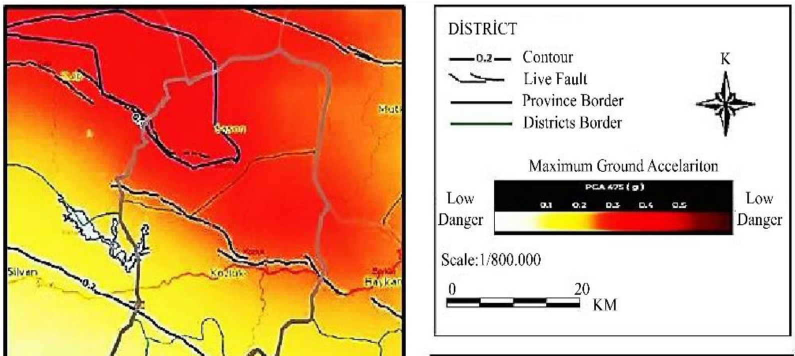


Figure 3.5. Map of earthquake zones of Türkiye (AFAD, 2023).



EARTHQUAKE HAZARD STATUS OF THE DISTRICTS

District	The Biggest Ground Acceleration (g)	Hazard Situation
Gercüş	0.1	Low Danger
Merkez	0.2	Low Danger
Beşiri	0.2	Low Danger
Hasankeyf	0.2	Low Danger
Kozluk	0.3	Dangerous
Sason	0.4	Dangerous

Figure 3.6. Earthquake hazard levels of Batman province according to Türkiye Earthquake Hazard Map (Batman Provincial Disaster and Emergency Directorate, 2022).

There is no record of a damaging earthquake within the borders of Batman Province. However, the province is under the influence of the Bitlis Thrust Zone (BBZ), which has produced significant destructive earthquakes in the past. According to the Türkiye Earthquake Hazard Map, the province's seismic hazard is not high, but it is considered to be at risk due to its proximity to the Bitlis Thrust Zone. In this context, the Elazığ (Sivrice) earthquake (magnitude 6.8), which occurred most recently on 24 January 2020, was felt intensely throughout the province (Batman Provincial Disaster and Emergency Directorate, 2022).

Some of the earthquakes that occurred in Batman Province between 1900 and 2023 are shown in Table 3.3 and the locations of the earthquakes that occurred in the same years are shown in Figure 3.7. (AFAD, 2023).

Table 3.3. Earthquakes greater than M_W=3 occured in Batman Province between 1900 and 2023 (AFAD, 2023).

Date	Location	Longitude	Latitude	Depth	Type	Magnitude
2022-10-17 - 20:49:11	Beşiri (Batman)	41,332	37,812	7	ML	3,1
2022-05-21 - 00:30:09	Beşiri (Batman)	41,3445	37,7943	11,25	ML	3,2
2021-10-28 - 05:04:41	Kozluk (Batman)	41,5225	38,2405	5,99	ML	3,1
2021-02-06 - 10:29:30	Gercüş (Batman)	41,173	37,69	8,26	ML	3,1
2014-09-04 - 17:16:05	Hasankeyf (Batman)	41,5585	37,7116	10,24	Mw	3,8
2014-09-04 - 16:16:06	Hasankeyf (Batman)	41,5671	37,6873	4,05	ML	3,1
2014-09-02 - 14:38:26	Beşiri (Batman)	41,285	37,998	17,4	ML	3,3
2014-06-30 - 09:52:48	Beşiri (Batman)	41,312	38,025	13,8	Mw	3,2
2011-01-03 - 10:04:34	Hasankeyf (Batman)	41,5806	37,6506	3,34	Md	3,1
2009-02-10 - 07:25:26	Kozluk (Batman)	41,3497	38,1287	4,5	Md	3,2
2008-10-04 - 03:59:46	Sason (Batman)	41,414	38,382	10,54	Md	3,1
2008-06-15 - 23:21:33	Hasankeyf (Batman)	41,5543	37,7198	7,12	Md	3,2
2006-12-04 - 11:38:48	Kozluk (Batman)	41,5727	38,1315	9,42	Md	3,5
2006-09-22 - 14:54:54	Kozluk (Batman)	41,3107	38,0722	7,7	Md	3,3
2006-09-20 - 23:20:49	Beşiri (Batman)	41,3742	38,0156	3	Md	3,1
2006-09-14 - 05:46:11	Kozluk (Batman)	41,4529	38,1952	23,18	Md	3,1
2006-01-17 - 08:30:17	Sason (Batman)	41,5678	38,366	19,04	Md	3,7
2006-01-17 - 07:44:19	Kozluk (Batman)	41,4684	38,2298	19,3	Md	3,3
2006-01-15 - 04:28:35	Sason (Batman)	41,477	38,4707	1,68	Md	3,1
2005-11-03 - 14:49:00	Merkez (Batman)	41,2113	38,0678	28,8	Md	3,2
2005-07-08 - 16:14:39	Sason (Batman)	41,4627	38,4836	16,69	Md	3,7
2004-12-26 - 19:34:38	Sason (Batman)	41,4855	38,4211	12,43	Md	3,3
2004-04-17 - 16:23:04	Merkez (Batman)	41,2177	38,0037	10,09	Md	3,5
2004-03-21 - 07:06:03	Sason (Batman)	41,4692	38,3947	3,1	Md	3,1
2001-09-25 - 15:42:10	Beşiri (Batman)	41,25	38,01	12,7	Md	3,8

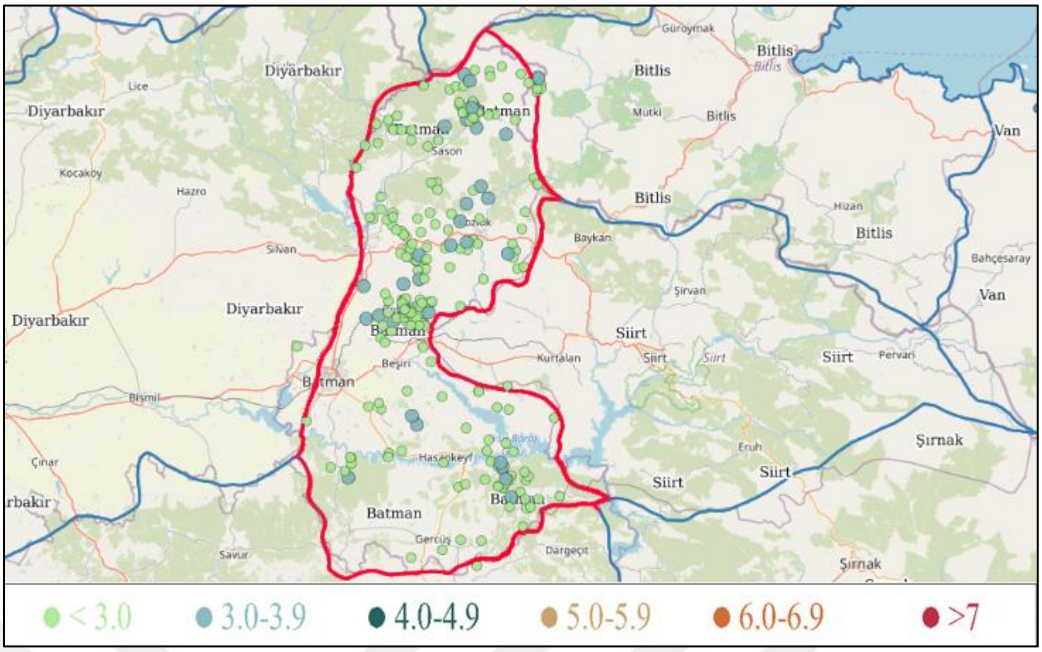


Figure 3.7. Distribution of earthquakes that occurred in Batman between 1900 and 2023 (AFAD, 2023).

3.3. Standard Penetration Test (SPT)

SPT has become a standard field test for determining soil properties. Since its development in the late 1920s, this test has been widely used in several countries. This test method, generally for sand and sandy silt and fine gravels, was developed to obtain some soil parameters in cohesionless sandy soils and there is extensive experimental experience in its use (Orhan, 2022a).

This test, which is used to determine the density, strength, consistency and liquefaction status of cohesive and non-cohesive soils, as well as the bearing capacity and estimated settlement of the foundation soil, was first defined by Terzaghi in 1974 as the "Standard Penetration Test" and is defined as driving the sampling tube into the ground (Clayton, 1995).

The SPT is widely used because of its short test duration, simplicity of construction, the fact that it is the most widely used field test internationally, the ability to sample while measuring penetration resistance, its lower cost than other tests, and its applicability to cohesive and non-cohesive soils as well as solid, fine gravel and fill. It is also highly sensitive, subject to operator error and dependent on many variables ranging from borehole logs equipment to application method (Orhan, 2022a).

3.3.1. Standard penetration test practices

The test is very practical and gives very good results if the necessary precision is applied.

The standard penetration test is the measurement of how many blows are required to drive a sampler 45 cm depth into the ground. This is done by repeatedly dropping a 63.5 kg heavy hammer or driving it down to the bottom (Figure 3.8).

The number of blows obtained by driving the sampler 15 cm to penetrate the spalled soil at the bottom of the manhole is not taken into account. The soil penetration resistance is defined by the number of impacts that correspond to the first 15 cm of penetration, followed by the 30 cm of penetration (SPT-N).

If more than 50 blows are required for each 15 cm of penetration, or more than 100 blows for two 30 cm penetrations in total, the driving shall be stopped. In addition, if no progress is made during the 10-pulse application. It is recorded as REFU (Orhan, 2022a). The sampler in the tube is removed and the sample placed in it is sent to a laboratory for testing.

The test is carried out at intervals of 1.75m to 1.5m along the borehole. According to the practice in Türkiye, the test is carried out every 1.5 m. If the soil is gravelly, the lug at the end of the tube is removed and a conical tip with 60 bevelled edges is inserted (Aydın, 2010).

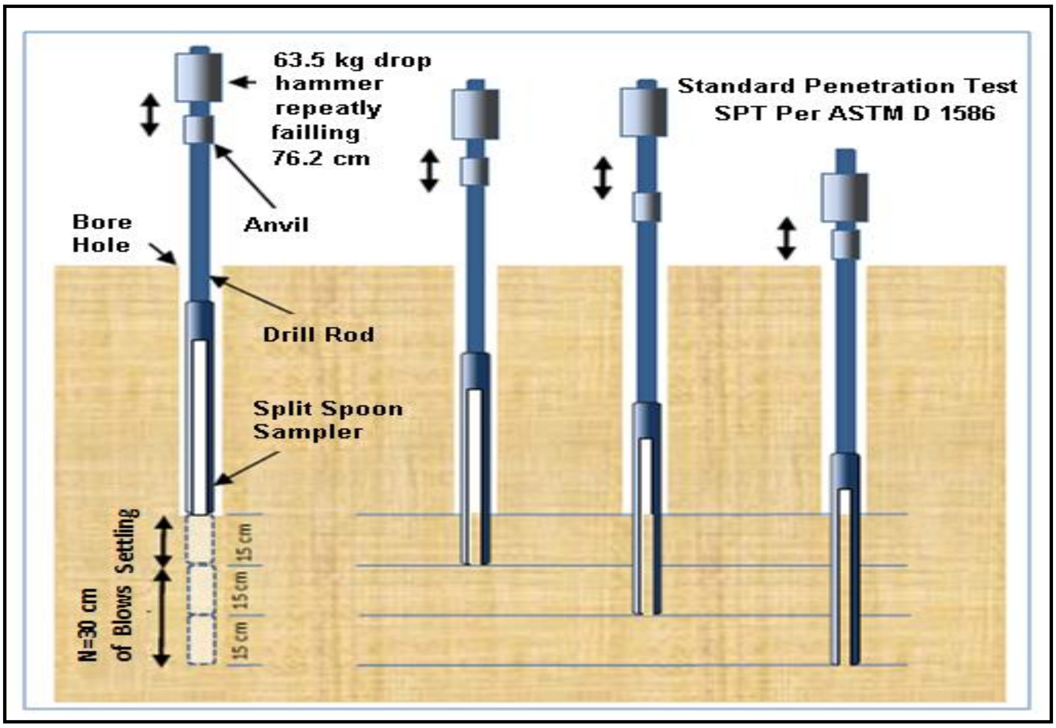


Figure 3.8. Stages of standard penetration (Mayne et al., 2002).

3.4. Bearing Capacity Calculations

The elements that transfer the building loads to the ground by converting them into stresses that the ground can withstand, depending on their shape, size and burial depth, are called foundations, and the medium that carries the loads directly or through the foundations is called the foundation soil (Genç, 2008).

The bearing capacity can be defined as maximum bearing pressure a soil can support while not exceeding its shear strengths and without settling in different areas.

SPT-N data are widely used to determine the bearing capacity of soils. The first studies on this subject were carried out by Terzaghi & Peck between 1948 and 1967.

3.4.1 Bearing capacity calculation methods with field tests

3.4.1.1. Terzaghi & Peck (1967) bearing capacity method

This method, developed by Terzaghi & Peck in 1967, allows the bearing capacity of soils to be determined graphically as a function of foundation width and SPT-N values.

In this graph, by Terzaghi & Peck, the total settlement on the foundation of 25mm was taken into consideration and some approximations regarding the bearing pressure allowed were made. These approximations were obtained as a result of experimental studies and the relationships between allowable bearing pressure, foundation width, B and SPT-N values are shown in Figure 3.9.

When using this graph, the average number of SPTs at a depth of length B, or more accurately 2B (2B for single foundations, 3B for strip foundations) from the base of the foundation is used (Uzuner, 2016).

In this study, a foundation width of 3 m was selected and the bearing capacity was determined using the approach shown in Figure 3.9.

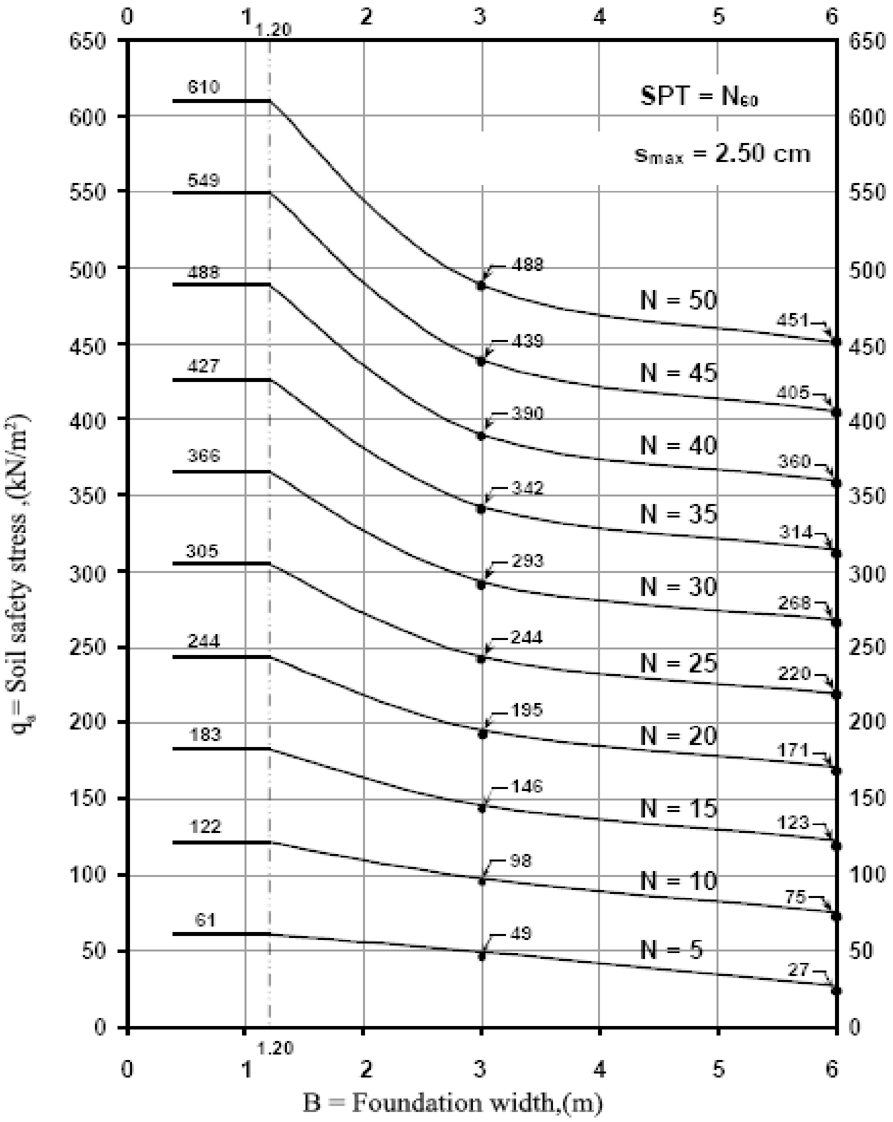


Figure 3.9. Change in allowable bearing capacity based on foundation width and SPT N (Bowles, 1996).

3.4.1.2. Meyerhof (1974) bearing capacity method

Another approach to calculating safe bearing capacity based on SPT-N values was developed by Meyerhof in 1974.

In this approach developed by Meyerhof, the safe bearing capacity values corresponding to a maximum settlement of 25 millimetres of the foundation for the calculation of the safe bearing capacity for single foundations are found by the following equations (Çinicioğlu, 2005).

$q_a = 12.N.K_d$ for $B \leq 1.22$ m (3.1)

$q_a = 8.N.\left(\frac{B+0.305}{B}\right)^2.K_d$ for $B > 1.22$ m (3.2)

$K_d = 1 + 0.33 \frac{D}{B} \leq 1.33$ (3.3)

It's here;

q_a : 25 mm. safe bearing capacity for settlement (kN/m²)

N : SPT blow count

D : Foundation depth (m)

B : Foundation width (m)

Meyerhof, taking into account the depth of the affected zone and the increase in the amount of settlement under large width raft foundations, gave the safe bearing capacity formula for raft foundations as follows (Bowles, 1996).

$q_a = 12{,}5 \, . \, N \, . \, K_d$ (3.4)

3.5. Groundwater

Groundwater can cause problems such as liquefaction in silty-sandy soils, swelling/change in viscosity limit in clay soils, and collapse due to increased water content in hollow soils. The interaction between structures and water is also very important. In cases where part of the foundation of a high-water table structure is below the water table, corrosion may occur due to the interaction between water and structural elements/materials. This can reduce the strength of the structure. Therefore, the presence of groundwater is an important factor in the design phase of engineering projects and must be taken into account in order to protect the structures by taking appropriate protective measures (Uyan, 2018).

Boreholes are an ideal tool for measuring groundwater levels if they are equipped with perforated tubes of sufficient stiffness. If drilling liquid is used, the static water level is determined by draining the borehole and monitoring the static water level for at least 3 consecutive days to establish the level. In cases when groundwater is encountered and the water is close to the foundation, water is sampled and laboratory tests conducted to determine whether concrete or other building material is affected. These tests help to determine the properties of the water, such as sulphate content, pH, etc. This ensures that the structural elements are protected and the water level is kept under control (IMO, 2016).

3.6. Water Content

The ratio of water in the intergranular spaces to the dry mass is used to express the soil water content. This amount of water is expressed as a percentage of the dry weight of the soil. The soil water content is calculated as the ratio between the dry weight of the soil and the water weight remaining after subtracting it (Uzuner, 2007).

When the soil water content reaches a certain value, the soil becomes liquid and exhibits viscous liquid behaviour ($w_n \geq w_{LL}$). When the water content falls below the plastic limit ($w_n \leq w_{PL}$), the soil becomes semi-solid. The shrinkage limit (w_{SL}) is the water content at which the soil is solid. When the soil water content is between liquid and plastic ($w_{PL} < w_n < w_{LL}$), plastic behaviour is observed. (Tüzen, 2019).

These water limits affect soil properties such as consistency, bearing capacity and dynamic and mechanical properties. These properties are important factors for design in geotechnical engineering as they affect the structural behaviour of the soil. Therefore, the determination of soil water content and water limits is of critical importance.

$$w = \frac{M_w}{M_d} = \frac{w_w}{w_s} \quad (3.5)$$

In this equation;

w; Water content value

M_d; Dry mass value

M_w; Wet mass value

w_w; Water mass value

w_s; It gives the value of the grain mass value.

Water content is dimensionless and is usually expressed in decimal or percentage form. In some cases, it can take values greater than 1. The water content of soil can vary depending on its water mass, while the dry weight remains constant. Therefore, the dry mass is used as the denominator in the water content formula. For natural soils, the water content is called the natural water content (w_n) (Uzuner, 2007).

3.7. Grain Size Distribution (Sieve Analysis)

A pile of soil is made up of grains of different sizes. The process of analyzing soil particle size involves using a set of standard sieves with varying aperture sizes to separate and collect particles. The weight percentage of particles within each size range is then calculated. Commonly used standard sieves are listed in Table 3.4 (Özaydın, 2015).

Table 3.4. Standard sieve openings to measure the grain size distribution of soils (ASTM D422).

Sieve No	Sieve Opening (mm)
4	4.75
10	2.00
20	0.85
40	0.425
60	0.25
100	0.15
140	0.106
200	0.075

Sieve analysis is performed by stacking sieves of decreasing aperture. The sieve with the smallest aperture is placed at the bottom. The samples are placed on the top sieve and then sieved by a sieve analyser at 15-minute intervals. After this movement, the samples remaining on each size sieve are weighed and calculated. These tests are carried out in accordance with TS EN 933-1 (Danışman, 2022). A typical grain diameter distribution curve is shown in Figure 3.10.

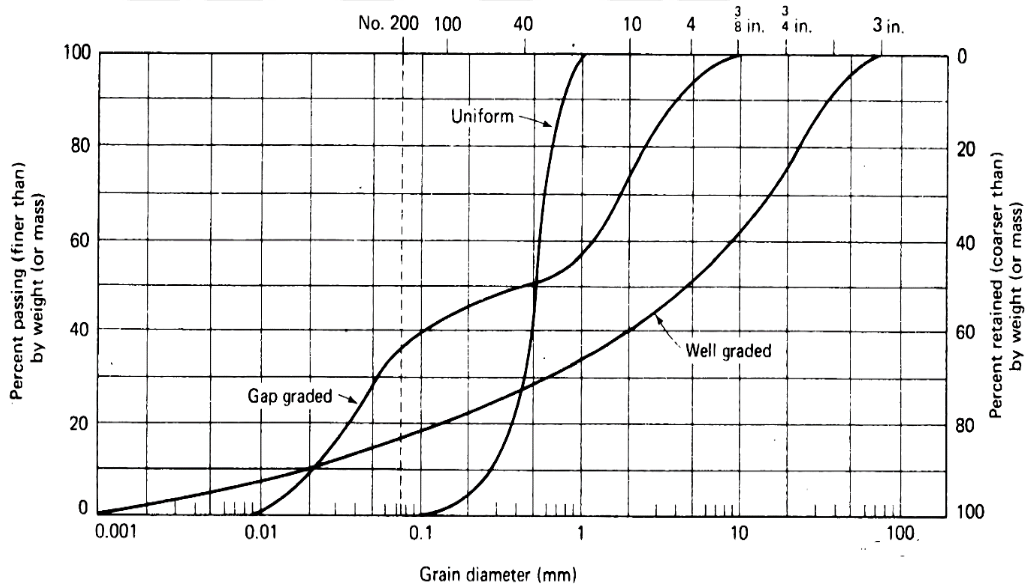


Figure 3.10. Typical grain size distribution curves (Holtz et al., 1981).

3.8. Analysis of Consistency (Atterberg) Limits

Gravitational forces between soil grains bind them together if the grains are below a certain size. This force of attraction is called cohesion force. Grains bound together by the force in question are specified as cohesive soils (Okman, 1998).

Depending on the water content, fine grain soils can be in various states. As increasing amounts of water are added to a dry soil and kneaded, the soil becomes solid, semi-solid, plastic, liquid and its volume increases slightly. The Swedish scientist Albert Atterberg (1911) defined these states and the limiting water contents that separate them. These limits are called Atterberg limits or consistency limits (Uzuner, 2016).

The engineering behaviour of soils, particularly fine-grained soils, depends on the amount of water contained in their pores. It is not enough to have knowledge of the water content of a natural deposit of soil this water content should be compared to standard values with a certain engineering behaviour. This is where the Atterberg limits (consistency limits) come into play. According to the Atterberg limits, if the water content of the sample is known, some predictions can be made about the engineering behaviour of the soil (Holtz et al., 1981).

In geotechnical practice, liquid limit (W_L or L_L) and plastic limit (W_P or P_L) are most often used; less frequently, shrinkage limit (W_S or S_L). Albert Atterberg also defined the plasticity index, defined as the range of water content at which soils are plastic, and proposed the use of this property in soil classification. Terzaghi and Casagrande standardised consistency limits (Holtz et al., 1981).

Liquid Limit (W_L or L_L) is the lowest water content at which the soil can flow under its own weight. In other words, it is defined as the water content at which the soil passes from the plastic state to the liquid state (Genç, 2008; Uzuner, 2016).

Plastic Limit (W_P or P_L) is the water content at the point where it changes from the plastic state to the semi-solid state as a result of the decrease in water content. At this point, cracks begin to form on the surface of the soil (Whyte, 1982).

Shrinkage Limit (W_S or S_L) is the lowest water content at which soils can be fully saturated with water. This water content means that the volume of the soil is no longer reduced (Sekercioglu, 1993; Uzuner, 2016).

Plasticity Index (P_I or I_P), is defined as the range of water content values at which the soil exhibits plastic behaviour. In other words, it is the difference between the liquid and plastic limits (Sekercioglu, 1993).

Stress-strain of the soil at different water contents and consistency limits defined by Albert Atterberg are shown in Figure 3.11.

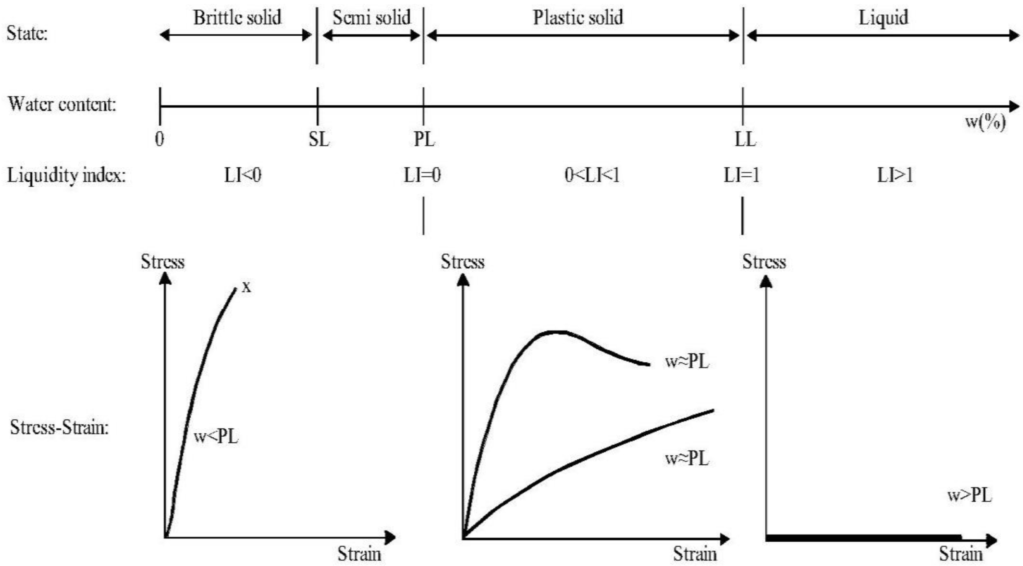


Figure 3.11. Consistency limits and stress-strain of soils at different water contents (Holtz et al., 1981).

3.9. Dominant Vibration Period of Site (To)

The ground vibration characteristics are a major factor in determining the seismic performance of a structure. It is important to evaluate the response of the ground to its motion in order to understand the behaviour of structures under seismic loads. Therefore, many parameters are used to describe the dynamic properties of the site. One of these parameters is the "dominant vibration period".

In earthquake engineering, the frequency content of ground motion is often characterized by a parameter known as the dominant vibration period. This parameter corresponds to the period of vibration with the highest value in the Fourier amplitude spectrum of the ground motion. For soils, the dominant vibration period typically ranges from 0 to 1. In rocky soils the dominant vibration period is found at lower values than in other soil types. The dominant vibration period can be calculated from the thickness of the non-resistant units and the shear wave velocity on the resistant soil (Öncül, 2016).

According to Kanai (1983), the dominant vibration period can be calculated using the following equation.

$$\mathbf{To = \Sigma\ (4H / V_{S,30})} \quad (3.6)$$

In this equation;

To: Dominant vibration period of site

$V_{S,30}$: Average shear wave velocity at 30 m depth

H: It refers to the layer thickness.

As a result, the dominant vibration period is an important parameter affecting the seismic performance of structures. It is used in structural dynamic analysis to understand the vibration characteristics of the ground and is important in evaluating the response of structures to ground vibration. Its accurate determination is of great importance in the safe and durable design of structures.

3.10. Compression (Vp) and Shear Wave (Vs) Velocity

Earthquakes are important events that can cause great destruction and loss of life among the natural disasters that occur on Earth. Earthquake waves are the vibrations that occur as a result of the energy emitted by the earthquake source propagating in different waves on and within the earth's surface. These earthquake waves include two different types of waves called P-waves and S-waves.

The propagation of P and S waves is presented in the Figure 3.12.

Mechanical properties of soil can be determined by analyzing the P-wave and S-wave velocities. P-waves propagate in the same direction as their vibration, while S-waves propagate perpendicular to their vibration direction. These two types of waves are important parameters for understanding the behavior of soil under stress and can provide useful information for geotechnical engineering applications. (i.e. perpendicular to the direction of displacement of particles in the soil).

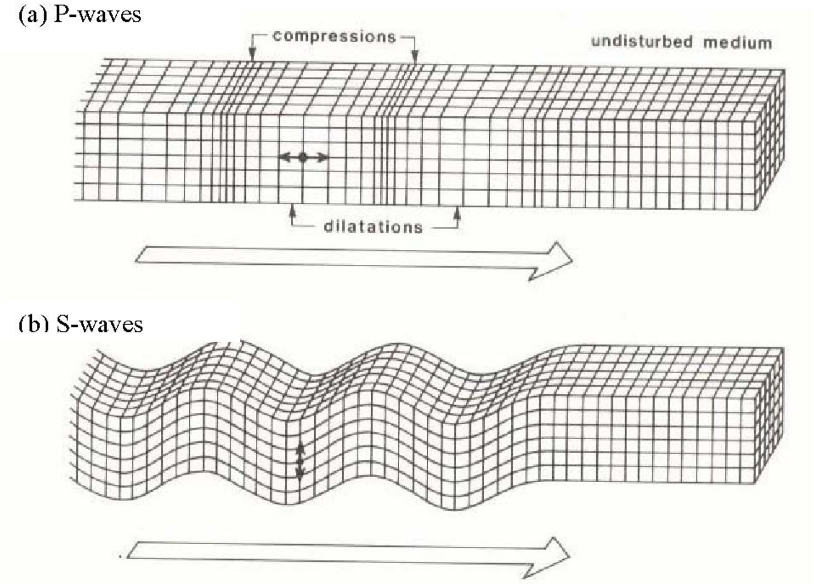


Figure 3.12. Propagation of P and S waves (Thitimakorn, 2003).

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

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

λ =

σ = Stress

G = Shear Modulus

D = Density

μ = Poisson Ratio

E = Modulus of Elasticity

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

$$Vs = \sqrt{\frac{G}{P}} = \sqrt{\frac{E}{2\rho(1+\mu)}} \qquad (3.8)$$

Shear waves are a type of seismic wave that usually follows primary earthquake waves. Shear waves travel perpendicular to particle movement while primary waves usually move along it. They do not propagate in liquids and gases. Shear wave velocities are an important parameter reflecting the strength of the soil and soil classifications are given according to these velocities. $Vs_{(30)}$ is the average of shear wave velocities obtained from in-situ seismic studies to a depth of 30 meters (Uyanık, 2015).

Shear wave velocity is used in current earthquake codes (NEHRP, EUROCODE-8, TBDY 2018) for determining soil classes, calculating shear modulus and modulus of elasticity at low levels of deformation, liquefaction, loss of bearing capacity, and soil amplification analyses. This is why soil shear waves velocity is an important parameter when it comes to geotechnical earthquake engineering (Akdeniz, 2015). Vs(30) can be expressed mathematically as follows.

$$Vs_{30} = \frac{30}{t_d + \frac{30-d}{Vs_1}} \qquad (3.9)$$

Where Vs_1:is the velocity of the layer between depth d and 30m. In its simplest form, it is equal to the velocity at the bottom of the subsurface model. t_d: is the propagation time of the wave in the layers up to depth d. To make the above equation clearer, we consider a 3-layer medium;

$$Vs_{30} = \frac{30}{\frac{h_1}{Vs_1} + \frac{h_2}{Vs_2} + \frac{30-(h_1+h_2)}{Vs_1}} \qquad (3.10)$$

is expressed by the relation (Uyanık, 2015).

3.11. Earthquake Hazard Level according to Soil Amplification Method

Seismic waves travel rapidly through the Earth’s crust when an earthquake occurs. Once an earthquake occurs, seismic waves travel through the earth before eventually reaching the surface where they can cause vibrations of varying duration. Their length depends on factors like earthquake magnitude, distance from epicenter and characteristics of ground surface - each can play an influential role. Vibrations may last anywhere between seconds to several minutes and cause serious damage to buildings, infrastructure and other structures. While most of the seismic waves pass through the hard rock that makes up the Earth's crust, the last part passes through the soft soil layers, which have very different properties from the rock, and the properties of these soil layers largely determine the nature of the vibrations observed in the Earth. Soil layers can have an enormous effect on the propagation of seismic waves, acting as filters to attenuate or amplify various frequencies of waves as they travel through it. When seismic waves pass through soil layers they can either absorb or reflect depending on characteristics of both soil layers and frequency of waves, leading to changes in strength and duration of ground motion at different locations. The "site effect" is the term used to describe the changes that seismic waves cause in the earth's layers. Because these changes are usually observed as an increase in amplitude, the term local site effect is also known as ground amplification, ground transfer function, or site response (Yalçinkaya, 2002). In the context of this thesis, the amplification of the soil has been calculated according to the following formula of Midorikawa (1987).

Table 3.5. Relationship between soil amplification and shear wave velocity ($Vs_{,30}$) (Midorikawa, 1987).

Researcher	Relation	
Midorikawa (1987)	$A=68V_1^{-0.6}$	(V_1<1100 m/s)
	A=1	(V_1>1100 m/s)
A : Relative amplification coefficient		
V_1 : Shear wave velocity for depth of 30 meters		

Ground amplification values can be determined for the study area using the information given in Table 3.5 and shear wave velocity data to a depth of 30 metres below the ground surface.Ground amplification values are determined according to the seismic hazard level. Accordingly, amplification values of 0.0-2.0 represent low hazard (C), amplification values of 2.0-4.0 represent medium hazard (B) and amplification values of 4.0 - 6.5 represent high hazard (A) (Kurnaz, 2011).

3.12. Soil Classification according to NEHRP

NEHRP is a code that specifies requirements for the seismic design and construction of new buildings and other structures in the United States. It was developed by the BSSC for the FEMA. Earthquake codes are primarily designed to reduce risk of damage to critical structures during and after an earthquake. These codes are designed to minimise the potential hazards posed by both new and existing structures, particularly in regions at high risk of seismic activity. By establishing standards for construction practices, materials and design criteria, earthquake codes aim to ensure that buildings and infrastructure can withstand seismic forces and protect human life and property in the event of an earthquake (Baştürk, 2003).

The NEHRP classification divides soils into six groups, A, B, C, D, E and F, based on shear wave velocity ($Vs_{,30}$). Class A soils are those with the hardest bedrock and $Vs_{,30}$ values of 1500 m/s or greater, while Class E soils, which are the lowest quality soils, are those with $Vs_{,30}$ values of 180 m/s or less. Soil classification is used for the construction of engineering structures and it is considered appropriate to base this on the $Vs_{,30}$ velocity in the area where the structure will be built up to a depth of 30 metres from the surface. In addition, soils 36 metres or depther are classified as Class F soils if the $Vs_{,30}$ value is 180 m/s or less. The NEHRP soil classification is shown in Table 3.6 (Ayday et al., 2001).

Table 3.6. Soil classification criterias according to NEHRP (Romero & Rix, 2001).

Soil Type	General Description	Average S wave speed (up to 30 m) Vs,30
A	Hard Rock	> 1500 m/s
B	Rock	760 - 1500 m/s
C	Hard and/or stiff/very stiff soils; most gravels	360 - 760 m/s
D	Sand, silts and/or stiff/very stiff clays, some gravels. Having average blow counts of $15 \leq N \leq 50$ or average shear strength of 50 kPa ≤ S ≤ 100 kPa	180 - 360 m/s
E	Having thickness lower than 3 meters and PI > 20, w > 40% and s_u < 25 kPa soft clay	< 180 m/s
F	(1) Soils susceptible to failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils (2) Peats/highly organic clays with a thickness greater than 3 m. (3) Very high plasticity clays with a thickness greater than 8 m and PI > 75 (4) Very thick soft/medium stiff clays with a thickness greater than 36 m	

3.13. Soil Classification according to EUROCODE-8

The European Committee for Standardisation has published EUROCODE 8, a regulatory code that sets standards for the design and assessment of structures in European Union countries. It provides guidelines for the assessment of the seismic vulnerability of structures as well as for the design of new buildings or the retrofitting of existing buildings to withstand seismic activity, while the setting of uniform earthquake-resistant design standards aims to ensure safety in regions with increased seismic risks.

The application rules in this regulation allow calculations to be made for different countries according to their specific conditions (climate, seismic risk, tradition, etc.). For this reason, EUROCODE approaches are also used in many countries that are not members of the European Union. The map shown in Figure 3.13 has been developed by the Joint Research Centre (JRC) and will be updated according to the information collected. (Karakaş, 2022; Joint Research Centre, 2023).

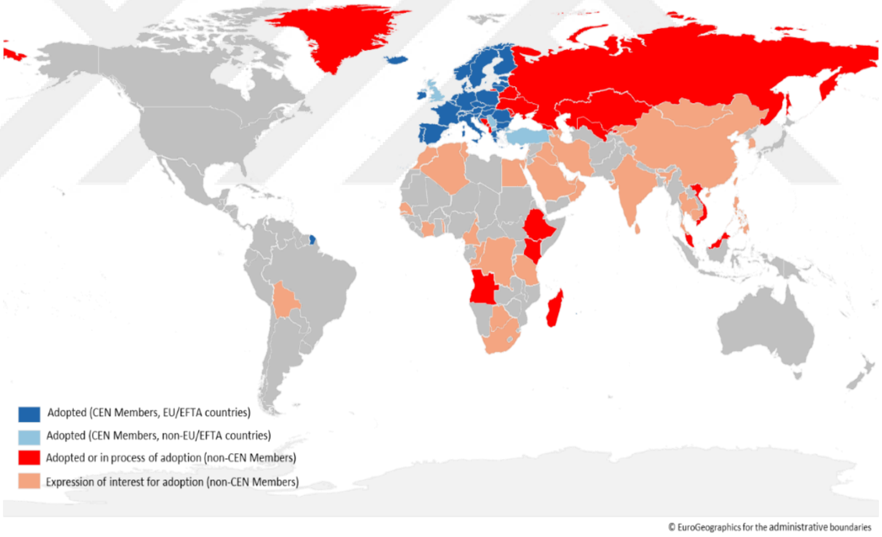


Figure 3.13. A world map showing the interest in EUROCODE regulations (Joint Research Centre, 2023).

The soil classes defined in EUROCODE 8 and information on their properties are given in Table 3.7.

Table 3.7. Soil classification criterias according to EUROCODE-8.

Ground Type	Description of stratigraphic profile	Parameters		
		$V_{S,30}$ (m/s)	N_{SPT} (blows/ 30 cm)	Cu (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	>800	-	-
B	Deposits of very dense sand, gravel or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360-800	>50	>250
C	Depth deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180-360	15- 50	70-250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	<180	<15	<70
E	A soil profile consisting of a surface al1uvium layer with Vs values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with Vs>800 m/s.			
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high-water content	< 100 (indicative)	-	10-20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

3.14. Soil Classification according to TBDY 2018

Turkey Building Earthquake Code (TBDY), published in the Official Gazette dated March 18, 2018 and numbered 30364 with the decision of the Council of Ministers numbered 2018/11275, entered into force on January 1, 2019.

In the 16th section of TBDY titled "Special Rules for the Design of Foundation Soil and Foundations under Earthquake Effects", local soil classes are determined in Table 5.4 by considering the average shear wave velocity $Vs_{,30}$ (Equation 3.11) values in the upper 30 meters. In this thesis, a database was created using the (Vs)30 values obtained from the geological-geotechnical survey reports, and soil class maps of the study area were prepared using ArcGIS software.

$$(V_s)_{30} = \frac{30}{\sum_{i=1}^{N} \frac{hi}{Vs,i}} \tag{3.11}$$

Table 3.8. Soil classification criterias according to TBDY 2018 (TBDY, 2018).

Ground Type	Description of stratigraphic profile	$V_{S,30}$ (m/s)
ZA	Solid, hard rocks	> 1500
ZB	Lightly weathered, moderately intact rocks	760-1500
ZC	Very compact layers of sand, gravel and hard clay or weathered, weak rocks with many cracks	360-760
ZD	Moderately compact to compact sand, gravel or very stiff clay layers	180-360
ZE	Profiles containing loose sand, gravel or soft-solid clay layers or soft clay layers (c_u < 25 kPa)more than 3 metres thick in total, meeting the conditions *PI* >20 or *w* > 40%.	< 180
ZF	Grounds requiring site-specific investigation and evaluation, 1) Soils with the risk of collapse and potential collapse under earthquake impact (liquefiable soils, highly vulnerable clays, collapsible weak cement soils, etc.); 2) Peat and/or clays with high organic content with a total thickness of more than 3 meters, 3) High plasticity (*PI* >50) clays with a total thickness of more than 8 meters, 4) Very thick (>35 m) soft or medium-stiff clays	

3.15. Unified Soil Classification System (USCS)

USCS can be defined as a system that classifies soils according to their physical properties. The USCS was first developed by Arthur Casagrande in 1942 for the accurate classification of soils used in airport construction. The use of the USCS has been widely adopted by soil engineers and other relevant professionals. ASTM D 2487 (2000) defines the use of the USCS and is recognised as the standard method for soil classification (Orhan, 2022b). Soils with a similar USCS classification tend to exhibit similar engineering properties, including permeability and strength. This classification system takes into account various soil properties such as grain size, plasticity and compressibility, which provide invaluable information about their behaviour under various conditions. Therefore, the USCS soil classification system is useful in determining the type of soil that will achieve the desired performance (Kalinski, 2011).

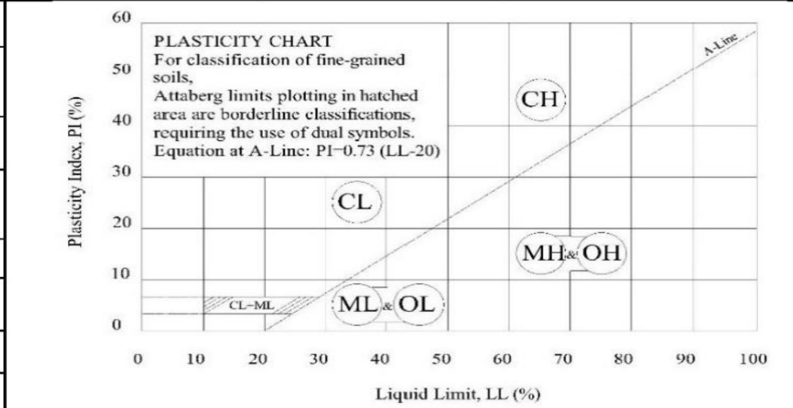
The USCS divides soils into three main categories: coarse-grained, fine-grained, and organic, based on specific parameters within each group. Soil classification depends on factors such as the percentage of material passing through #200 (0.075mm) and #4 (4.75mm) sieves, and the coeffiecient of uniformity (Cu) and coefficient of curvature (Cc), which are obtained from the grain-size curve. Consistency limits, including grain size distribution, liquid limit, and plastic limit, are also important for determining the USCS classification of a soil (Dingil, 2020).

Figure 3.14 illustrates the Unified Soil Classification System.

CLASSIFCIATION OF SOILS FOR ENGINEERING PURPOSES
ASTMD2487 and D 2488
(Unified Soil Classification System)

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICALNAMES	FIELD IDENTFIICATION PROCEDURES	CLASSIFIACTION CRITEIRA	
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	CLASSIFICATION ON BASIS OF PERCETNAGE OF FINES Less than 5% pass No. 200 sieve=GW, GP, SW, SP. 5% to 12% pass No. 200 sieve=borderline classification, requiring the use of dual symbols. More than 12% pass No. 200 sieve=GM, GC, SM, SC.	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing		Not meeting both criteria for GW
		GRAVELS WITH FINES	GH	Silty gravels, gravel-sand-clay mixtures	Nonplastic fines or fines with low plasticity (for identification procedures, see ML below)		Atterberg limits plot below "A" line or plasticity index less than 4 / Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand clay mixtures	Plastic fines (for identification procedures, see CL below)		Atterberg limits plot above "A" line and plasticity index greater than 7
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines	Wide range in grain size and substantial amounts of all intermediate particle sizes		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			SP	Poorly graded sands and gravelly sands, little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing		Not meeting both criteria tor SW
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures	Nonplastic fines or fines with low plasticity (for identification procedures, see ML below)		Atterberg limits plot below "A" line or plasticity index less than 4 / Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures	Plastic fines (for identification procedures, see CL below)		Atterberg limits plot above "A" line and plasticity index greater than 7

MAJOR DIVISIONS		GROUP SYMBOLS	TYPICALNAMES	Identification Procedure On Fraction Smaller Than No. 40 Sieve Size: Dry Strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands	None to slight	Quick to slow	None
		CL	Inorganic clays of low to medium plasitcity gravelly clays, sandy clays, silty clays, lean clays	Medium to high	None to very slow	Medium
		OL	Organic silts and organic silty clays of low plasitcity	Slight to medium	Slow	Slight
	SILTS AND CLAYS Liquid limit greater than 50%	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts	Slight to medium	Slow to none	Sligh to medium
		CH	Inorganic clays of high plasticity, fat clays	High to very high	None	High
		OH	Organic clays of medium to high plasticity	Medium to high	None to very slow	Slight to medium
Highly Organic Soils		PT	Peat, muck, and other highly organic soils	Readily identified by color, odor, spongy feel, and frequently by fibrous texture		



*Based on the material passing the 3 inch sieve

Figure 3.14. Chart of Unified Soil Classification System (Schaefer et al., 2008).

CHAPTER 4
RESULT AND DISCUSSION

4.1. Introduction

In order to assess the suitability of the approximately 54 km² area within the boundaries of the Central District of Batman Province for settlement, the studies carried out as part of the geotechnical survey reports, which were prepared on the basis of 253 geological-geotechnical borehole data, were used as part of this thesis study.

The study investigated parameters such as standard penetration test, liquefaction potential, natural water content, consistency limits, sieve analysis and groundwater level at various depths (1.5 m, 3 m, 4.5 m, 7.5 m, 9 m, 15 m). In addition, factors such as soil classification using the USCS, bearing capacity and shear wave velocity were evaluated.

The study also includes topics such as shear wave velocity ($V_{s(30)}$), soil classification according to the NEHRP, EUROCODE-8 and TBDY 2018 standards, seismic hazard level according to soil amplification, and local soil class according to the prevailing vibration period.

GIS maps were used in the evaluations. These maps were produced using ArcGIS and the IDW method. ArcGIS is a widely used software for geographic data analysis, mapping and geographic information systems. The IDW method is an interpolation method used to estimate a non-point surface using the relationship between point data. The IDW method calculates the estimated value of a point based on the values of the points around it. The values of nearby points are weighted more heavily in the estimated value of the point, while the values of distant points are weighted less heavily.

4.2. Analysis of SPT-N Maps

SPT, a field test with great importance for soil investigations, helps determine the engineering characteristics of the soil. SPT is important because it provides access to important parameters such as bearing capacity and liquefaction. This part of the research aims to investigate engineering behaviour and soil properties by using SPT maps created from the 253 boreholes.

Table 4.1. Relationships between standard penetration test and relative density (Demir, 2013).

Description (Soil Compactness)	[1]Neo* [2]N1/60* (Terzaghi & Peck 1967)	Relative Density D_r (%)			
		Meyerhof (1956)[1]	Bowles (1968)[1]	Duncan ve Buchinani (1976)[2]	Mitchell ve Katti (1981)[2]
Very loose	< 4	< 20	< 15	< 15	< 15
Loose	4-10	20-40	15-30	13-35	15-35
Medium	10-30	40-60	35-65	35-65	35-65
Dense	30-50	60-80	65-85	65-85	65-85
Very dense	> 50	> 80	85-100	85-100	85-100

The study includes maps that illustrate the distribution of SPT values for soils at various depths, ranging from the surface to 15 meters deep. These maps depict the changes in SPT values as the depth increases. Specifically, maps were created to display the variations in SPT values at depths of 1.5m, 3.0m, 4.5m, 7.5m, 9.0m, and 15m.

The gathered information from 241 borehole locations at the 1.5m depth in the study area indicated that 78% of SPT-N data fell between the values of 1 to 20. The values between 21 and 30 accounted for 16%, and those between 31 and 50 constituted 6% of the data. The distribution map for SPT-N values found at the depth of 1.5m can be seen in Figure 4.1.

According to the map showing the variation of SPT-N values measured for 1.5 m depth of the study area;

- According to Terzaghi & Peck's (1967) classification in This part of the research aims to investigate engineering behaviour and soil properties by using SPT maps created from the 253 boreholes.

Table 4.1, the soil in certain parts of Yediyol Village and Tilmerc neighbourhoods is described as "loose". This is because the SPT-N value ranges from 4 to 10 in these areas. On the other hand, some parts of Yediyol Village, Tilmerc, Gültepe, Belde, and Çamlıtepe neighbourhoods have an SPT-N value ranging from 11 to 50, indicating that the soil in these areas is considered "medium-dense".

- In the southern part of the study area, specifically in Petrolkent and Seyitler neighbourhoods, the SPT-N value ranges from 10 to 22. In these areas, the soil is categorized as "medium".

- Certain areas within the southwestern part of Güneykent and Çamlıca neighbourhoods have an SPT-N value ranging from 12 to 30, which classifies the ground as "medium". In other parts of the same neighbourhoods, the SPT-N value is between 45-50, indicating that the soil in these areas is classified as "dense".

- Certain areas within the southeastern part of Site and Bayındır neighbourhoods have an SPT-N value ranging from 4 to 28, which classifies the soil in those areas as "loose-medium". Additionally, in other parts of the same neighbourhoods, the SPT-N value ranges from 34 to 50, indicating that the soil in those areas is classified as "dense".

- In certain parts of GAP, Hilal, Çay, Yeşiltepe, 19 Mayıs, and Kısmet neighbourhoods located in the inner areas of the study area, the SPT-N value ranges from 4 to 10. These areas are characterized as having "loose" soil. Conversely, in some parts of Pazaryeri, Cumhuriyet, Şafak, Yavuz Selim, Yeni, Aydınlıkevler, and Yeşiltepe neighbourhoods, the SPT-N value ranges from 11 to 30, indicating that the soil in these areas is categorized as "medium".

- Certain areas within the eastern part of Fatih and Petrol neighbourhoods have an SPT-N value ranging from 7 to 30. These areas are characterized as having "loose-medium" soil.

- Certain areas within the western region of Girbereşik Neighbourhood and Yeniköy have an SPT-N value ranging from 7 to 29, indicating that the soil in these areas is categorized as "loose-medium".

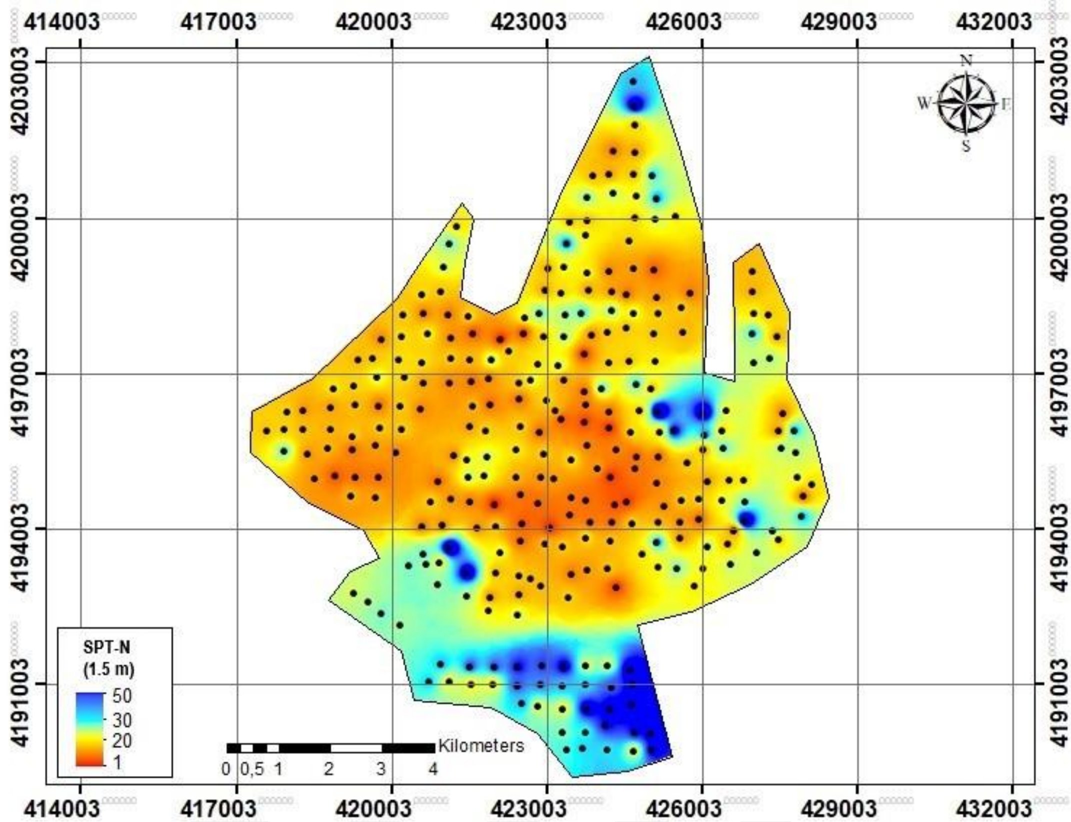


Figure 4.1. Distribution of SPT-N values according to 1.5 m depth.

Out of the 235 borehole points surveyed throughout the study area, the SPT-N data revealed that 48% of the values ranged from 1 to 20, 35% fell between 21 and 30, and 17% were between 31 and 50 at a depth of 3.0 m. The distribution of these SPT-N values at a 3.0 m depth can be seen in Figure 4.2.

According to the map showing the variation of SPT-N values measured for 3.0 m depth of the study area;

- According to Terzaghi & Peck (1967) as shown in This part of the research aims to investigate engineering behaviour and soil properties by using SPT maps created from the 253 boreholes.

Table 4.1 shows that the soil in certain parts of Yediyol Village and Tilmerc Neighbourhood is categorized as "medium" due to the SPT-N values ranging from 10 to 30. Camlitepe and Belde Neighbourhood are situated in the northern region. Some parts of Yediyol Village and Tilmerc Neighbourhood have SPT-N values between 31 and 50, indicating that the soil in these areas is considered "dense".

- The southern part of Petrolkent and Seyitler Neighbourhood is characterized by an SPT-N value ranging from 17 to 24. The soil in these particular areas is classified as "medium".

- Certain areas within the southwest section of Güneykent and Çamlıca Neighbourhood have an SPT-N value ranging from 16 to 50. In these specific areas, the soil is described as "medium-dense".

- Certain sections within the southeastern part of Site and Bayındır neighbourhoods have an SPT-N value ranging from 7 to 30. In these particular areas, the soil is classified as "loose-medium". Additionally, in specific parts of Bayındır Neighbourhood, the SPT-N pulse count is between 34 and 50, indicating that the soil in these areas is considered "dense".

- Certain areas within GAP, Hilal, Çay, Yeşiltepe, Bahçelievler, 19 Mayıs, and Huzur neighbourhoods, located in the inner parts of the study area, have an SPT-N value ranging from 6 to 30. In these particular areas, the soil is categorized as "loose-medium". Additionally, in specific parts of Hilal, Kültür, GAP, Bahçelievler, Yavuz Selim, and Yeşiltepe neighbourhoods, the SPT-N value ranges from 32 to 50. In these areas, the soil is identified as "dense".

- Certain sections within the eastern part of Fatih and Petrol neighbourhoods have an SPT-N value ranging from 15 to 29. In these specific areas, the soil is classified as "medium". Furthermore, in certain parts of the neighbourhood, the SPT-N impact number ranges from 39 to 50, indicating that the soil in these areas is categorized as "dense".

- Certain areas within the western part of Girbereşik Neighbourhood and Yeniköy have an SPT-N value ranging from 8 to 30. In these particular areas, the soil is described as "loose-medium". Additionally, in some sections of the neighbourhood, the SPT-N pulse count ranges from 32 to 50, which classifies the soil in those areas as "dense".

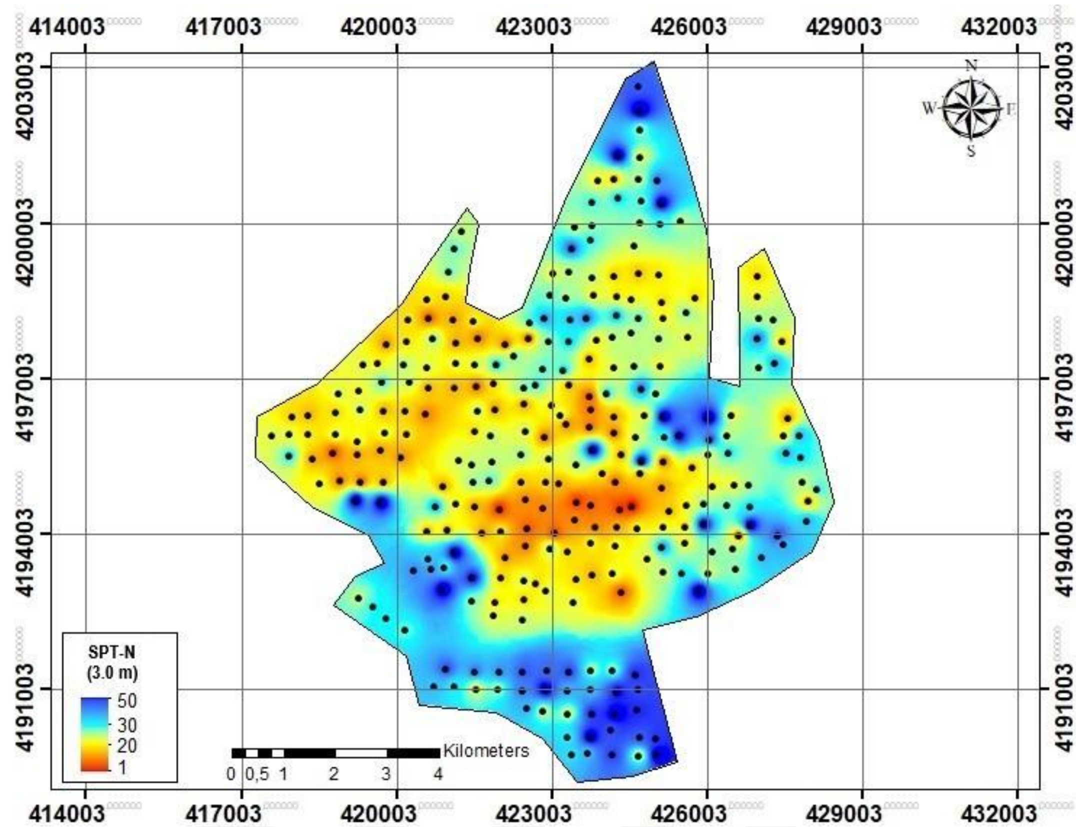


Figure 4.2. Distribution of SPT-N values according to 3.0 m depth.

The data collected from 241 borehole points at a depth of 4.5 m in the study area revealed that 22% of the SPT-N values fell within the range of 1-20, 40% were between 21-30, and 38% were between 31-50. These findings are depicted in Figure 4.3, which shows the distribution of SPT-N values at a depth of 4.5 m.

According to the map showing the variation of SPT-N values measured for 4.5 m depth of the study area;

- According to Terzaghi & Peck (1967) as shown in This part of the research aims to investigate engineering behaviour and soil properties by using SPT maps created from the 253 boreholes.

Table 4.1- The southern part of the city, specifically Petrolkent and Seyitler neighbourhoods, have an SPT-N number of blows ranging from 24 to 30. This suggests that the soil in that area falls under the classification of "medium". Similarly, in certain sections of Güneykent and Çamlıca neighbourhoods located in the southwest area, the

SPT-N number of blows ranges from 15 to 50, which classifies the soil as "medium-dense".

- Certain parts of Site and Bayındır neighbourhoods located in the southeastern part of the region have an SPT-N number of blows ranging from 9 to 30. As per the Terzaghi & Peck (1967) classification, the soil in those areas falls under the category of "loose-medium". Additionally, some sections of Bayındır Neighbourhood have an SPT-N pulse count between 32 and 50, which defines the soil in those parts as "dense".

- Certain sections within the inner parts of the study area, including GAP, Hilal, Çay, Yeşiltepe, Bahçelievler, 19 Mayıs, and Huzur neighbourhoods, have an SPT-N number of blows ranging from 8 to 30. According to the classification system, the soil in these areas is described as "loose-medium firm". In some parts of 19 Mayıs, Çay, Hilal, Pazaryeri, Pınarbaşı, Kültür, GAP, Sağlık, and Yeşiltepe neighbourhoods, the SPT-N number of blows falls between 31 and 50, which categorizes the soil in those areas as "dense".

- In certain sections of the eastern part of Fatih, Korik, and Petrol neighborhoods, the number of blows in the SPT-N test ranges from 13 to 30. The ground in these areas is classified as "medium". Similarly, in some parts of Fatih and Petrol neighborhoods, the number of blows in the SPT-N test ranges from 35 to 48. These areas are characterized by "dense" soil.

- In certain areas of Girbereşik Neighbourhood and Yeniköy in the western part, the number of blows in the SPT-N test ranges from 11 to 38. The soil in these areas is classified as "medium-dense".

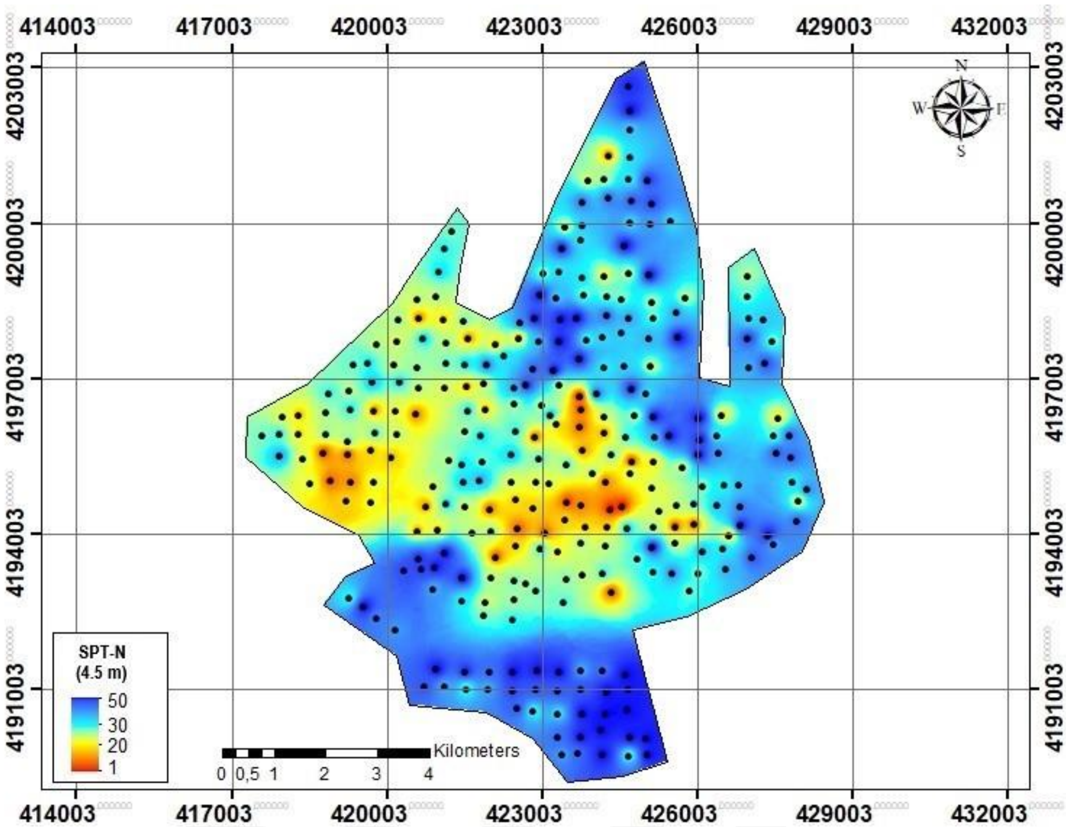


Figure 4.3. Distribution of SPT-N values according to 4.5 m depth.

After analyzing data gathered from 241 borehole points with a depth of 7.5 meters throughout the study area, it was found that 10% of the SPT-N values ranged between 1 and 20, 13% between 21 and 30, and 77% between 31 and 50. Figure 4.4 shows a map illustrating the distribution of SPT-N values at a depth of 7.5 meters in the study area.

According to the map showing the variation of SPT-N values measured for 7.5 m depth of the study area;

- According to Terzaghi & Peck (1967) as shown in This part of the research aims to investigate engineering behaviour and soil properties by using SPT maps created from the 253 boreholes.

Table 4.1- Petrolkent and Seyitler neighbourhoods in the southern part have an SPT-N value, with the number of blows ranging from 19 to 50. The soil in these areas is classified as "medium-dense".

- Similarly, in certain sections of Güneykent and Çamlıca neighbourhoods in the southwest, the SPT-N value shows a range of 40 to 50 blows. The soil in these areas is classified as "dense".

- In certain sections of Site and Bayındır neighbourhoods in the southeastern part, the SPT-N value ranges from 9 to 30 blows. The soil in these areas is classified as "loose-medium".Additionally, in certain parts of Bayındır Neighbourhood, the SPT-N values range from 31 to 50 blows. The soil in these areas is classified as "dense".

- In certain sections of GAP, Hilal, Çay, Huzur, Kültür, Yeşiltepe, Bahçelievler, Yavuz Selim, 19 Mayıs, and Huzur neighbourhoods within the study area, the SPT-N value ranges from 7 to 30 blows. The soil in these areas is classified as "loose-medium firm".Moreover, in certain parts of these neighbourhoods, the SPT-N values range from 32 to 50 blows, indicating a "dense" soil classification.

- In certain parts of Fatih and Petrol neighbourhoods in the eastern section, the SPT-N value ranges from 20 to 50 blows. These areas are characterized by a "medium-dense" soil classification. Similarly, in specific sections of Girbereşik Neighbourhood and Yeniköy in the western part, the SPT-N value ranges from 8 to 30 blows, indicating a "loose-medium" soil classification. Additionally, in some parts of these neighbourhoods, the SPT-N values range from 32 to 50 blows, suggesting a "dense" soil type.

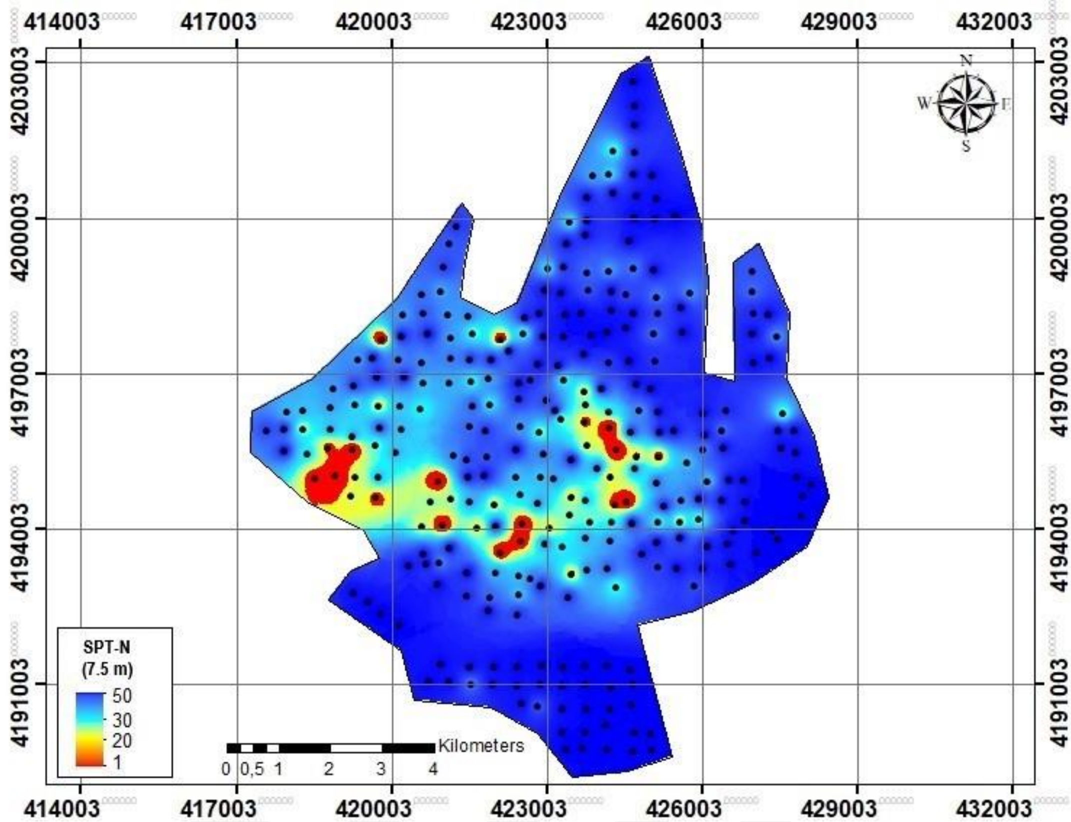


Figure 4.4. Distribution of SPT-N values according to 7.5 m depth.

The analysis of SPT-N data collected from 236 borehole points throughout the study area at a depth of 9.0 m revealed that 7% of the data fell within the range of 1-20, 7% fell within the range of 21-30, and a majority of 86% fell within the range of 31-50. Consequently, a map illustrating the distribution of SPT-N values at a depth of 9.0 m is presented in Figure 4.5.

According to the map showing the variation of SPT-N values measured for 9.0 m depth of the study area;

- According to Terzaghi & Peck (1967) as shown in This part of the research aims to investigate engineering behaviour and soil properties by using SPT maps created from the 253 boreholes.

Table 4.1, providing an overview of the soil characteristics in these regions.

- Petrolkent and Seyitler neighbourhoods in the southern part of the area have SPT-N values ranging from 29 to 50 blows. The soil in these areas is classified as "medium-dense".

- In certain sections of Güneykent and Çamlıca neighbourhoods in the southwest, the SPT-N values range from 47 to 50 blows. These areas are characterized by "dense" soil.

- Similarly, in some parts of Site and Bayındır neighbourhoods in the southeastern section, the SPT-N values range from 17 to 29 blows, classifying the soil as "medium". Additionally, in some parts of Bayındır Neighbourhood, the SPT-N values range from 31 to 50 blows, indicating "dense" soil.

- In certain sections of GAP, Hilal, Çay, Huzur, Kültür, Yeşiltepe, Bahçelievler, Yavuz Selim, 19 Mayıs, and Huzur neighbourhoods, which are located in the central part of the study area, the SPT-N values range from 8 to 30 blows. These areas are characterized by "loose-medium firm" soil. Additionally, in some parts of these neighbourhoods, the SPT-N values range from 31 to 50 blows, indicating "dense" soil.

- The eastern parts of Fatih and Petrol neighbourhoods are characterized by SPT-N values ranging from 36 to 50 blows, indicating "dense" soil. On the other hand, in certain areas of Girbereşik Neighbourhood and Yeniköy in the western part, the SPT-N values range from 12 to 29 blows, classifying the soil as "medium-dense". Moreover, in some parts of the neighbourhood, the SPT-N values range from 34 to 50 blows, indicating "dense" soil.

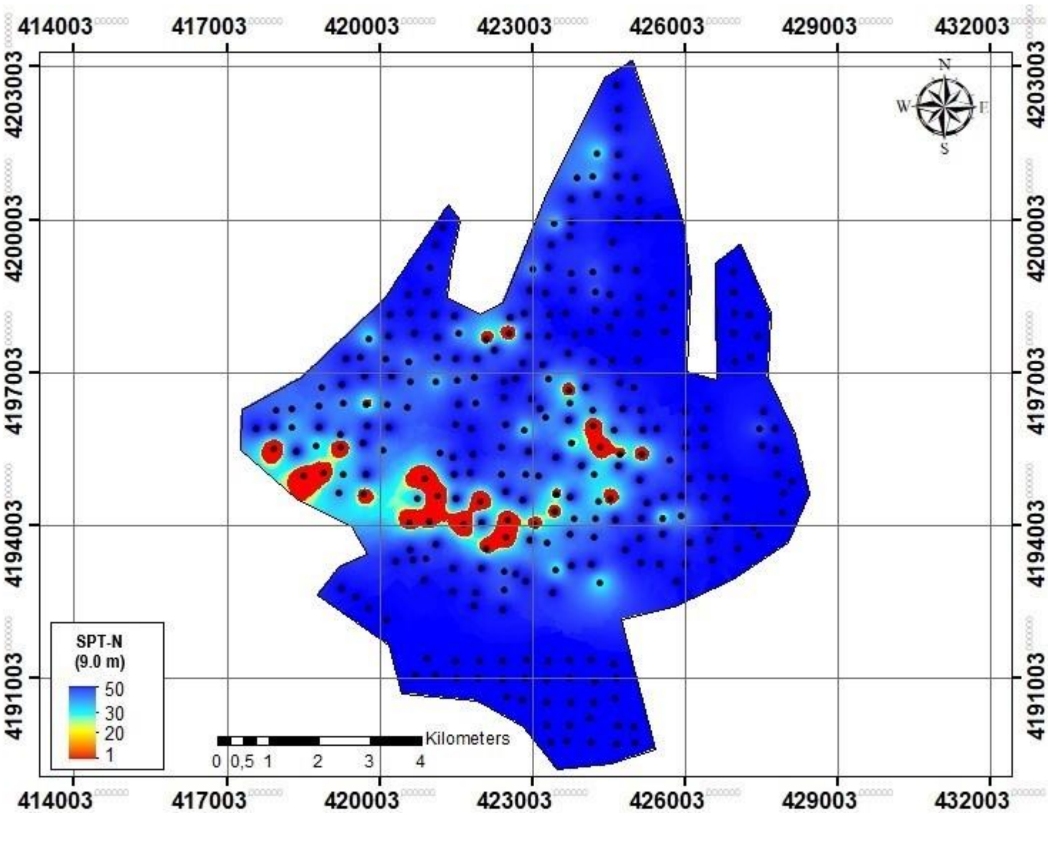


Figure 4.5. Distribution of SPT-N values according to 9.0 m depth.

Analysis of the SPT-N data collected from 241 borehole points at a depth of 15.0 m across the study area revealed that 2% of the data fell within the range of 1 to 20, 3% fell within the range of 21 to 30, and the majority, 95%, fell within the range of 31 to 50. As a result, Figure 4.6 displays a map illustrating the distribution of SPT-N values at a depth of 15.0 m.

According to the map showing the variation of SPT-N values measured for 15.0 m depth of the study area;

- According to Terzaghi & Peck (1967) as shown in This part of the research aims to investigate engineering behaviour and soil properties by using SPT maps created from the 253 boreholes.

Table 4.1- The soil in the southern parts of Petrolkent and Seyitler neighbourhoods is classified as "dense" due to the SPT-N values ranging from 44 to 50 blows.

- Similarly, certain areas of Güneykent and Çamlıca neighbourhoods in the southwest section exhibit SPT-N values ranging from 19 to 50 blows, indicating "medium-dense" soil.

- In the southeastern part, certain areas of Site and Bayındır neighbourhoods have SPT-N values ranging from 19 to 30 blows, classifying the soil as "medium". In addition, some parts of Bayındır Neighbourhood exhibit SPT-N values ranging from 44 to 50 blows, confirming the presence of "dense" soil.

- In certain areas including GAP, Hilal, Çay, Huzur, Kültür, Yeşiltepe, Bahçelievler, Yavuz Selim, 19 Mayıs, and Huzur neighbourhoods situated in the central part of the study area, the SPT-N values range from 20 to 50 blows, indicating soil classification as "medium-dense".

- In certain areas of the eastern section, including Fatih and Petrol neighbourhoods, the SPT-N values range from 44 to 50 blows, indicating "dense" soil.

- Similarly, in some parts of Girbereşik Neighbourhood and Yeniköy in the western part, the SPT-N values range from 26 to 50 blows, classifying the soil as "medium-dense".

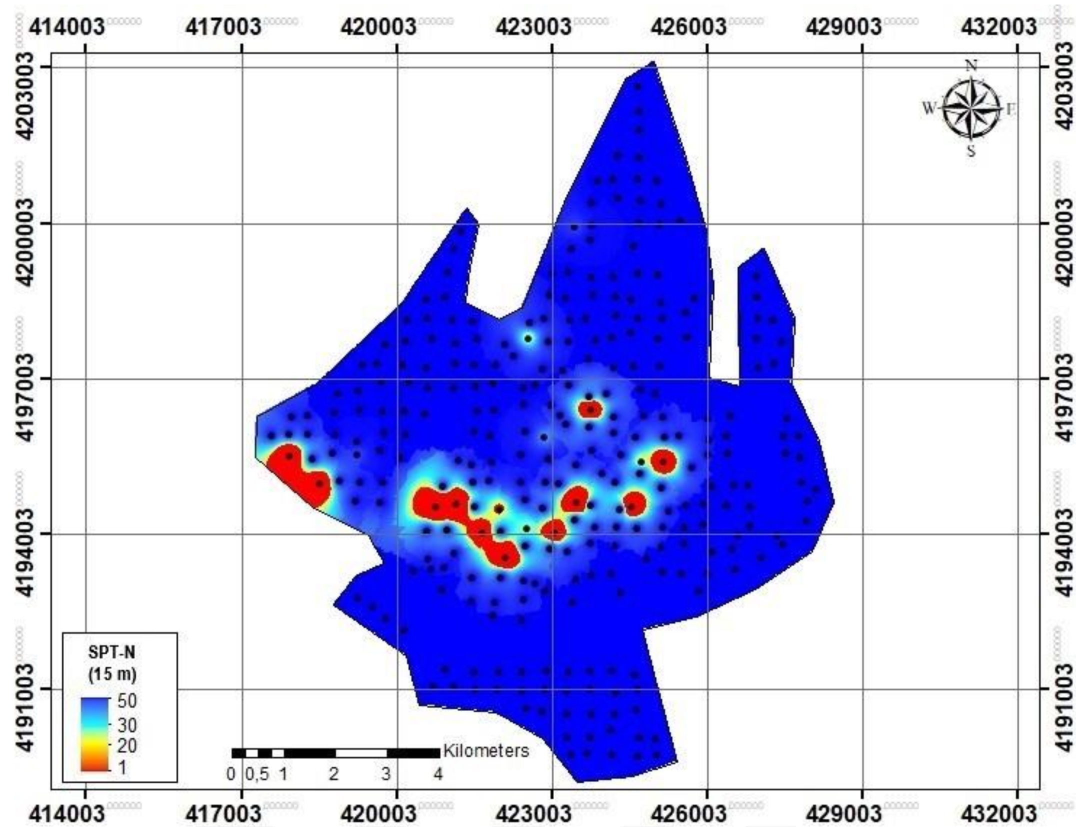


Figure 4.6. Distribution of SPT-N values according to 15.0 m depth.

The study includes SPT-N values obtained for 241 boreholes boreholeed at different depths (1.5, 3.0, 4.5, 7.5, 9.0 and 15.0 m). Figure 4.7 depicts a comparison graph that displays the distribution of SPT-N values within three ranges: 1-20, 21-30, and 31-50. The graph represents the number of boreholes falling into each depth-specific SPT-N range.

When the results are analyzed, it is clear that the SPT-N value between 1-20 dominates the 1.5 m depth. The SPT-N value between 31-50 dominates the 15.0 m. Analysis of SPT-N values is important in evaluating bearing capacity and liquefaction analyses, as it depends on the number impacts. Therefore, the comparison between SPT-N values obtained at different depths is critical for geotechnical evaluation and safety analyses.

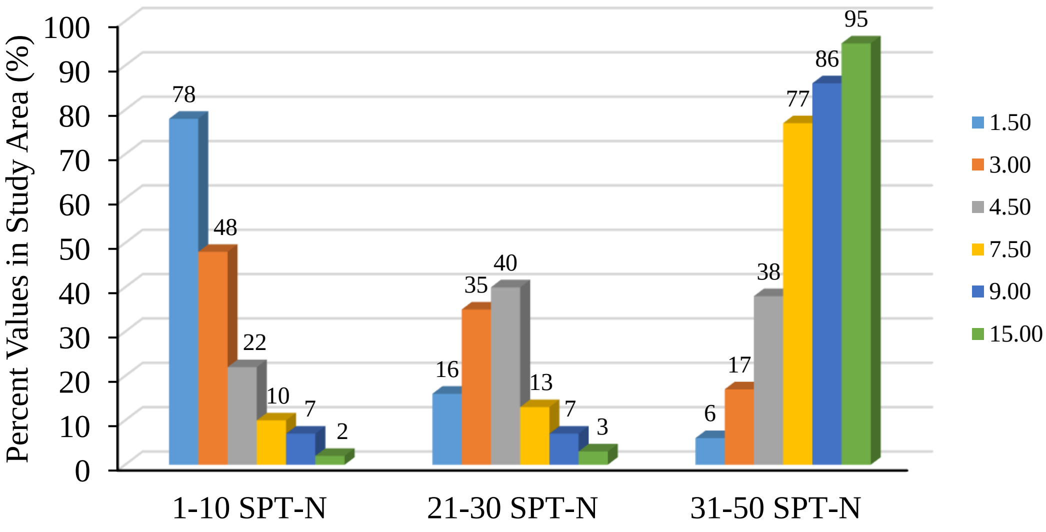


Figure 4.7. Distribution of SPT-N values for different depths.

The vertical and horizontal changes of the soil in the study area were determined and compared by field tests. The map is showing the variation of SPT values of all depths in the study area and is presented in layered form in Figure 4.8.

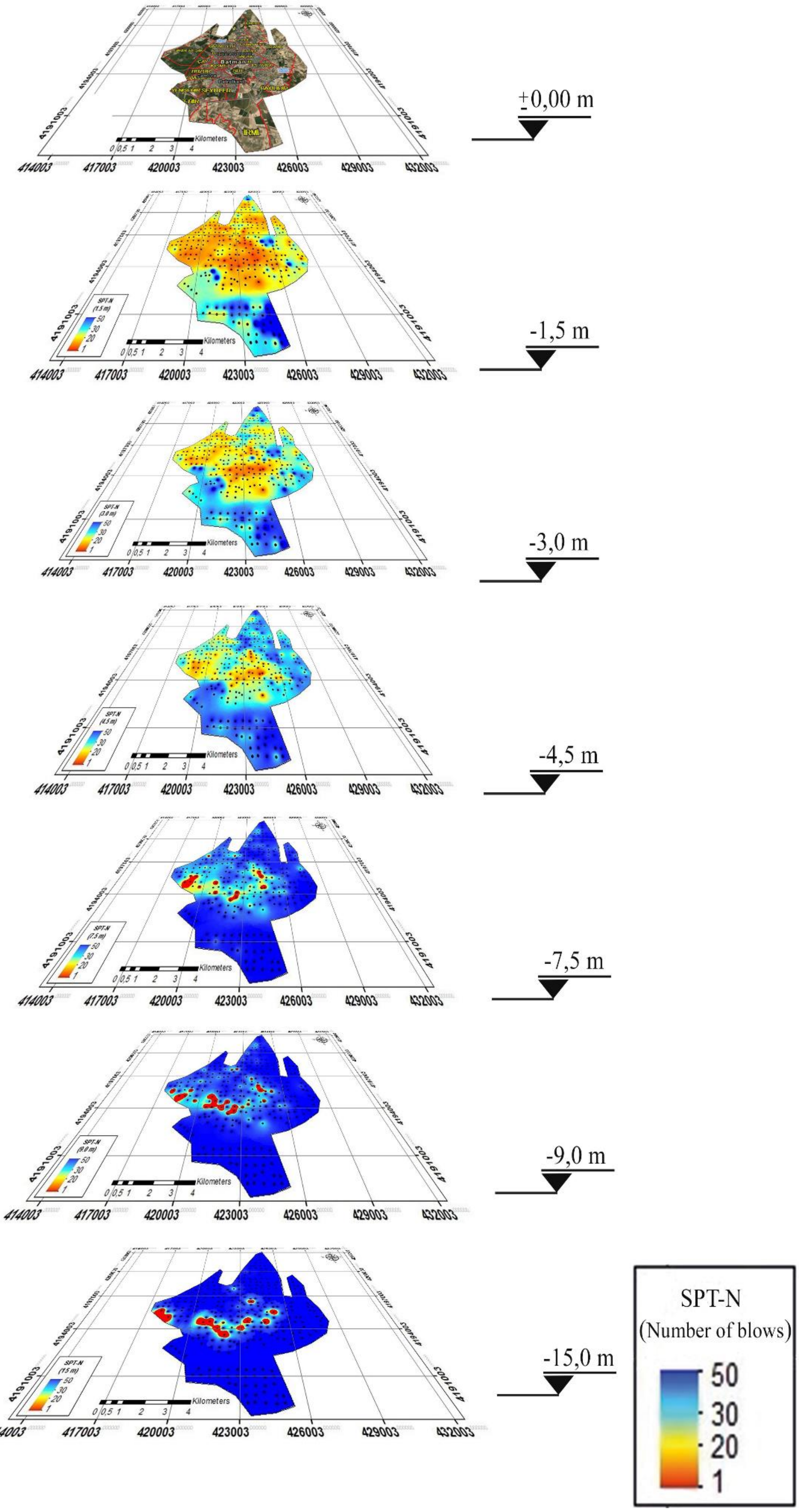


Figure 4.8. SPT-N maps of the study area according to the depth.

4.3. Analysis of Bearing Capacity Maps

The methods of calculation used were the method of Terzaghi & Peck and the method of Meyerhof. These methods are widely used to estimate bearing capacity using SPT-N values and soil parameters.

The method developed by Terzaghi & Peck in 1967 shows that the bearing capacity of soils can be determined graphically from foundation width and SPT-N values. Terzaghi & Peck presented some approaches to allowable bearing pressure, taking into account the 25 mm settlement of the foundation. These approaches are presented in a graph showing the relationship between the footing width (B) and the SPT-N values obtained from experimental studies Figure 3.2.

When using this graph, the average number of SPTs at a depth of B, or more precisely, 2B (2B for single foundations and 3B for strip foundations), from the base of the foundation is used. In this study, the width of the foundation was chosen to be 3 m for the purpose of determining the bearing capacity and calculated using a graphical approach.

The study analyzed the bearing capacity using data from 253 boreholes and field tests and compared the Terzaghi & Peck method with the Meyerhof method. The comparative bearing capacity map calculated using both methods is shown in Figure 4.9.

The information provided here is intended to give an indication of the bearing capacity of the soil at different locations and depths in the study area. However, this is only a sample data set, and more data and detailed studies are required for a complete soil analysis.

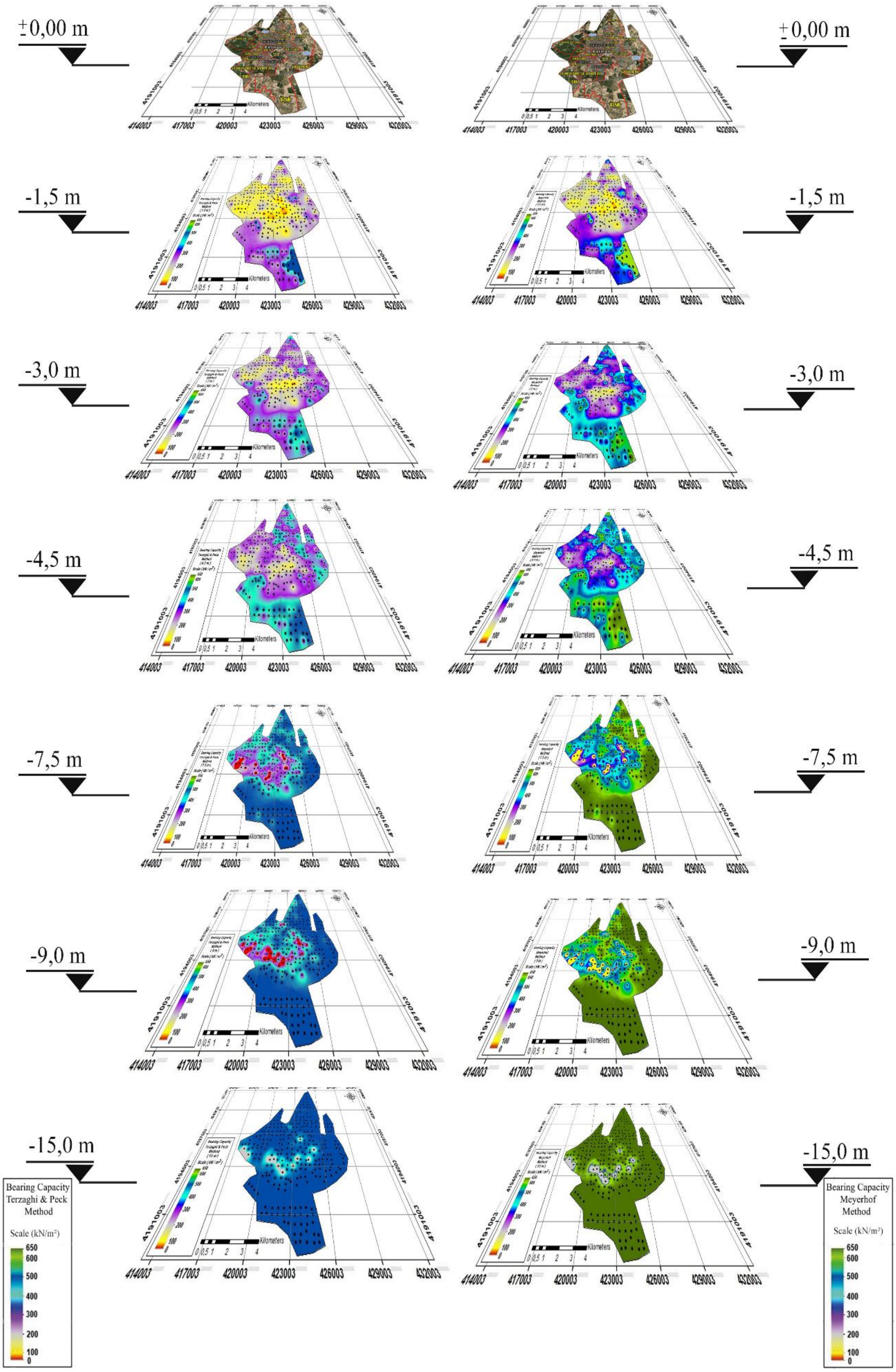


Figure 4.9. Comparison of bearing capacity maps according to Terzaghi & Peck and Meyerhof.

To make a comparison, calculations were conducted for a foundation width of 3 m using the values from the boreholes that extended from the surface to a depth of 15 m. Bearing capacity maps for both calculation methods were generated at various depths, including 1.5 m, 3 m, 4.5 m, 7.5 m, 9 m, and 15 m. These maps were created using the IDW method on a 10 m square grid with the assistance of the ArcGIS software.

Calculations were performed using data from 241 boreholes regarding SPT-N values. Figure 4.10 displays the bearing capacity maps calculated by the Meyerhof method for a depth of 1.5 m. Similarly, Figure 4.11 showcases the bearing capacities calculated using the Terzaghi & Peck method. Additionally, Figure 4.12 provides a comparison graph. The values obtained from the Terzaghi & Peck method ranged from 39-488 kN/m², while the Meyerhof method yielded values between 45-566 kN/m².

According to the map showing the variation of the SPT-N values measured for 1.5 m depth of the study area and the calculated bearing capacity analyses;

- In the northern region of the study area, specifically in Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc neighbourhoods, the values obtained from the Terzaghi & Peck method ranged from 39-488 kN/m², while the Meyerhof method yielded values between 45-566 kN/m².

- In the inner parts of the study area, specifically in Hilal, Kültür, GAP, Sağlık, Cumhuriyet, Yavuz Selim, Huzur, and Karşıyaka neighbourhoods, the Terzaghi & Peck method produced values ranging from 39-293 kN/m², while the Meyerhof method yielded values between 45-339 kN/m².

- On the other hand, in the southern regions of Petrolkent and Seyitler neighbourhoods, the Terzaghi & Peck method resulted in values ranging from 98-215 kN/m², while the Meyerhof method produced values between 113-249 kN/m².

- The Terzaghi & Peck method revealed values ranging from 117-488 kN/m², whereas the Meyerhof method produced values between 136-566 kN/m² in Güneykent and Çamlıca neighbourhoods located in the southwestern area.

- Values obtained from the Terzaghi & Peck method ranged from 39-488 kN/m², while the Meyerhof method yielded values between 45-566 kN/m² in the southeastern neighborhoods of Bayındır, Petrol, and Site.

- The values obtained from the Terzaghi & Peck method ranged from 69-293 kN/m², whereas the Meyerhof method yielded values between 79-339 kN/m² in the eastern neighborhoods of Fatih and Petrol.

- In the western neighborhoods of Girbereşik and Yeniköy, the Terzaghi & Peck method resulted in values ranging from 69-283 kN/m², while the Meyerhof method produced values between 79-328 kN/m².

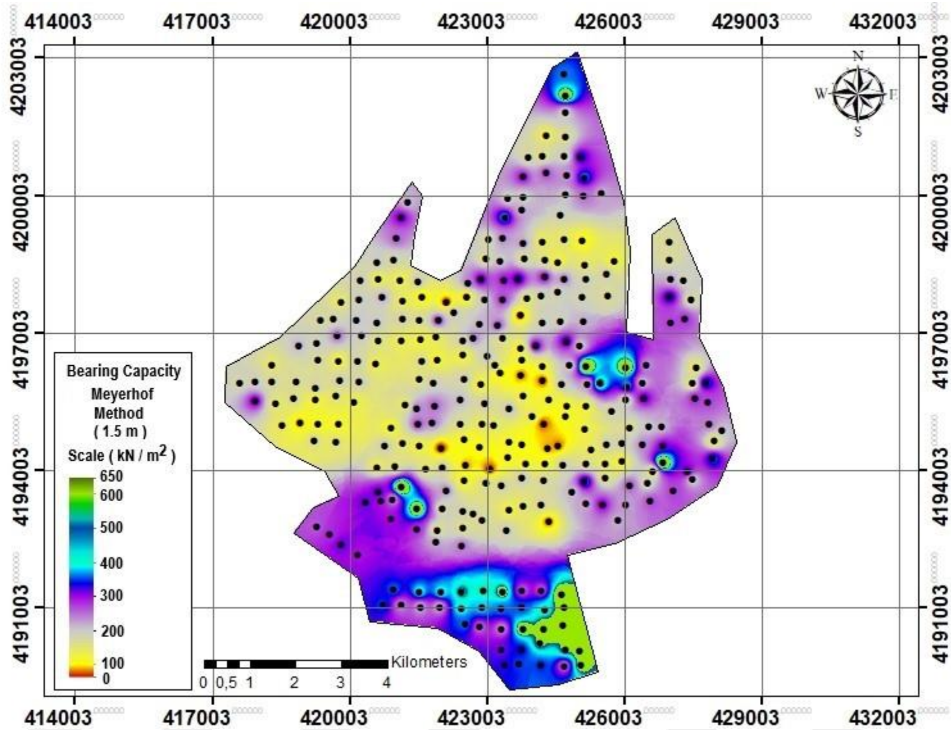


Figure 4.10. Bearing capacity map according to Meyerhof for 1.5 m depth.

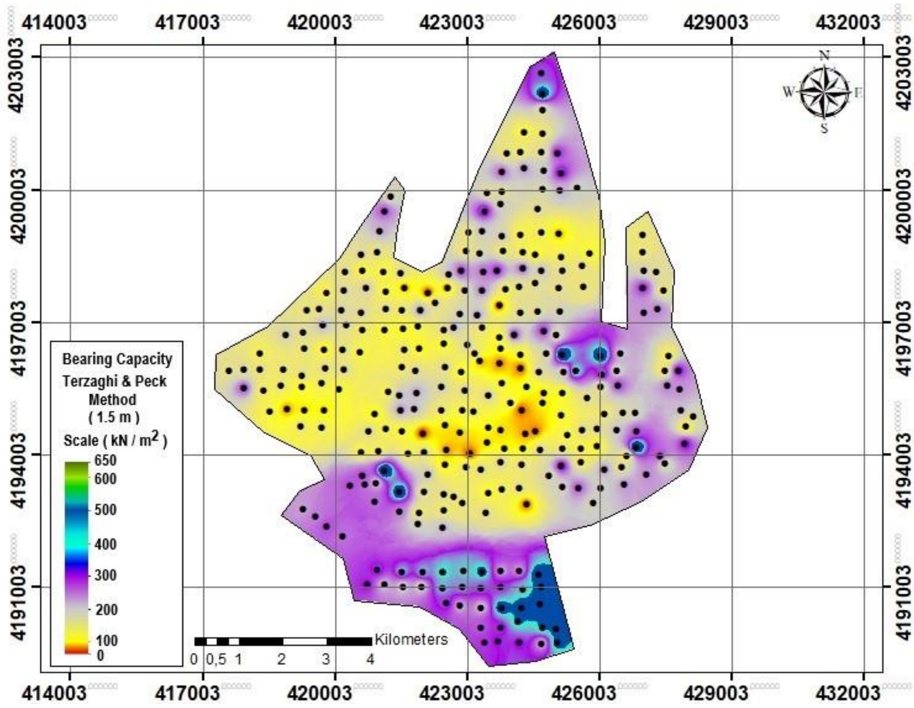


Figure 4.11. Bearing capacity map according to Terzaghi & Peck (1967) method for 1.5 m depth.

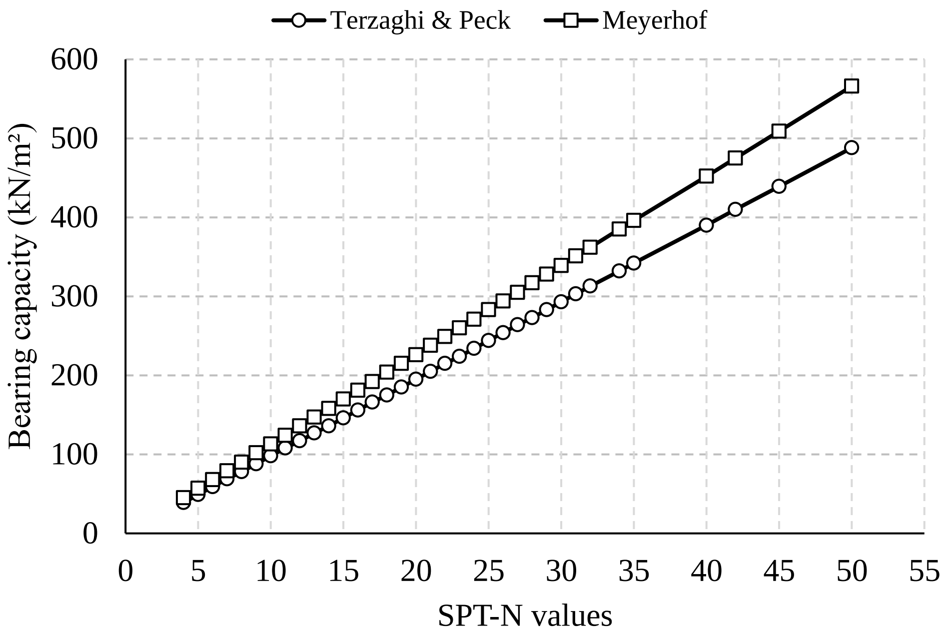


Figure 4.12. Graph of bearing capacity vs. SPT-N values according to Meyerhof and Terzaghi & Peck for 1.5 m depth.

Calculations were made using SPT-N data from 241 boreholes. In this context, Figure 4.13 shows the bearing capacity maps calculated by Meyerhof for 3.0 m depth,

Figure 4.14 shows the bearing capacities calculated by Terzaghi & Peck method, and Figure 4.15 presents the comparison graph. Terzaghi & Peck method yielded values between 49-488 kN/m² and Meyerhof method yielded values between 65-646 kN/m².

According to the map showing the variation of the SPT-N values measured for 3.0 m depth of the study area and the calculated bearing capacity analyses;

- Located in the northern region of the study zone, the Terzaghi & Peck method yielded values ranging from 98-488 kN/m², and the Meyerhof method produced values between 129-646 kN/m² in the neighborhoods of Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc.

- The neighborhoods of Hilal, Kültür, GAP, Sağlık, Cumhuriyet, Yavuz Selim, Huzur, and Karşıyaka in the inner parts of the study area showed values ranging from 59-488 kN/m² according to the Terzaghi & Peck method and 77-646 kN/m² according to the Meyerhof method.

- Values obtained using the Terzaghi & Peck method in the southern neighborhoods of Petrolkent and Seyitler ranged from 166-234 kN/m², while the Meyerhof method yielded values between 220-310 kN/m².

- The Terzaghi & Peck method determined values ranging from 156-488 kN/m² in the southwest neighborhoods of Güneykent and Çamlıca, while the Meyerhof method produced values between 207-646 kN/m².

- Values obtained using the Terzaghi & Peck method in the southeastern neighborhoods of Bayındır, Petrol, and Site ranged from 39-488 kN/m², while the Meyerhof method determined values between 65-646 kN/m².

- In the eastern neighborhoods of Fatih and Petrol, values ranging from 146-488 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 194-646 kN/m².

- In the western neighborhoods of Girbereşik and Yeniköy, values ranging from 78-488 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 103-646 kN/m².

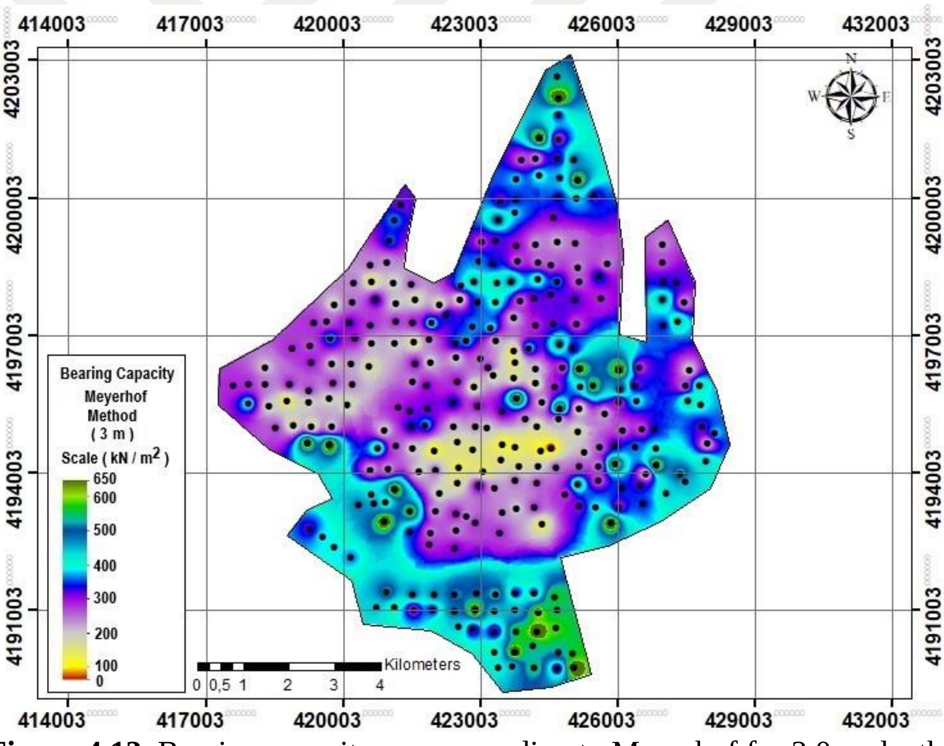


Figure 4.13. Bearing capacity map according to Meyerhof for 3.0 m depth.

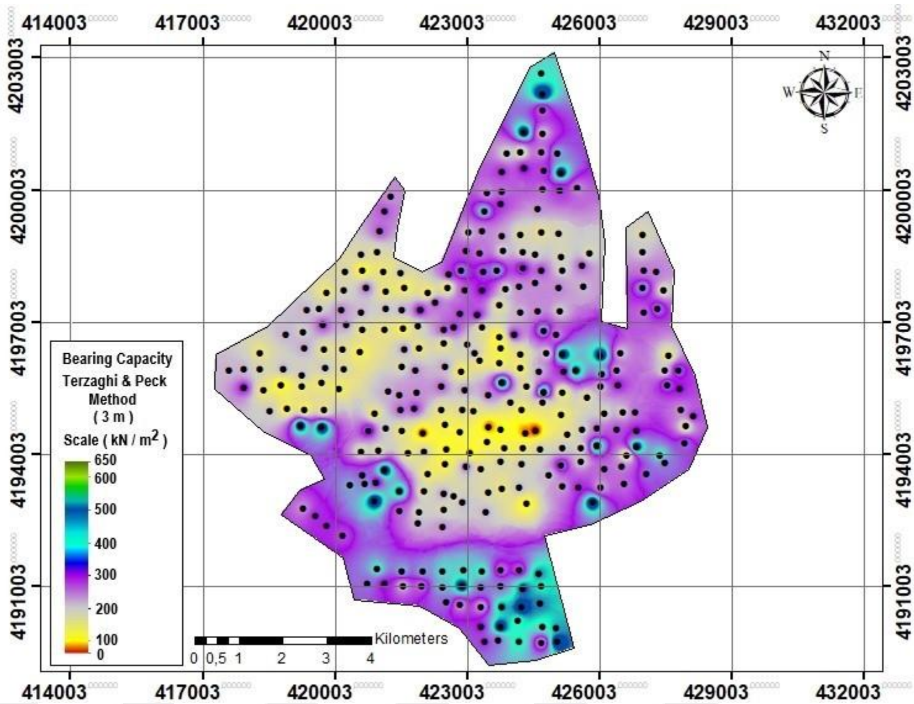


Figure 4.14. Bearing capacity map according to Terzaghi & Peck (1967) method for 3.0 m depth.

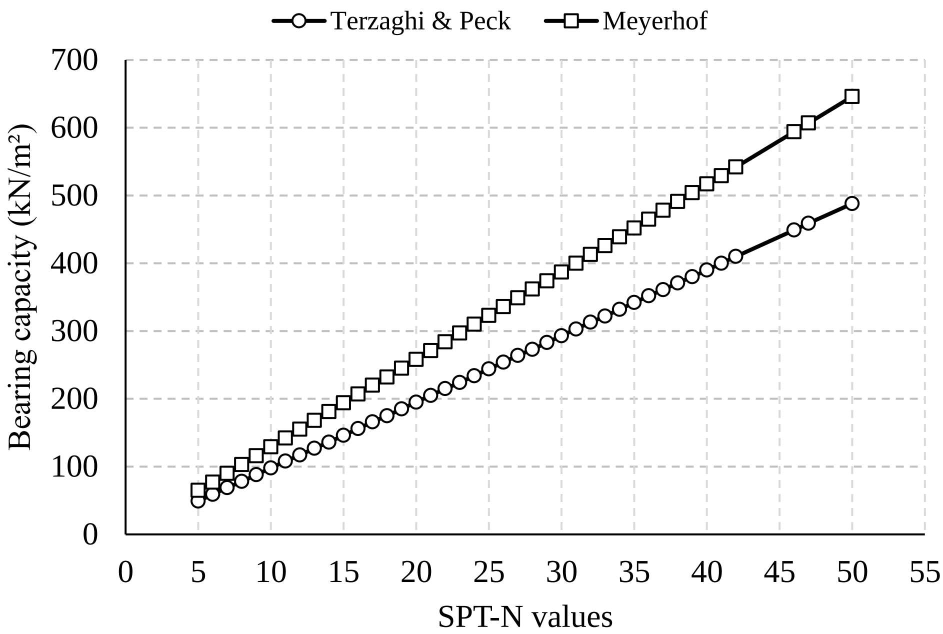


Figure 4.15. Graph of bearing capacity vs. SPT-N values according to Meyerhof and Terzaghi & Peck for 3.0 m depth.

Calculations were made using SPT-N data from 241 boreholes. In this context, Figure 4.16 shows the bearing capacity maps calculated by Meyerhof for 4.5 m depth, Figure 4.17 shows the bearing capacities calculated by Terzaghi & Peck method, and Figure 4.18 presents the comparison graph.Terzaghi & Peck method yielded values in the range of 78-488 kN/m² and Meyerhof method yielded values in the range of 103-646 kN/m².

According to the map showing the variation of SPT-N values measured for 4.5 m depth of the study area and the calculated bearing capacity analyses;

- Northern neighborhoods of the study area, including Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc, yielded values ranging from 136-488 kN/m² using the Terzaghi & Peck method and from 181-646 kN/m² with the Meyerhof method.

- Values ranging from 78-488 kN/m² were determined in Hilal, Kültür, GAP, Sağlık, Cumhuriyet, Yavuz Selim, Huzur, and Karşıyaka Neighborhoods using the Terzaghi & Peck method, while the Meyerhof method yielded values between 103-646 kN/m². These neighborhoods are located in the inner parts of the study area.

- Values ranging from 234-293 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 310-387 kN/m² in the southern neighborhoods of Petrolkent and Seyitler.

- In the southwest neighborhoods of Güneykent and Çamlıca, values ranging from 146-488 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 194-646 kN/m².

- In the southeast neighborhoods of Bayındır, Petrol, and Site, values between 88-488 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 116-646 kN/m².

- Values ranging from 127-468 kN/m² were determined in the eastern neighborhoods of Fatih and Petrol using the Terzaghi & Peck method, while the Meyerhof method yielded values between 168-620 kN/m².

- In the western neighborhoods of Girbereşik and Yeniköy, values between 108-371 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 142-491 kN/m².

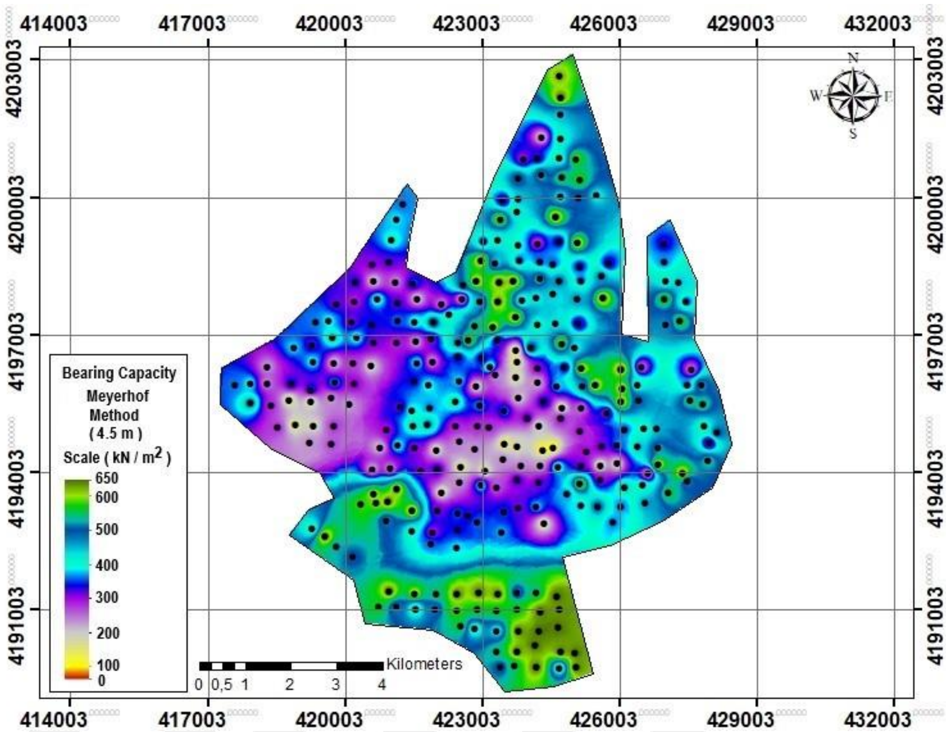


Figure 4.16. Bearing capacity map according to Meyerhof for 4.5 m depth.

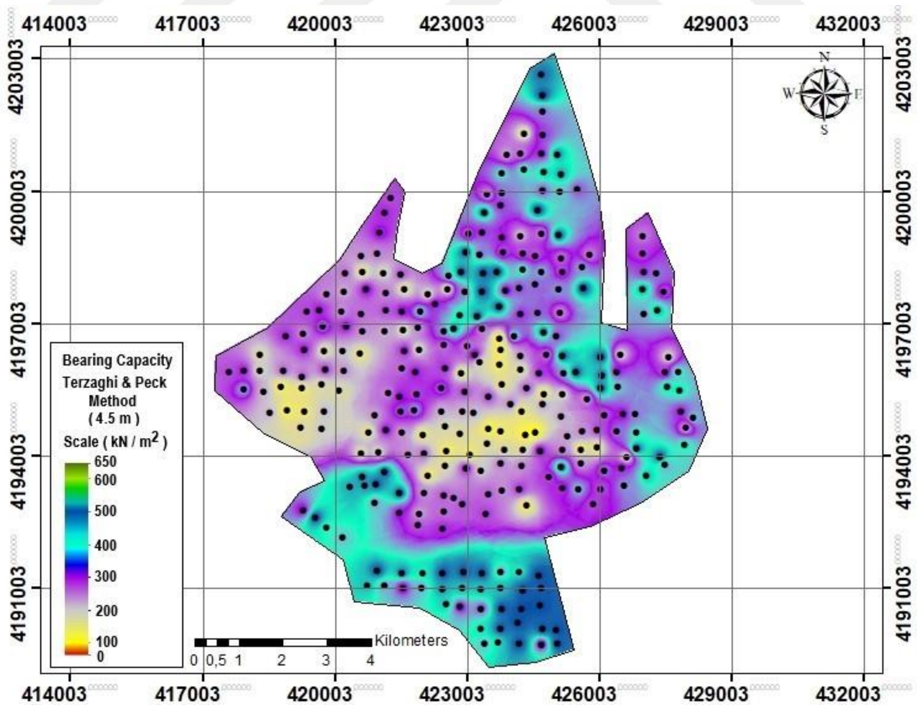


Figure 4.17. Bearing capacity map according to Terzaghi & Peck (1967) method for 4.5 m depth.

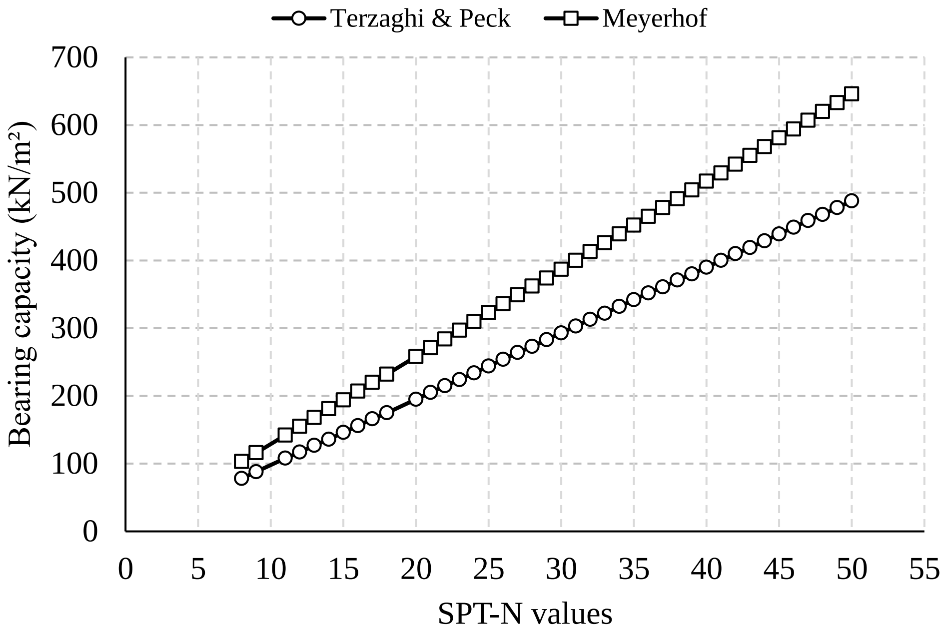


Figure 4.18. Graph of bearing capacity vs. SPT-N values according to Meyerhof and Terzaghi & Peck for 4.5 m depth.

Calculations were made using SPT-N data from 241 boreholes. In this context, Figure 4.19 shows the bearing capacity maps calculated by Meyerhof for 7.5 m depth, Figure 4.20 shows the bearing capacities calculated by Terzaghi & Peck method, and Figure 4.21 presents the comparison graph. Terzaghi & Peck method yielded values between 49-488 kN/m² and Meyerhof method yielded values between 65-646 kN/m².

According to the map showing the variation of SPT-N values measured for 7.5 m depth of the study area and the calculated bearing capacity analyses;

- In the northern part of the study area, the values ranging from 98-488 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 129-646 kN/m² in Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc Neighborhoods.

- Located in the inner parts of the study area, Hilal, Kültür, GAP, Sağlık, Cumhuriyet, Yavuz Selim, Huzur, and Karşıyaka Neighborhoods had values ranging from 69-488 kN/m² according to the Terzaghi & Peck method, while the Meyerhof method yielded values between 90-646 kN/m².

- In the southern neighborhoods of Petrolkent and Seyitler, values ranging from 185-488 kN/m² were determined using the Terzaghi & Peck method, while the Meyerhof method yielded values between 245-646 kN/m².

- In the southwest neighborhoods of Güneykent and Çamlıca, the Terzaghi & Peck method determined values ranging from 49-488 kN/m², while the Meyerhof method yielded values between 65-646 kN/m².

- In the southeast neighborhoods of Bayındır, Petrol, and Site, the Terzaghi & Peck method determined values ranging from 88-488 kN/m², while the Meyerhof method yielded values between 116-646 kN/m².

- In the eastern neighborhoods of Fatih and Petrol, the Terzaghi & Peck method determined values ranging from 195-488 kN/m², while the Meyerhof method yielded values between 258-620 kN/m².

- In the western neighborhoods of Girbereşik and Yeniköy, the Terzaghi & Peck method determined values ranging from 78-488 kN/m², while the Meyerhof method yielded values between 103-646 kN/m².

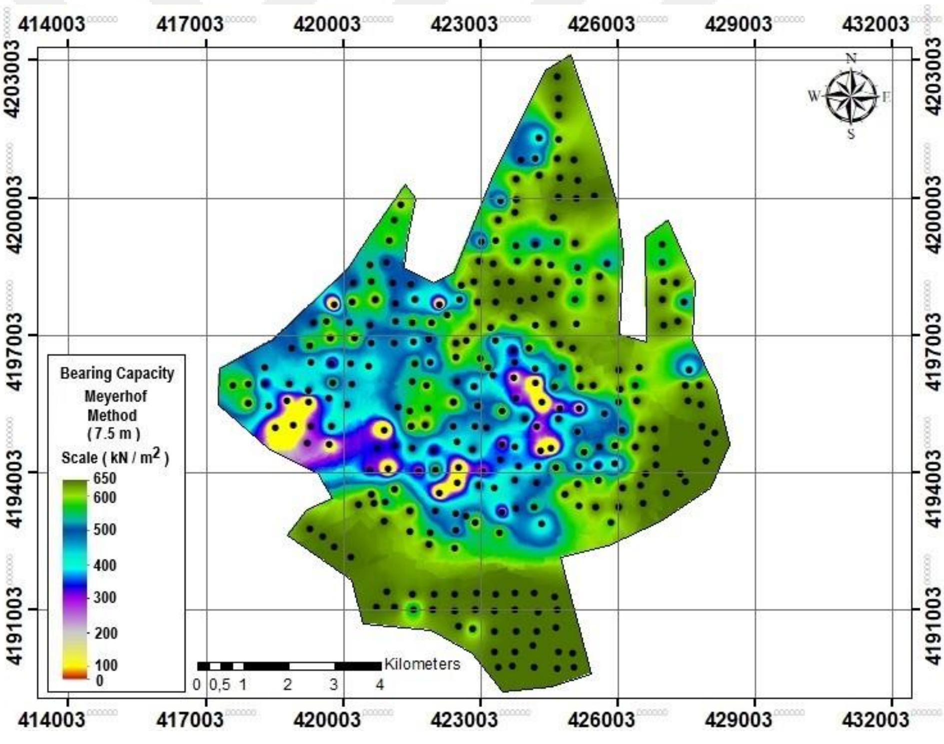


Figure 4.19. Bearing capacity map according to Meyerhof for 7.5 m depth.

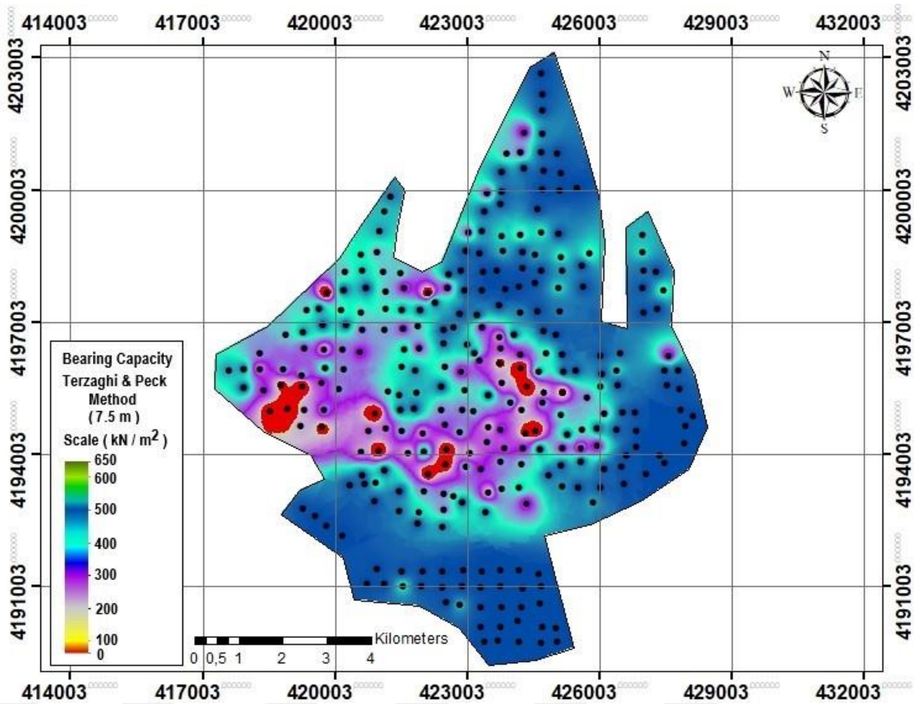


Figure 4.20. Bearing capacity map according to Terzaghi & Peck (1967) method for 7.5 m depth.

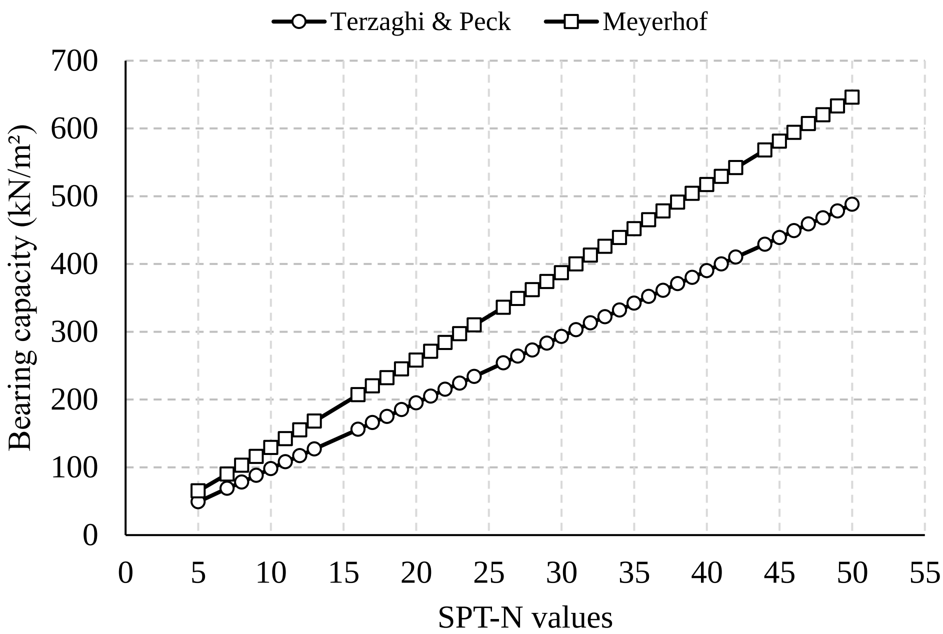


Figure 4.21. Graph of bearing capacity vs. SPT-N values according to Meyerhof and Terzaghi & Peck for 7.5 m depth.

Calculations were made using SPT-N data from 237 boreholes. In this context, Figure 4.22 shows the bearing capacity maps calculated by Meyerhof for 9.0 m depth, Figure 4.23 shows the bearing capacities calculated by Terzaghi & Peck method, and Figure 4.24 presents the comparison graph. Terzaghi & Peck method yielded values in the range of 78-488 kN/m² and Meyerhof method yielded values in the range of 103-646 kN/m².

According to the map showing the variation of the measured SPT-N values for 9.0 m depth of the study area and the calculated bearing capacity analyses;

- In the north of the study area, specifically in Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc Neighborhoods, the Terzaghi & Peck method determined values ranging from 117-488 kN/m². Similarly, the Meyerhof method yielded values between 155-646 kN/m².

- Moving to the inner parts of the study area, including Hilal, Kültür, GAP, Sağlık, Cumhuriyet, Yavuz Selim, Huzur, and Karşıyaka Neighborhoods, the Terzaghi & Peck method determined values between 78-488 kN/m², while the Meyerhof method resulted in values ranging from 103-646 kN/m².

- Heading towards the south, specifically in Petrolkent and Seyitler Neighborhoods, the Terzaghi & Peck method determined values spanning from 283-488 kN/m², while the Meyerhof method yielded values between 374-646 kN/m².

- In the southwest neighborhoods of Güneykent and Çamlıca, the Terzaghi & Peck method determined values ranging from 459-488 kN/m², while the Meyerhof method yielded values between 607-646 kN/m².

- In the southeast neighborhoods of Bayındır, Petrol, and Site, values between 166-488 kN/m² were determined by the Terzaghi & Peck method, and the Meyerhof method resulted in values ranging from 220-646 kN/m².

- Moving to the east, specifically in Fatih and Petrol Neighborhoods, the Terzaghi & Peck method determined values between 352-488 kN/m², while the Meyerhof method yielded values ranging from 465-646 kN/m².

- In Girbereşik Neighborhood and Yeniköy neighborhoods in the west, values between 117-488 kN/m² according to the Terzaghi & Peck method and 155-646 kN/m² according to the Meyerhof method were determined.

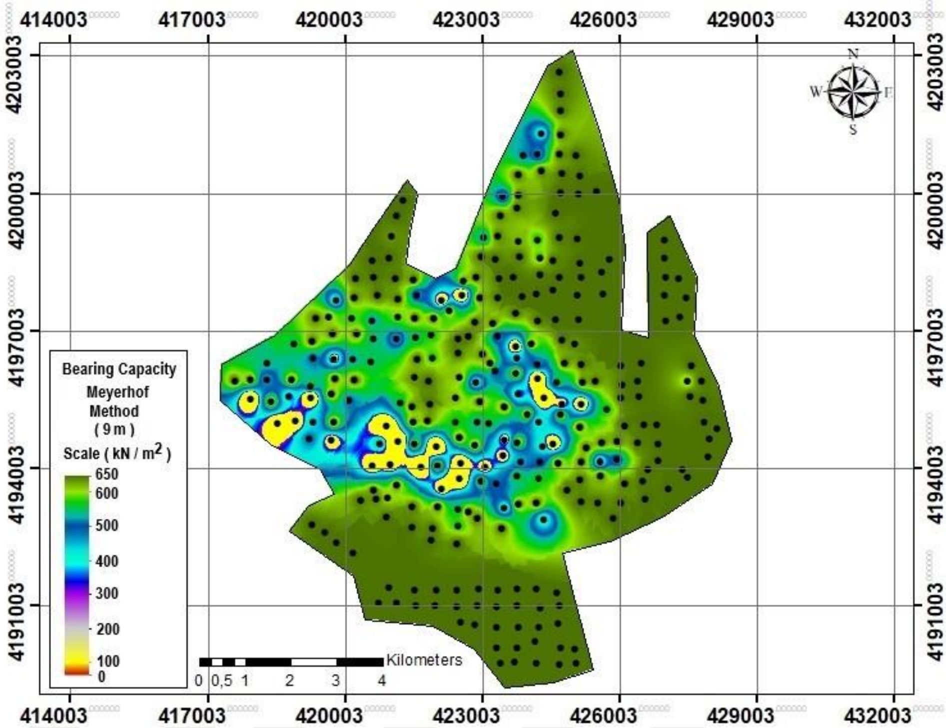


Figure 4.22. Bearing capacity map according to Meyerhof for 9.0 m depth.

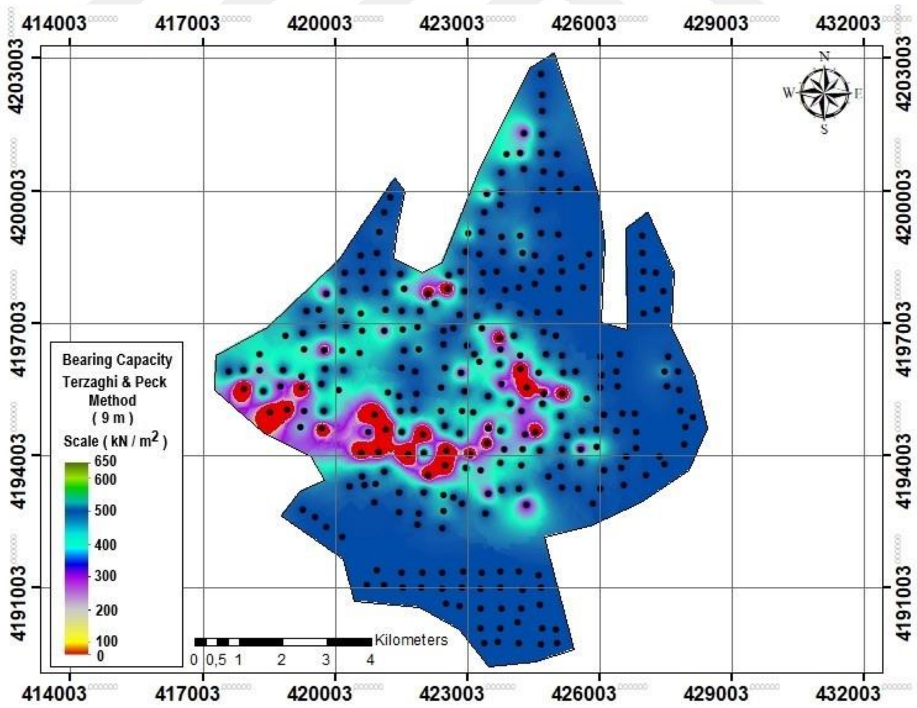


Figure 4.23. Bearing capacity map according to Terzaghi & Peck (1967) method for 9.0 m depth.

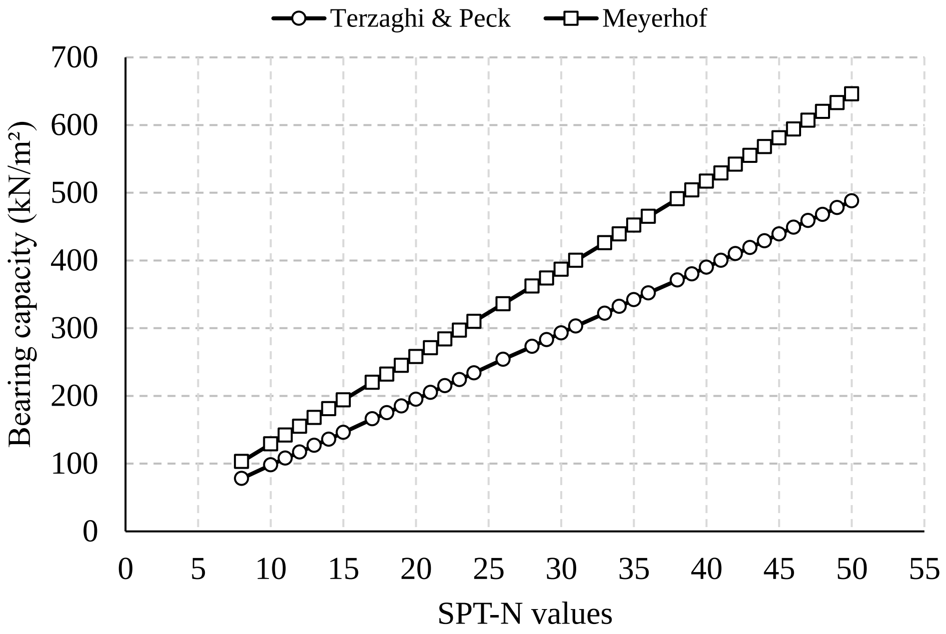


Figure 4.24. Graph of bearing capacity vs. SPT-N values according to Meyerhof and Terzaghi & Peck for 9.0 m depth.

Calculations were made using SPT-N data from 244 boreholes. In this context, Figure 4.25 shows the bearing capacity maps calculated by Meyerhof for 15.0 m depth, Figure 4.26 shows the bearing capacities calculated by Terzaghi & Peck method, and Figure 4.27 presents the comparison graph. Terzaghi & Peck method yielded values between 88-488 kN/m² and Meyerhof method yielded values between 116-646 kN/m².

According to the map showing the variation of the SPT-N values measured for 15.0 m depth of the study area and the calculated bearing capacity analyses;

- In the northern neighborhoods of Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc, the Terzaghi & Peck method yielded values ranging from 410-488 kN/m², while the Meyerhof method resulted in values between 542-646 kN/m².

- Moving to the inner parts of the study area, including Hilal, Kültür, GAP, Sağlık, Cumhuriyet, Yavuz Selim, Huzur, and Karşıyaka neighborhoods, the Terzaghi & Peck method determined values between 195-488 kN/m², while the Meyerhof method yielded values ranging from 258-646 kN/m².

- In the southern neighborhoods of Petrolkent and Seyitler, the Terzaghi & Peck method yielded values around 488 kN/m², while the Meyerhof method resulted in a value of 646 kN/m².

- Moving to the southwest neighborhoods of Güneykent and Çamlıca, the Terzaghi & Peck method determined values between 185-488 kN/m², while the Meyerhof method yielded values ranging from 245-646 kN/m².

- In the southeast neighborhoods of Bayındır, Petrol, and Site, values between 185-488 kN/m² according to the Terzaghi & Peck method and 245-646 kN/m² according to the Meyerhof method were determined.

- In the eastern neighborhoods of Fatih and Petrol, the Terzaghi & Peck method yielded values between 88-488 kN/m², while the Meyerhof method resulted in values ranging from 116-646 kN/m².

- Finally, in the western neighborhoods of Girbereşik and Yeniköy, the Terzaghi & Peck method determined values between 254-488 kN/m², while the Meyerhof method yielded values ranging from 336-646 kN/m².

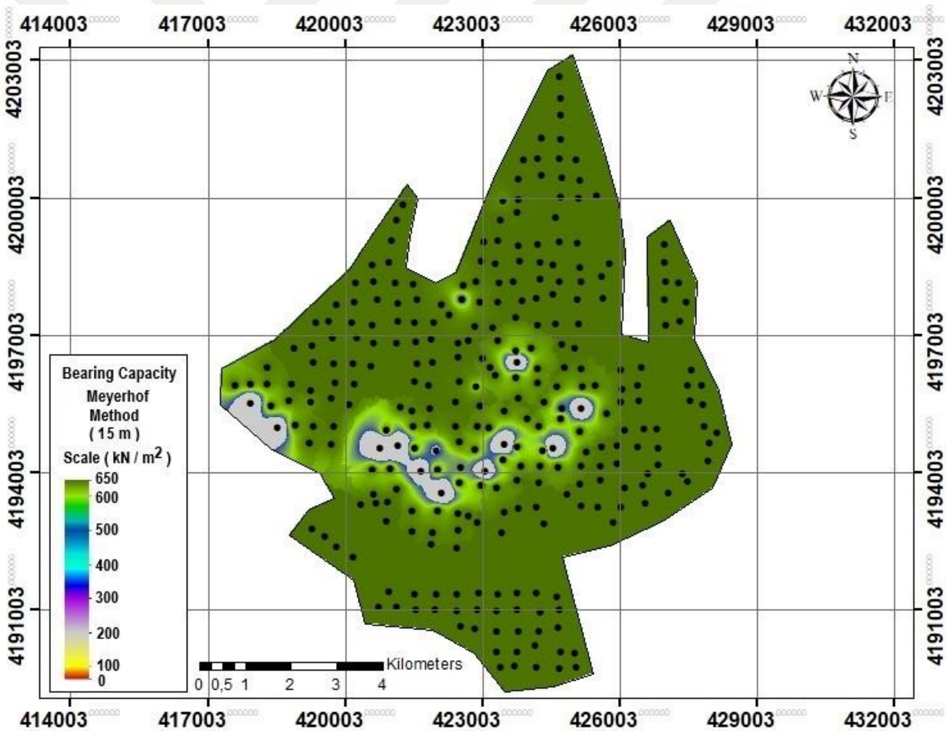


Figure 4.25. Bearing capacity map according to Meyerhof for 15.0 m depth.

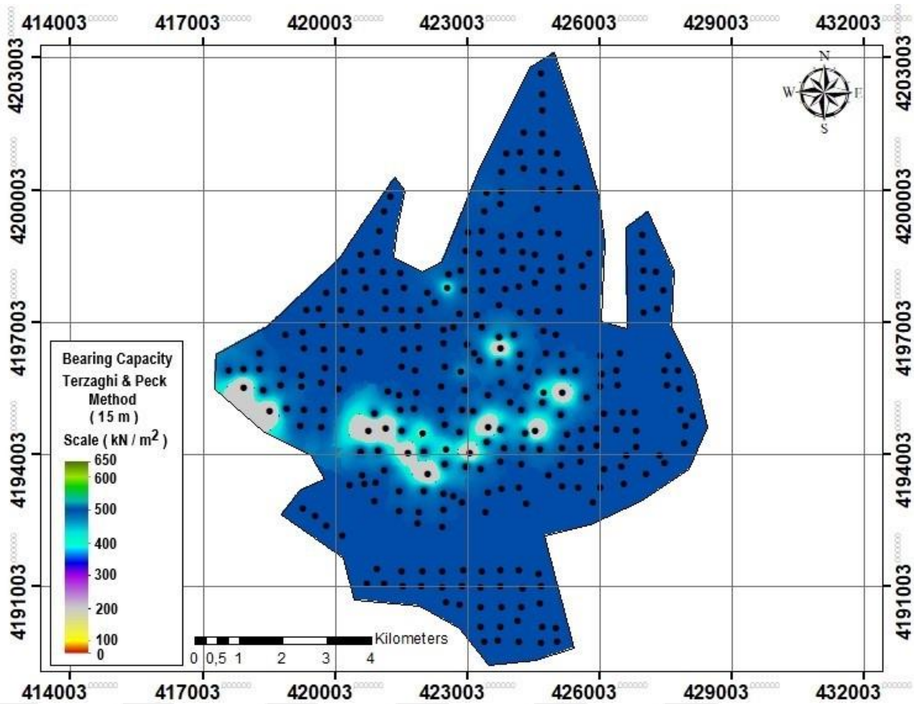


Figure 4.26. Bearing capacity map according to Terzaghi & Peck (1967) method for 15.0 m depth.

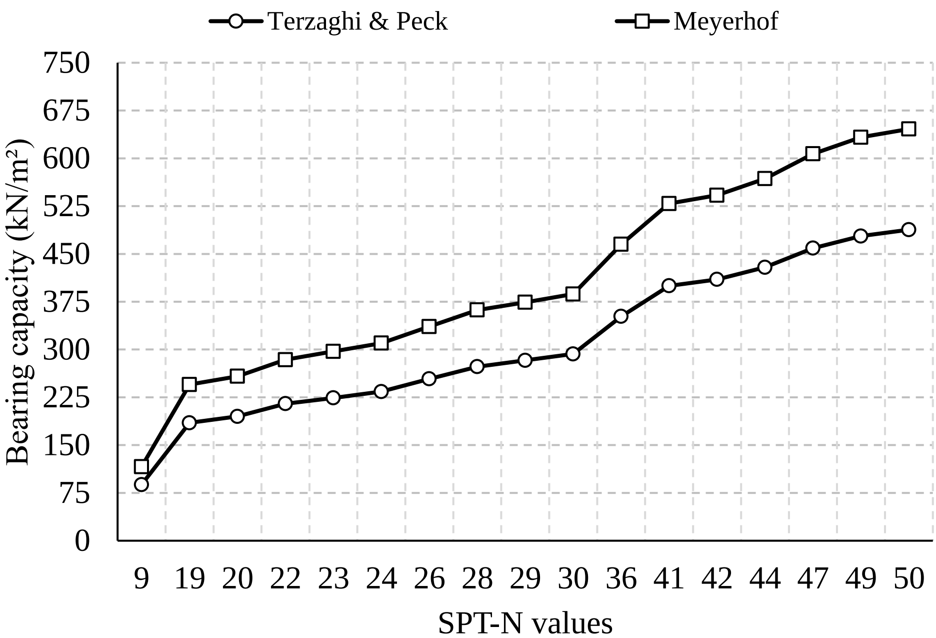


Figure 4.27. Graph of bearing capacity vs. SPT-N values according to Meyerhof and Terzaghi & Peck for 15.0 m depth.

4.4. Analysis of Groundwater Level and Water Content Maps

Groundwater is an important factor because it causes problems such as liquefaction and swelling of clay in the ground, deformation or corrosion of structural elements or materials in the foundations of engineering structures due to the effect of groundwater level, collapse due to the formation of melting voids in water-soluble or soluble rocks under the influence of water. Therefore, determining the groundwater level is crucial to reduce or eliminate the issues caused by groundwater. For these reasons, Figure 4.28 illustrates the groundwater depth maps that were created for the study area.

When values obtained from 114 boreholes throughout the study area are analysed;

- In the study area, a depth of 15 m from the surface was examined and it was found that the water level starts at 3 m.

- It varies between 3 m and 7 m due to the fact that some parts of Girbereşik neighbourhood and Yeniköy in the west are close to the Batman stream. Apart from this, a general examination of the study area shows that it is not rich in groundwater.

- When the groundwater level is closer than 10 metres to the surface, the liquefaction hazard increases. However, if the groundwater levels are depther than 20 metres and the soil has a dense, non-loose structure, the liquefaction potential is low. In this case, the liquefaction hazard decreases (Youd, 1984). This information is important in assessing potential risks in areas close to the Batman stream and can provide guidance on taking necessary precautions.

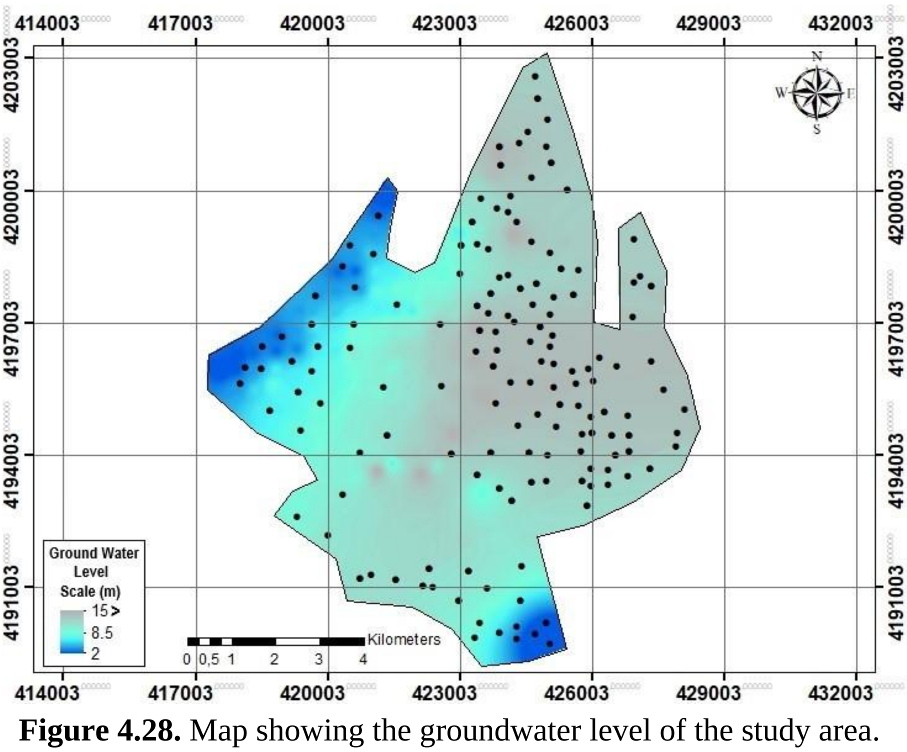


Figure 4.28. Map showing the groundwater level of the study area.

The soil water content is defined as the proportion of water held in the pore spaces between soil particles to the dry mass of the soil. Soil water content is typically determined by calculating the ratio between the weight of water remaining in the soil after subtracting the dry weight from the total weight of the soil, and the dry weight of the soil. In simpler terms, it is the weight of the water contained in the soil pore spaces divided by the dry weight of the soil.

The data collected from 215 borehole logs across the study area revealed the following distribution of water content values at a depth of 1.5 m:

- Approximately 2% of the study area had values ranging from 5.3 to 10.
- The majority, accounting for 56% of the study area, fell within the range of 11 to 20.
- Another 42% of the study area had water content values between 21 and 40.8.
- On average, the water content value for the entire study area was 20.23%.

To visually represent this distribution, a map displaying the water content values at a depth of 1.5 m in the study area is provided in Figure 4.29.

- In the northern villages of Yediyol, Gültepe, Beld, Çamlıtepe, and Tilmerc, the water content values range from 6% to 40.8%.

- Moving to the inner regions of the study area, including 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur, and Karşıyaka neighborhoods, the water content values range from 11.1% to 31.3%.

- The southern neighborhoods of Petrolkent and Seyitler have water content values ranging from 16.3% to 28.6%, while Güneykent and Çamlıca, located in the southwest, have values ranging from 15.8% to 25.3%.

- The Bayındır and Site neighborhoods in the southeast have water content values ranging from 5.3% to 30.4%.

- The eastern neighborhoods of Fatih, Korik, and Petrol display water content values between 12.6% and 27.8%.

- Finally, in the western neighborhoods of Girbereşik and Yeniköy, the water content values range from 11.1% to 30.9%.

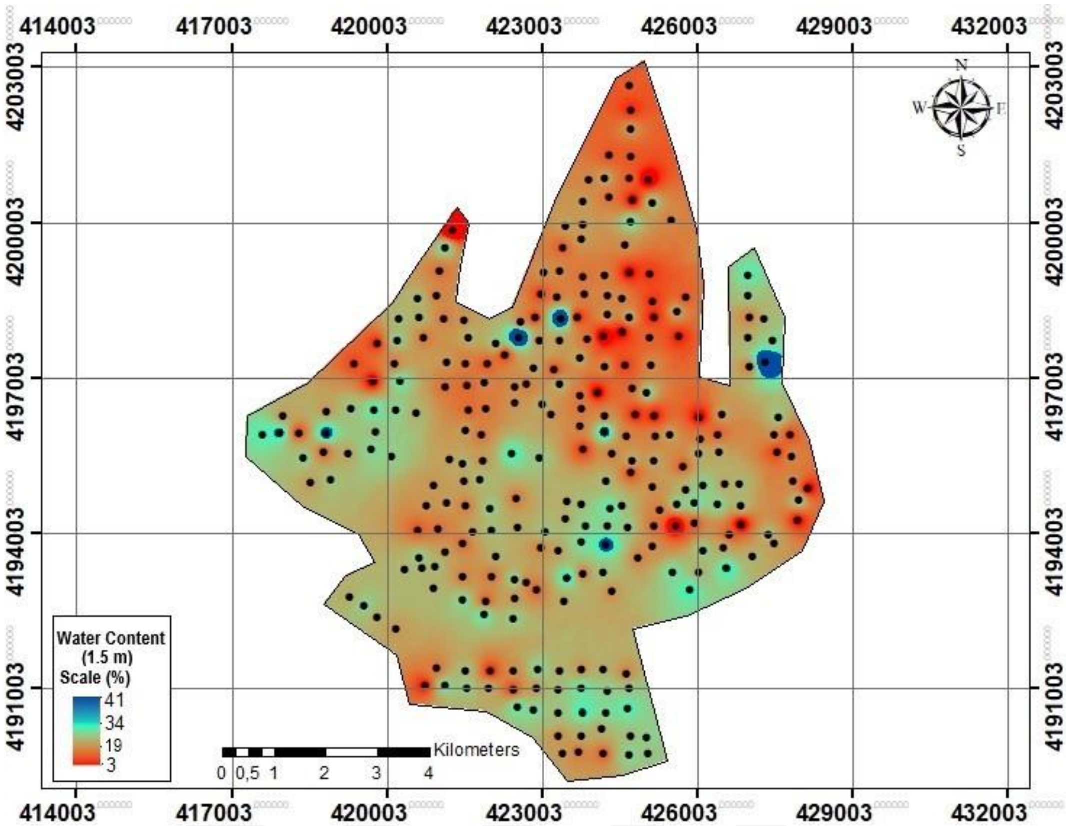


Figure 4.29. Map of laboratory water content values according to 1.5 m depth.

The data collected from 215 borehole points across the study area reveals the distribution of water content values at a depth of 3.0 m:

- Approximately 5% of the study area had values ranging from 3 to 10.
- The majority, accounting for 56% of the study area, fell within the range of 11 to 20.
- Another 39% of the study area had water content values between 21 and 36.90.
- On average, the water content value for the entire study area was 19.62%.

To visually showcase this distribution, a map displaying the water content values at a depth of 3.0 m in the study area is provided in Figure 4.30.

- In the northern neighborhoods of Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc, the water content values ranged from 6.5% to 36.9%.

- Moving towards the inner parts of the study area, including 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur, and Karşıyaka neighborhoods, the water content values ranged from 7.20% to 28.20%.

- In the southern neighborhoods of Petrolkent and Seyitler, the water content values ranged from 14.8% to 25.2%.

- The Güneykent and Çamlıca neighborhoods in the southwest had water content values ranging from 14.1% to 26.6%.

- The Bayındır and Site neighborhoods in the southeast had water content values ranging from 3.7% to 28.8%.

- In the eastern neighborhoods of Fatih, Korik, and Petrol, the water content values ranged from 11.20% to 28.1%.

- Finally, the Girbereşik and Yeniköy neighborhoods in the west displayed water content values ranging from 3% to 34.1%.

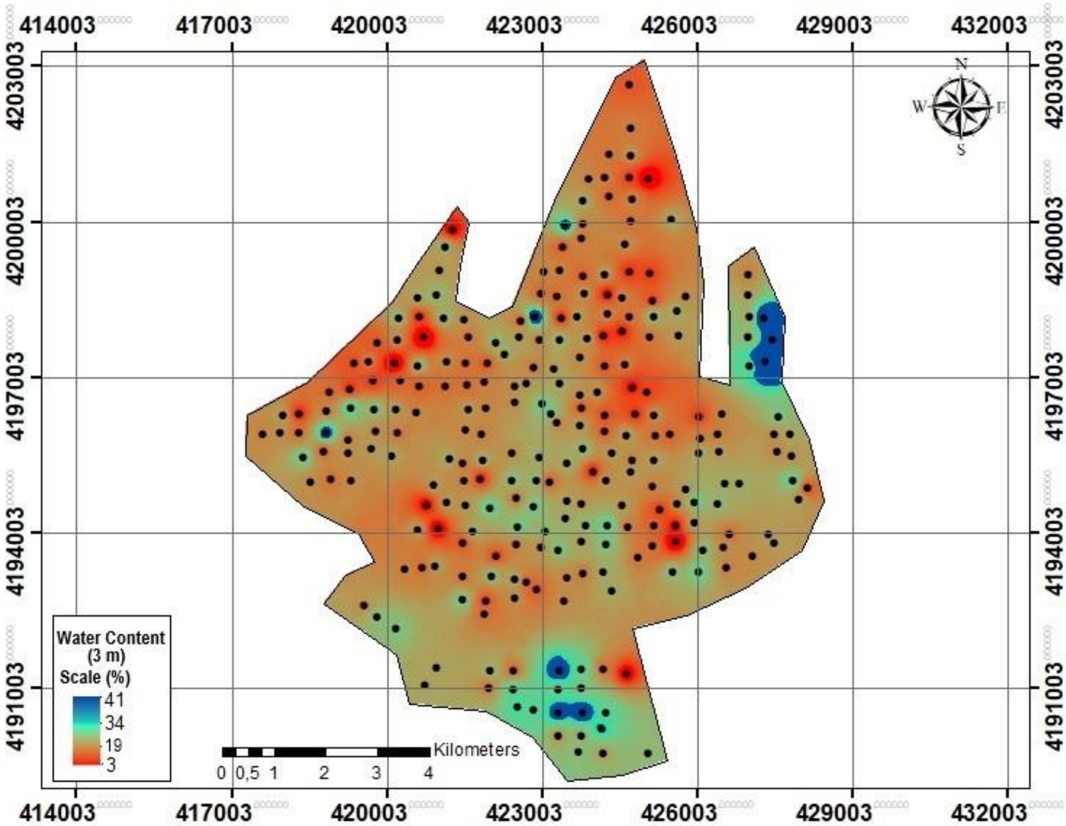


Figure 4.30. Map of laboratory water content values according to 3.0 m depth.

The data acquired from 207 boreholes across the study area reveals the distribution of water content values at a depth of 4.5 m:

- Around 5% of the study area had water content values ranging from 5.4 to 10.
- The majority, accounting for 59% of the study area, had water content values between 11 and 20.
- Another 36% of the study area had values between 21 and 32.10.
- On average, the water content value for the whole study area was 19.08%.

To provide a visual representation of this distribution, a map displaying the distribution of water content values at a depth of 4.5 m in the study area is presented in Figure 4.31.

- In the northern neighborhoods of Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc, the water content values ranged from 8.8% to 27.4%.

- Moving towards the inner parts of the study area, including 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur, and Karşıyaka neighborhoods, the water content values ranged from 12% to 25.3%.

- In the southern neighborhoods of Petrolkent and Seyitler, the water content values ranged from 16.1% to 32.1%.

- The Güneykent and Çamlıca neighborhoods in the southwest had water content values ranging from 15.6% to 23.1%.

- The Bayındır and Site neighborhoods in the southeast displayed water content values ranging from 5.4% to 27.8%.

- In the eastern neighborhoods of Fatih, Korik, and Petrol, the water content values ranged from 11.1% to 23.6%.

- Finally, the Girbereşik and Yeniköy neighborhoods in the west showed water content values ranging from 6% to 30.6%.

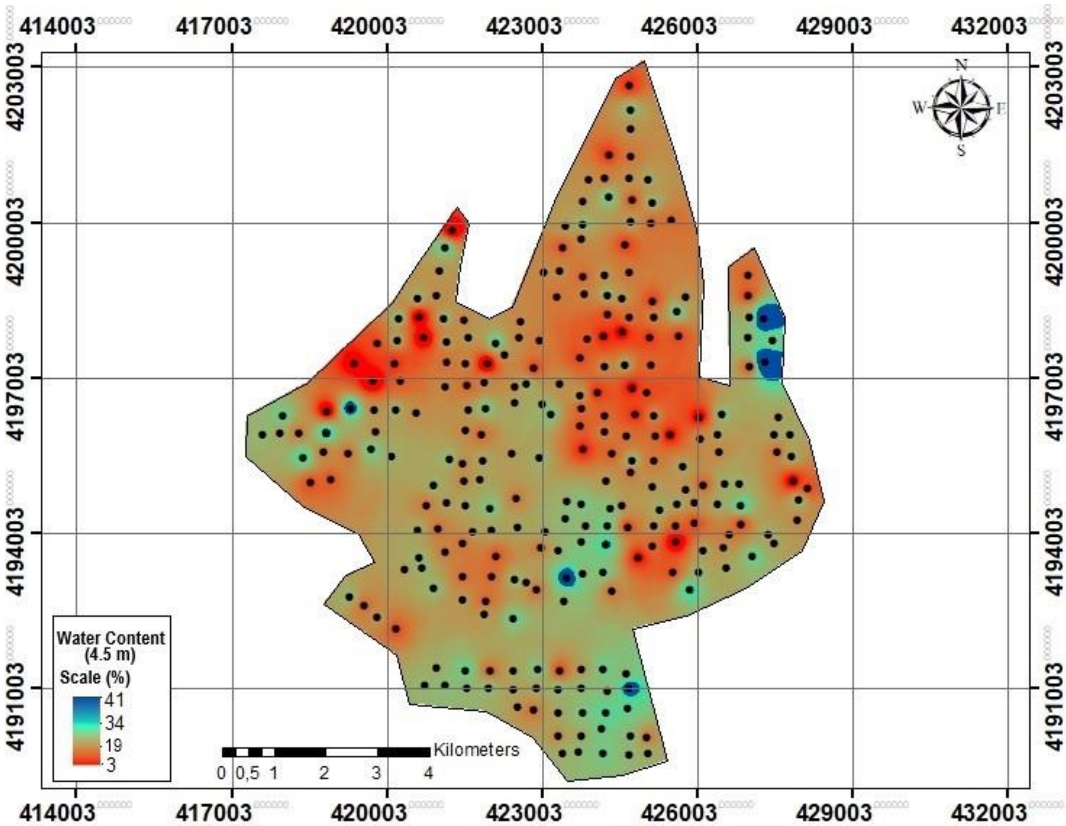


Figure 4.31. Map of laboratory water content values according to 4.5 m depth.

The data acquired from 175 boreholes across the study area provides insights into the distribution of water content values at a depth of 7.5 m:

- Approximately 7% of the study area had water content values ranging from 5.8 to 10.
- The majority, accounting for 55% of the study area, exhibited water content values between 11 and 20.
- Another 38% of the study area had values between 21 and 38.5.
- On average, the water content value for the entire study area was 19.18%.

To visualize this distribution, a map illustrating the distribution of water content values at a depth of 7.5 m in the study area is presented in Figure 4.32.

- In the northern neighborhoods of Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc, the water content values ranged from 8% to 26.8%.

- Moving towards the inner parts of the study area, including 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur, and Karşıyaka neighborhoods, the water content values ranged from 10.6% to 24.3%.

- In the southern neighborhoods of Petrolkent and Seyitler, the water content values ranged from 6.4% to 25.8%.

- The Güneykent and Çamlıca neighborhoods in the southwest exhibited water content values ranging from 6.7% to 24.6%.

- The Bayındır and Site neighborhoods in the southeast had water content values ranging from 11.2% to 29.9%.

- In the eastern neighborhoods of Fatih, Korik, and Petrol, the water content values ranged from 10.3% to 26.2%.

- Finally, the Girbereşik and Yeniköy neighborhoods in the west showed water content values ranging from 5.8% to 38.5%.

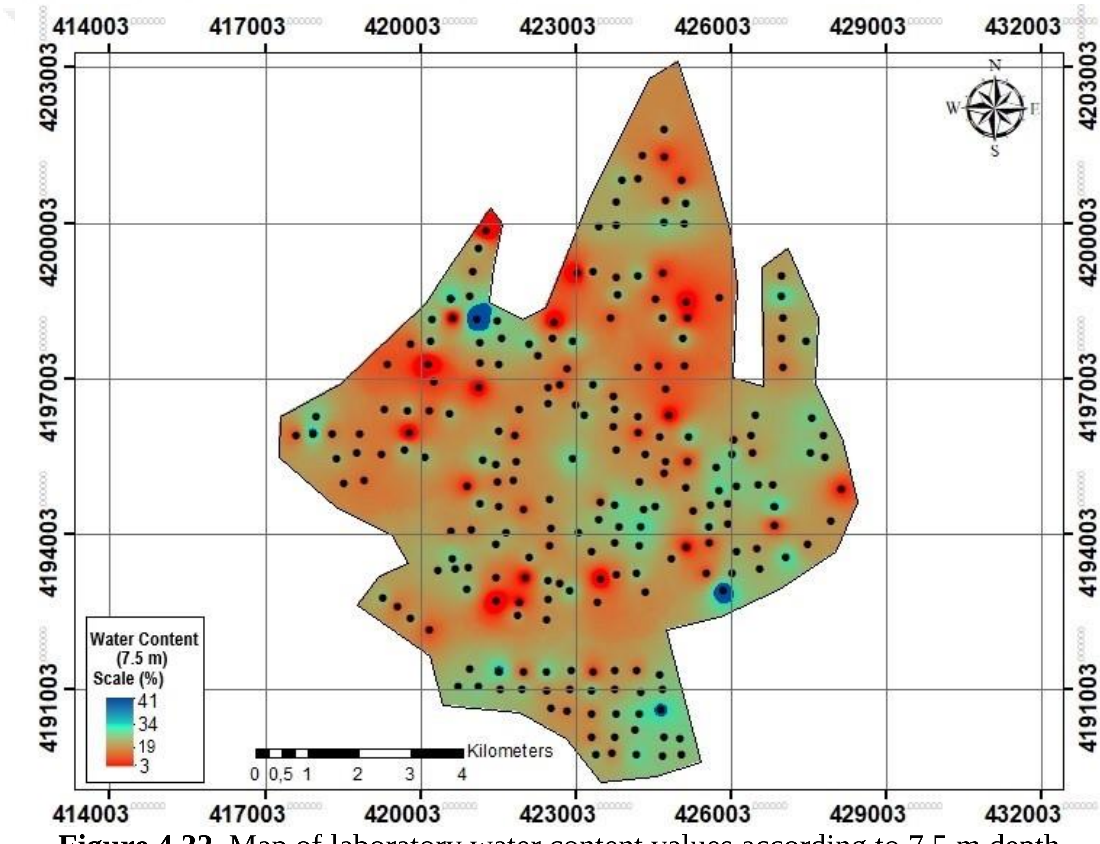


Figure 4.32. Map of laboratory water content values according to 7.5 m depth.

The data gathered from 175 boreholes across the study area provides information about the distribution of water content values at a depth of 9.0 m:

- Approximately 8% of the study area exhibited water content values ranging from 5.3 to 10.
- The majority, accounting for 55% of the study area, displayed values between 11 and 20.
- Another 37% of the study area showed values between 21 and 34.1.
- On average, the water content value for the entire study area was 19.34%.

To visualize this distribution, a map illustrating the distribution of water content values at a depth of 9.0 m in the study area is presented in Figure 4.33.

- In the northern neighborhoods of Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc, the water content values ranged from 9.6% to 24.4%.

- Moving towards the inner parts of the study area, including 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur, and Karşıyaka neighborhoods, the water content values ranged from 10.7% to 29.5%.

- In the southern neighborhoods of Petrolkent and Seyitler, the water content values ranged from 7.2% to 25.2%.

- The Güneykent and Çamlıca neighborhoods in the southwest exhibited water content values ranging from 12.7% to 26.6%.

- The Bayındır and Site neighborhoods in the southeast had water content values ranging from 10.1% to 28.5%.

- In the eastern neighborhoods of Fatih, Korik, and Petrol, the water content values ranged from 13.3% to 28.1%.

- Finally, the Girbereşik and Yeniköy neighborhoods in the west showed water content values ranging from 5.3% to 34.1%.

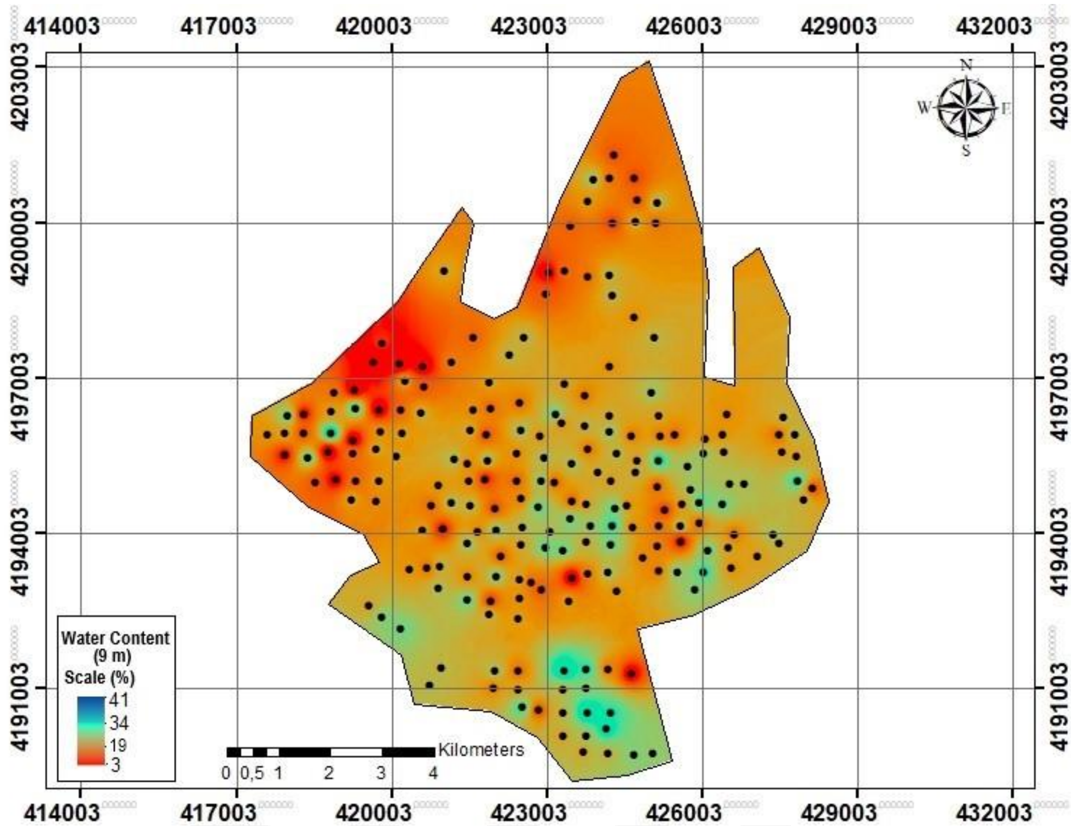


Figure 4.33. Map of laboratory water content values according to 9.0 m depth.

The data gathered from 154 boreholes across the study area provides information about the distribution of water content values at a depth of 15.0 m:

- Approximately 6% of the study area exhibited water content values ranging from 2.5 to 10.
- The majority, accounting for 56% of the study area, displayed values between 11 and 20.
- Another 38% of the study area showed values between 21 and 34.1.
- On average, the water content value for the entire study area was 19.57%.

To visualize this distribution, a map illustrating the distribution of water content values at a depth of 15.0 m in the study area is presented in Figure 4.34.

- In the northern neighborhoods of Yediyol Village, Gültepe, Belde, Çamlıtepe, and Tilmerc, the water content values ranged from 2.5% to 24.4%.

- Moving towards the inner parts of the study area, including 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur, and Karşıyaka neighborhoods, the water content values ranged from 7.4% to 26.9%.

- In the southern neighborhoods of Petrolkent and Seyitler, the water content values ranged from 7.2% to 25.2%.

- The Güneykent and Çamlıca neighborhoods in the southwest exhibited water content values ranging from 12.7% to 26.6%.

- The Bayındır and Site neighborhoods in the southeast had water content values ranging from 10.1% to 28.5%.

- In the eastern neighborhoods of Fatih, Korik, and Petrol, the water content values ranged from 13.3% to 28.1%.

- Finally, the Girbereşik and Yeniköy neighborhoods in the west showed water content values ranging from 3.6% to 34.1%.

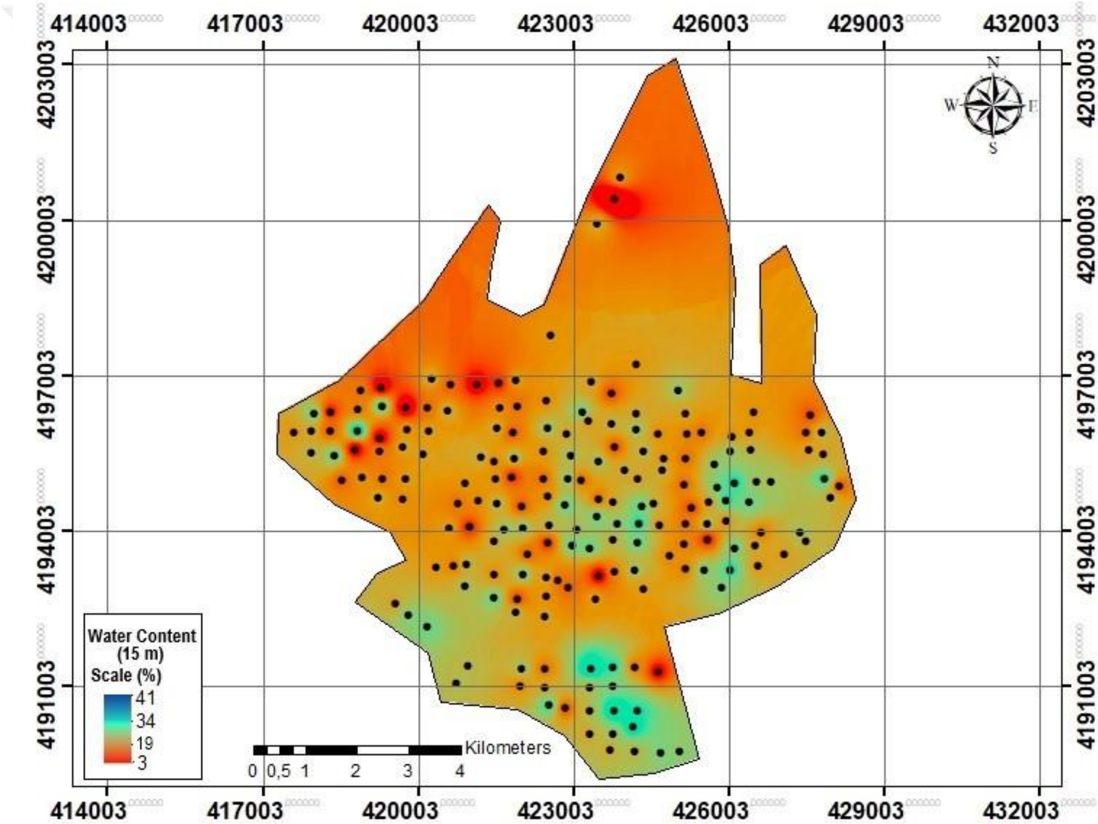


Figure 4.34. Map of laboratory water content values according to 15.0 m depth.

The dominant water content value within the study area is observed to be in the range of 11-20% wn. Figure 4.35 displays a map illustrating the variation of water content values across all depths in the study area. Additionally, Figure 4.36 presents a comparative graph that showcases the distribution of water content (wn) values in three ranges: 0-10%, 11-20%, and 21-40%. These values were obtained at depths of 1.5 m, 3 m, 4.5 m, 7.5 m, 9 m, and 15 m as part of this research study.

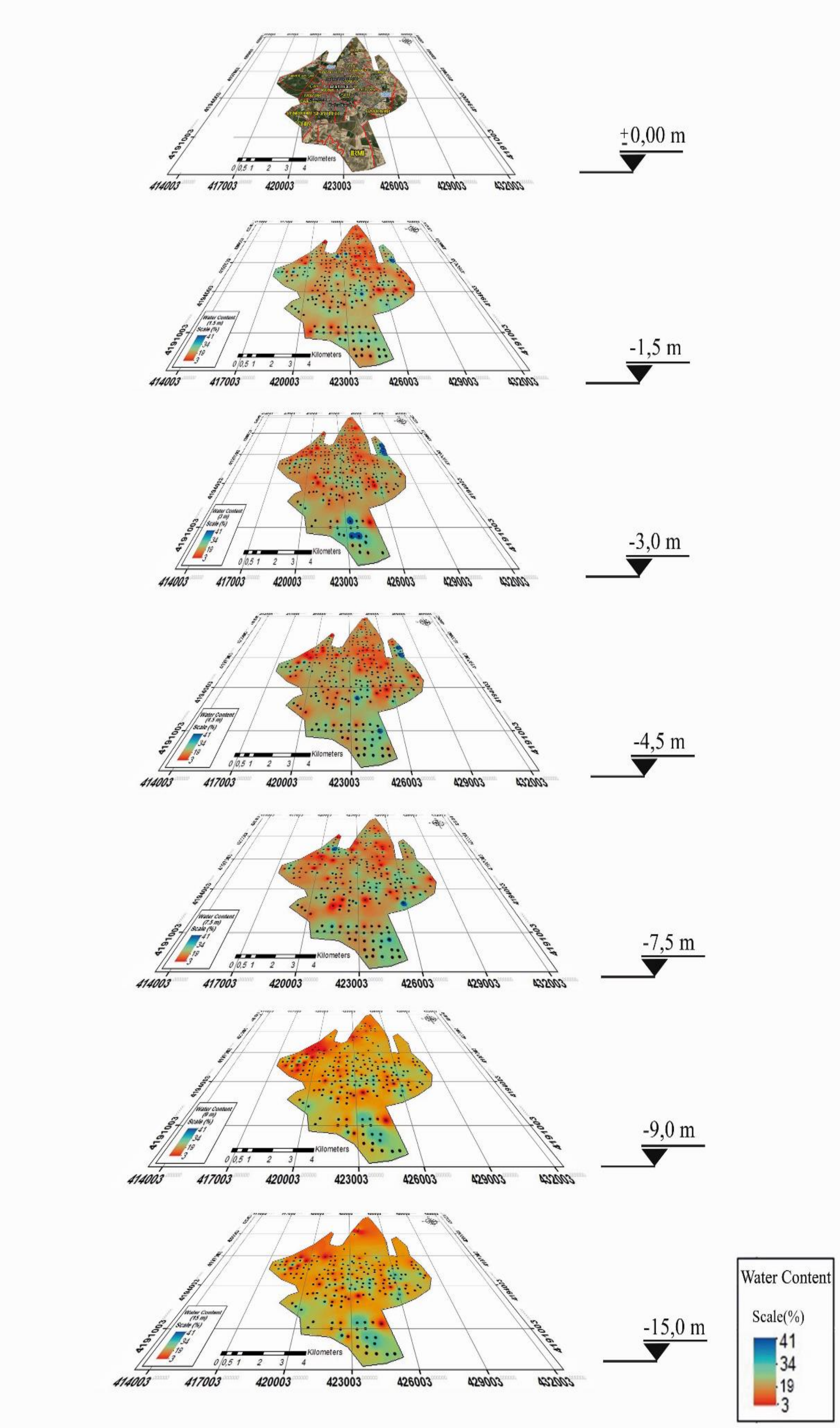


Figure 4.35. A view of water content maps.

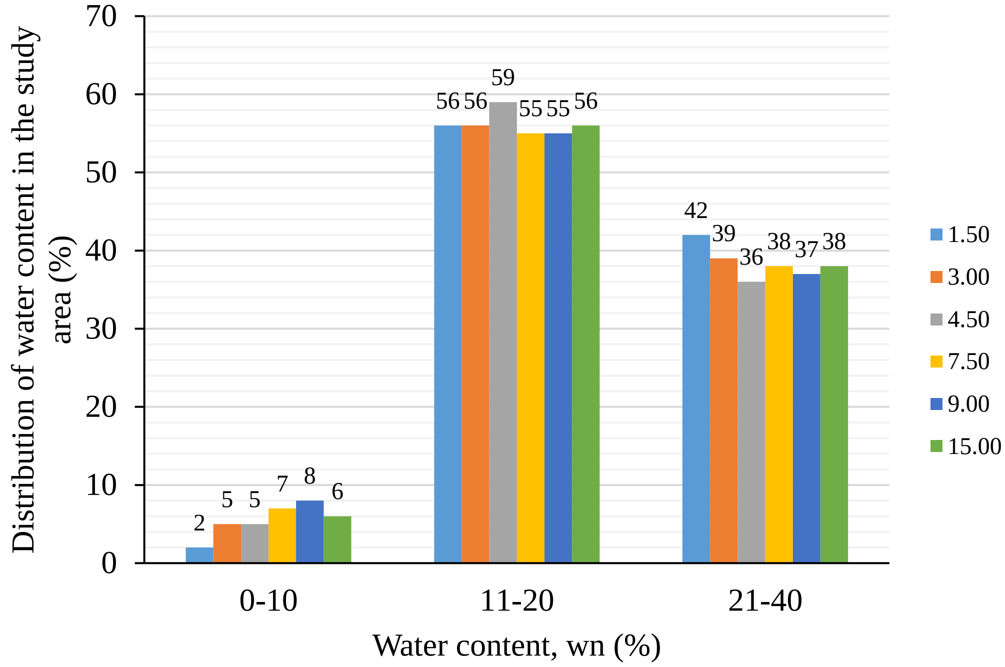


Figure 4.36. Bar chart of water content values according to the borehole depth.

4.5. Grain-Size Distribution (Sieve Analysis)

To determine soil grain-size distribution, a standard set of sieves with differing hole sizes is used. Soil is passed through these sieves, and the weight percentage of soil grains that pass through each sieve is measured. This data serves to determine the distribution of grain sizes in the soil.

In the present research study, data gathered from 253 boreholes was utilized to construct sieve analysis maps. These maps were employed to examine the engineering properties of soils.

Figure 4.37 displays the sizes of gravel, sand, silt, and clay, as outlined in various international and national standards, based on the grain-size distribution of the soils studied. According to the data obtained from 253 boreholes throughout the study area, the map showing the amount of soil remaining on the #10 (2.00 mm) sieve is shown in Figure 4.39 and the map showing the amount of soil passing through the #200 (0.075 mm) sieve is shown in Figure 4.40.

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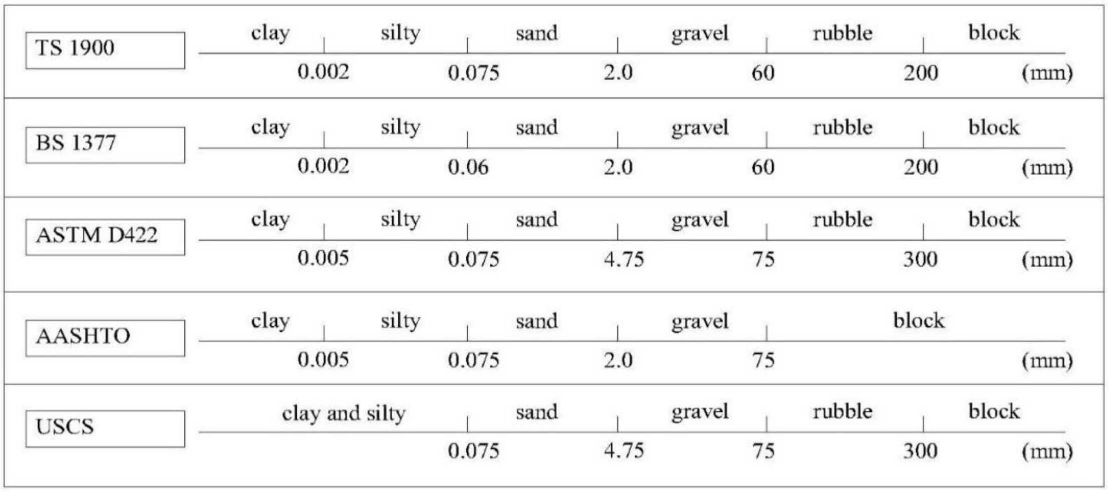

Figure 4.37. Sieve openings of gravel, sand, silt and clay described in some international and national standards (Orhan, 2022b).

According to TS 1900, ASTM D422 and AASHTO standards (Figure 4.37), soils accumulated above #10 sieve can be defined as "gravel and coarser grained soil", soils between #10 sieve and #200 sieve can be defined as "sand" and soils passing through #200 (0.075mm) sieve can be defined as "clay and silt" in general. The distribution of soil classification as a result of the sieve analysis performed on the study area is presented in Figure 4.38.

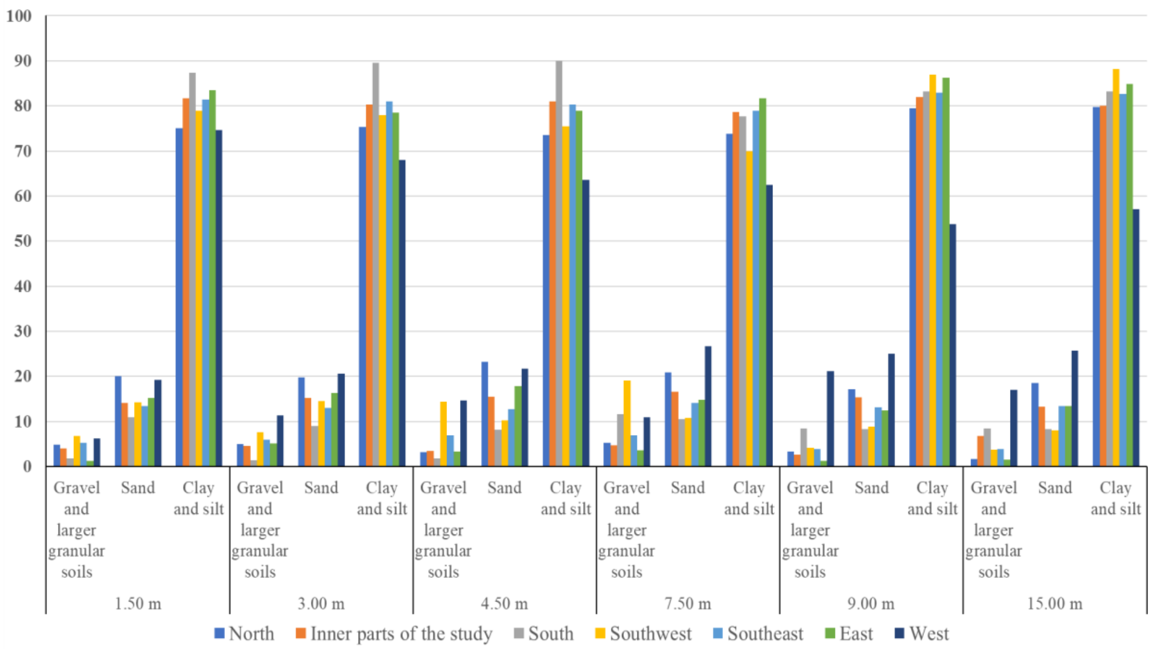

Figure 4.38. Distribution of the soil according to the sieve analysis over the study area.

According to the map showing the grain size distribution prepared for depths of 1.5, 3, 4.5, 4.5, 7.5, 9 and 15 m within the study area;

- According to TS 1900, ASTM D422 and AASHTO standards (Figure 4.37), approximately 4% of the soil in Yediyol Village, Gültepe, Belde, Çamlıtepe and Tilmerc neighbourhoods in the north of the study area is deposited above the #10 sieve with a size of 2.00 mm. Therefore, these portions can be defined as "gravel and coarser grained soil". In addition, approximately 20 percent of the soil lies between the #10 sieve and the #200 sieve. The soil in these areas can be defined as "sand". The remaining approximately 76% represents the amount of soil passing through the #200 (0.075mm) sieve. It can be said that the soil in these areas is distributed as "clay and silt".

- In 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur and Karşıyaka neighbourhoods located in the inner parts of the study area, approximately 4% of the soil was deposited on the #10 sieve with a size of 2.00 mm. Therefore, these areas can be defined as "gravel and coarser grained soil". In addition, approximately 15 percent of the soil lies between the #10 sieve and the #200 sieve. The soil in these areas can be defined as "sand". The remaining approximately 81% represents the amount of soil passing through the #200 (0.075mm) sieve. It can be said that the soil in these areas is distributed as "clay and silt".

- In Petrolkent and Seyitler neighbourhoods located to the south, approximately 6% of the soil is deposited on the #10 sieve with a size of 2.00 mm. Therefore, these areas can be defined as "gravel and coarser grained soil". In addition, approximately 9 percent of the soil lies between the #10 sieve and the #200 sieve. The soil in these areas can be defined as "sand". The remaining approximately 85% represents the amount of soil passing through the #200 (0.075mm) sieve. It can be said that the soil in these areas is distributed as "clay and silt".

- In Güneykent and Çamlıca neighbourhoods in the southwest, approximately 9% of the soil was deposited on the #10 sieve with a size of 2.00 mm. Therefore, these areas can be defined as "gravel and coarser grained soil". In addition, approximately 11 percent of the soil lies between the #10 sieve and the #200 sieve. The soil in these areas can be defined as "sand". The remaining approximately 80% represents the amount of soil passing through the #200 (0.075mm) sieve. It can be said that the soil in these areas is distributed as "clay and silt".

- In the Bayındır and Site neighbourhoods located in the south-east, approximately 5% of the soil is deposited on the #10 sieve with a size of 2.00 mm. Therefore, these areas can be defined as "gravel and coarser grained soil". In addition, approximately 13 percent of the soil lies between the #10 sieve and the #200 sieve. The soil in these areas can be defined as "sand". The remaining approximately 82% represents the amount of soil passing through the #200 (0.075mm) sieve. It can be said that the soil in these areas is distributed as "clay and silt".

- In Fatih, Korik and Petrol neighbourhoods located in the east, approximately 3% of the soil is deposited on the #10 sieve with a size of 2.00 mm. Therefore, these areas can be defined as "gravel and coarser grained soil". In addition, approximately 15 percent of the soil lies between the #10 sieve and the #200 sieve. The soil in these areas can be defined as "sand". The remaining approximately 82% represents the amount of soil passing through the #200 (0.075mm) sieve. It can be said that the soil in these areas is distributed as "clay and silt".

- In the vicinity of Girbereşik Neighbourhood and Yeniköy in the west, approximately 14% of the soil was deposited on the #10 sieve with a size of 2.00 mm. Therefore, these areas can be defined as "gravel and coarser grained soil". In addition, approximately 23% of the soil lies between the #10 sieve and the #200 sieve. The soil in these areas can be defined as "sand". The remaining approximately 63% represents the amount of soil passing through the #200 (0.075mm) sieve. It can be said that the soil in these areas is distributed as "clay and silt".

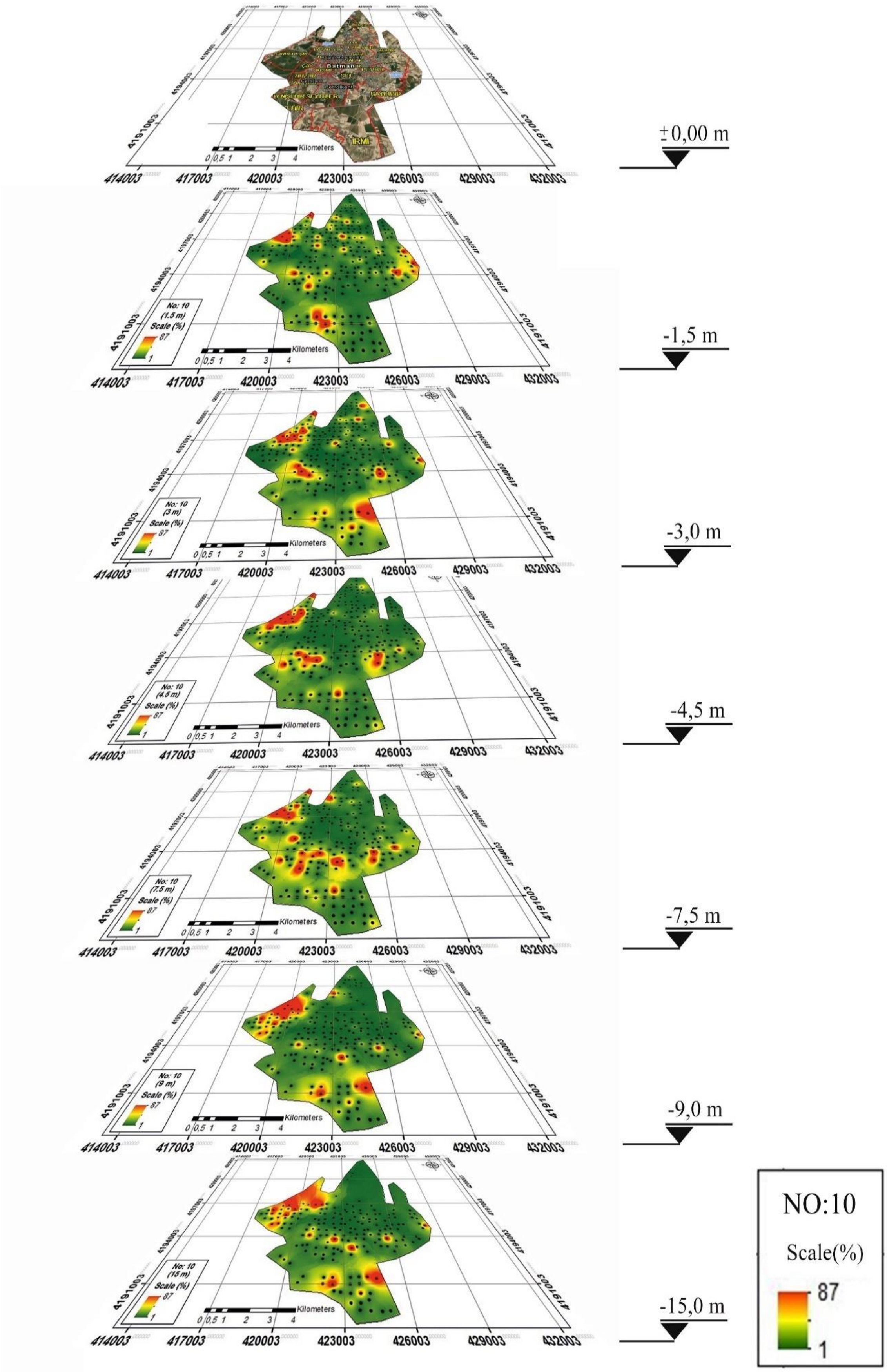

Figure 4.39. A view of all maps showing the remaining amount on the #10 sieve (2.00 mm).

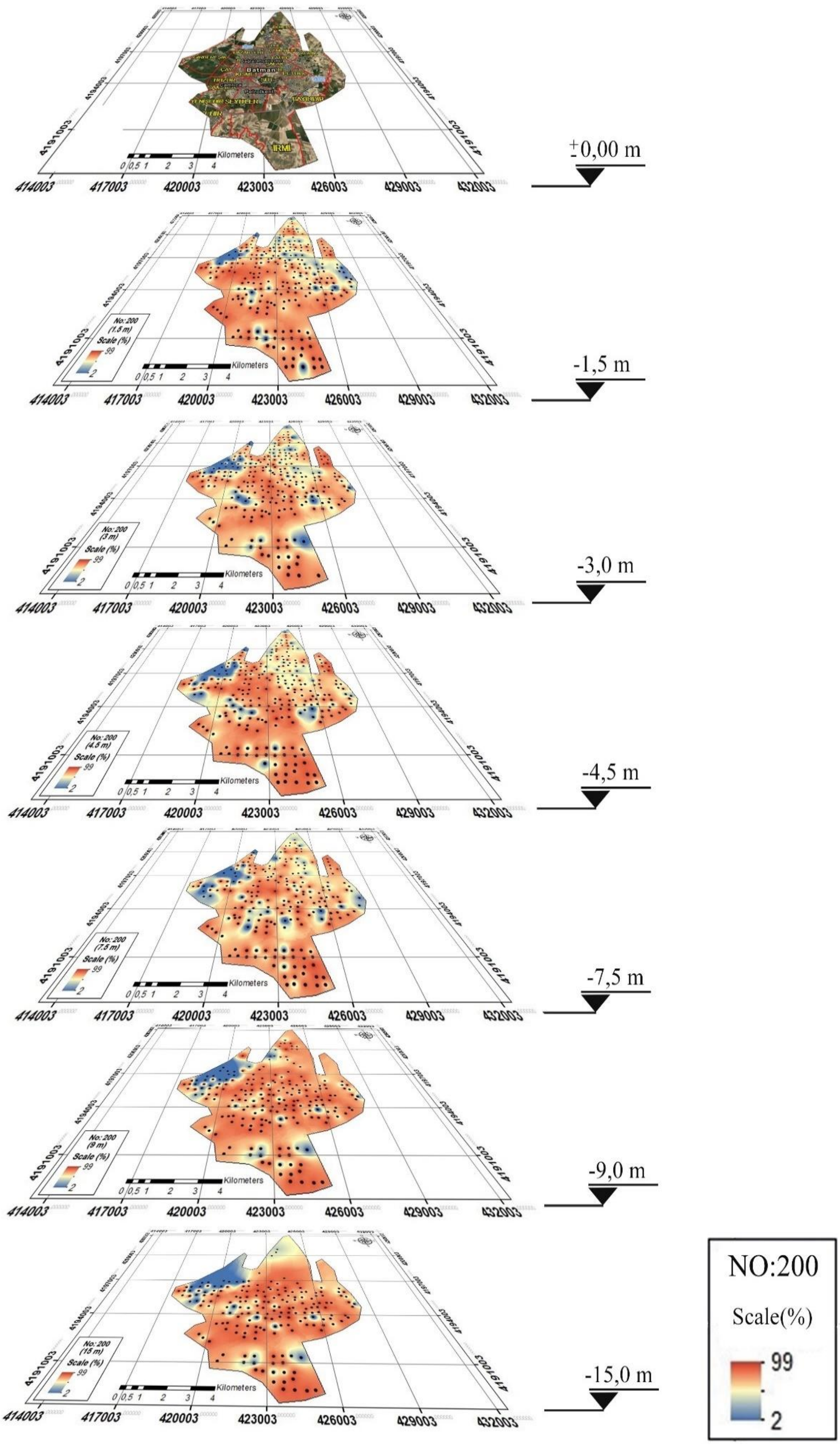

Figure 4.40. A view of all maps showing the amount passing the #200 sieve (0.075 mm).

4.6. Analysis of Consistency (Atterberg) Limits

The 244 boreholes in the study area were used to determine the consistency limits of the soil, based on the Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI) values obtained from the samples. The study determined consistency limits for 1.5, 3, 4.5, 4.5, 7.5, 9 and 15 m depths. It was found that the maximum value was at 3 m.

The fine-grained soils (>50% passing through 200 mesh sieve) in the study area show considerable variability in consistency indices. The LL values vary between 32 and 68 and the average value is 53.3%. Similarly, the PI values vary between 15 and 42 and the average value is 30.2%. From this data the position of the average values on the plasticity map is above the A line and to the right of the LL=50 limit line. The results suggest that the soil in the study area has high plasticity clay-silt characteristics. None of the soil samples are organic. The position of the soil properties on the plasticity map is shown in Figure 4.41.

LL distribution map of all depths in the study area is shown in layers in Figure 4.60, PL distribution map in Figure 4.61 and PI map in Figure 4.62.

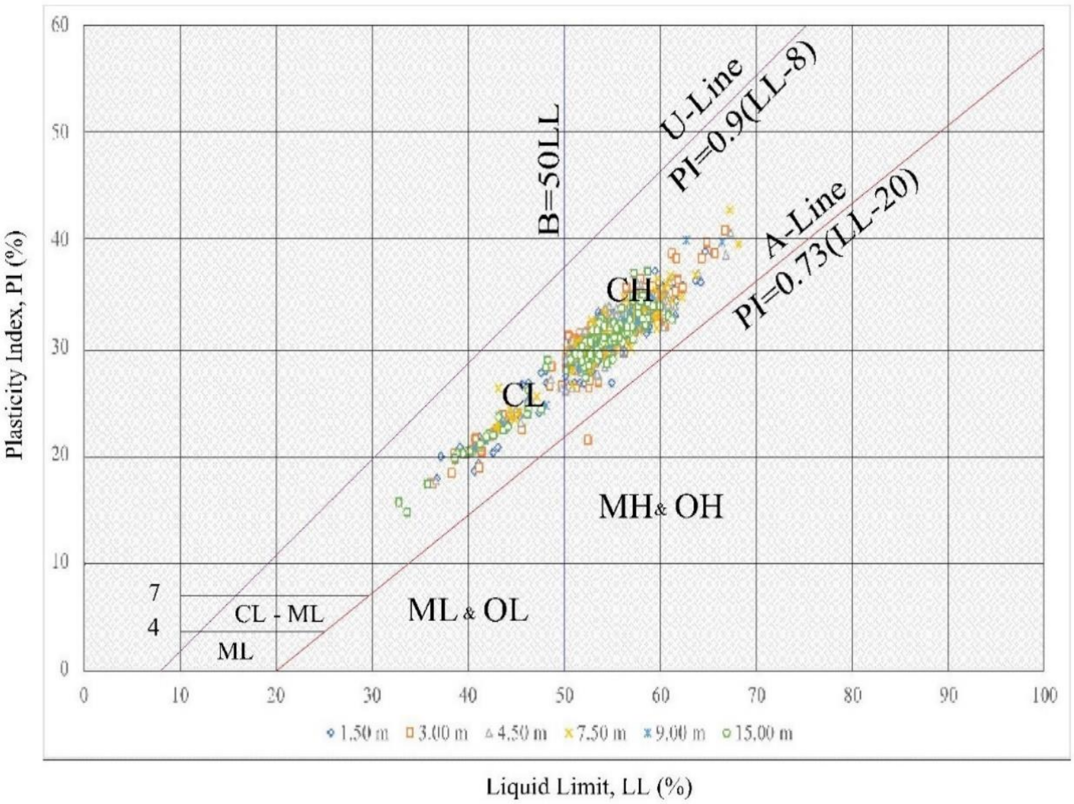

Figure 4.41. Distribution of soil samples on the plasticity chart.

Maps showing the change of Atterberg (Consistency) Limits measured for 1.5 m depth of the study area were prepared. The LL distribution map created for the depth in question is presented in Figure 4.42, PL distribution map in Figure 4.43 and PI map in Figure 4.44. When these maps are analysed;

- LL values vary between 36-65% in Yediyol Village, Gültepe, Belde, Çamlıtepe and Tilmerc neighbourhoods in the north. PL values in the same region vary between 16-28% and PI values vary between 17-38%.

- The LL values in the 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur and Karşıyaka neighbourhoods in the inner parts of the study area vary between 40-60%. PL values in the same region vary between 19-28% and PI values vary between 20-36%.

- LL values in Petrolkent, Seyitler, Güneykent, Bayındır, Site and Çamlıca neighbourhoods in the south vary between 36-63%. PL values in the same region vary between 19-28% and PI values vary between 17-37%.

- In Fatih, Korik and Petrol neighbourhoods in the east, LL values vary between 40-59%. PL values in the same region vary between 19-26% and PI values vary between 18-33%.

- LL values in the vicinity of Girbereşik Neighbourhood and Yeniköy in the west vary between 41-59%. PL values in the same region vary between 20-28% and PI values vary between 21-34%.

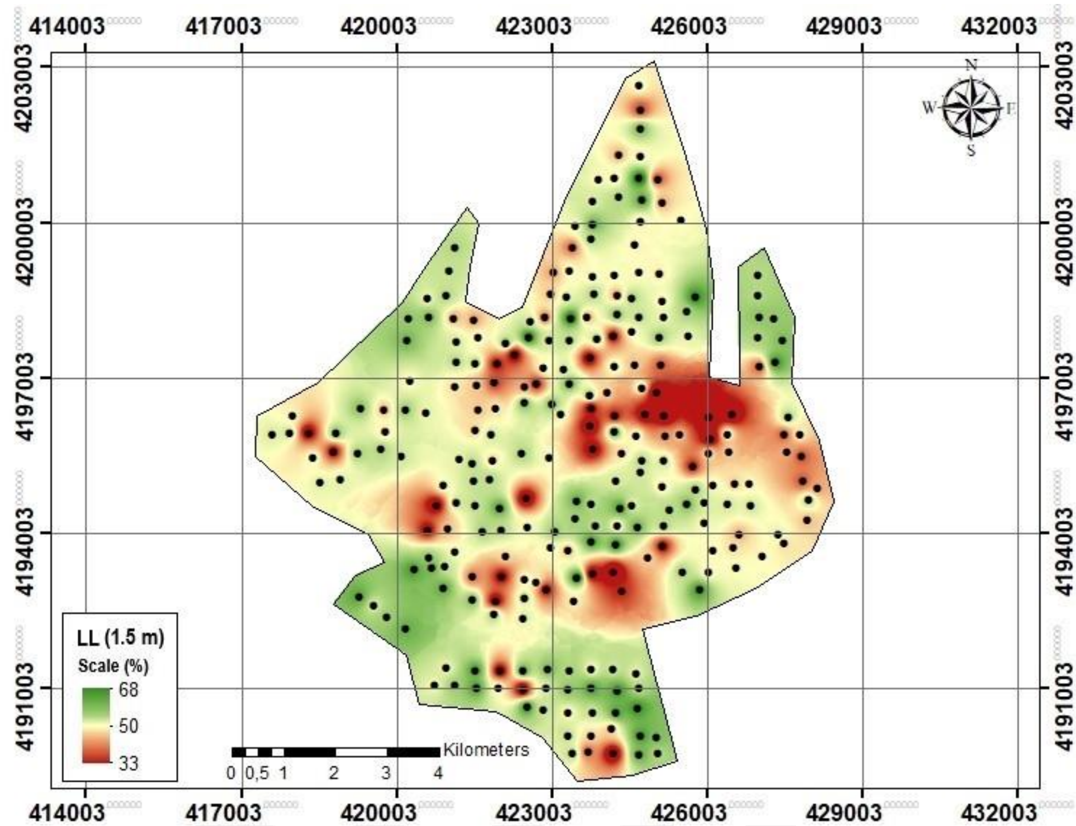

Figure 4.42. Map of liquid limit values according to 1.5 m depth.

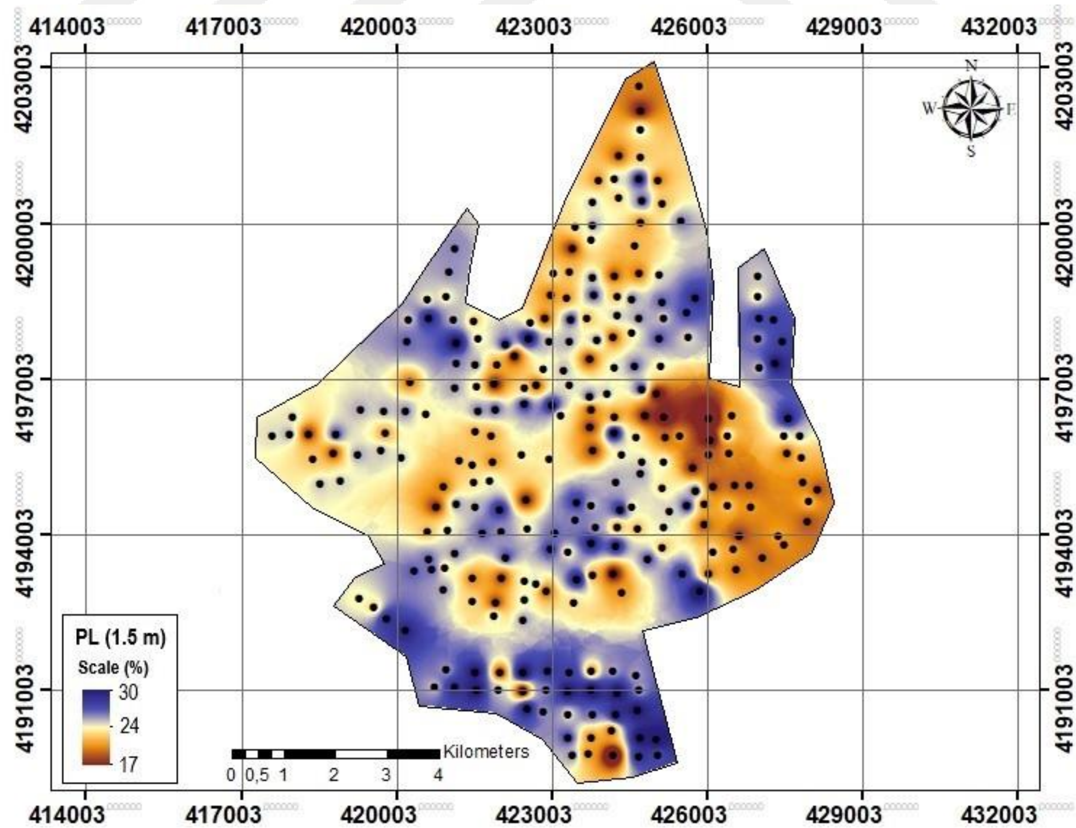

Figure 4.43. Map of plastic limit values according to 1.5 m depth.

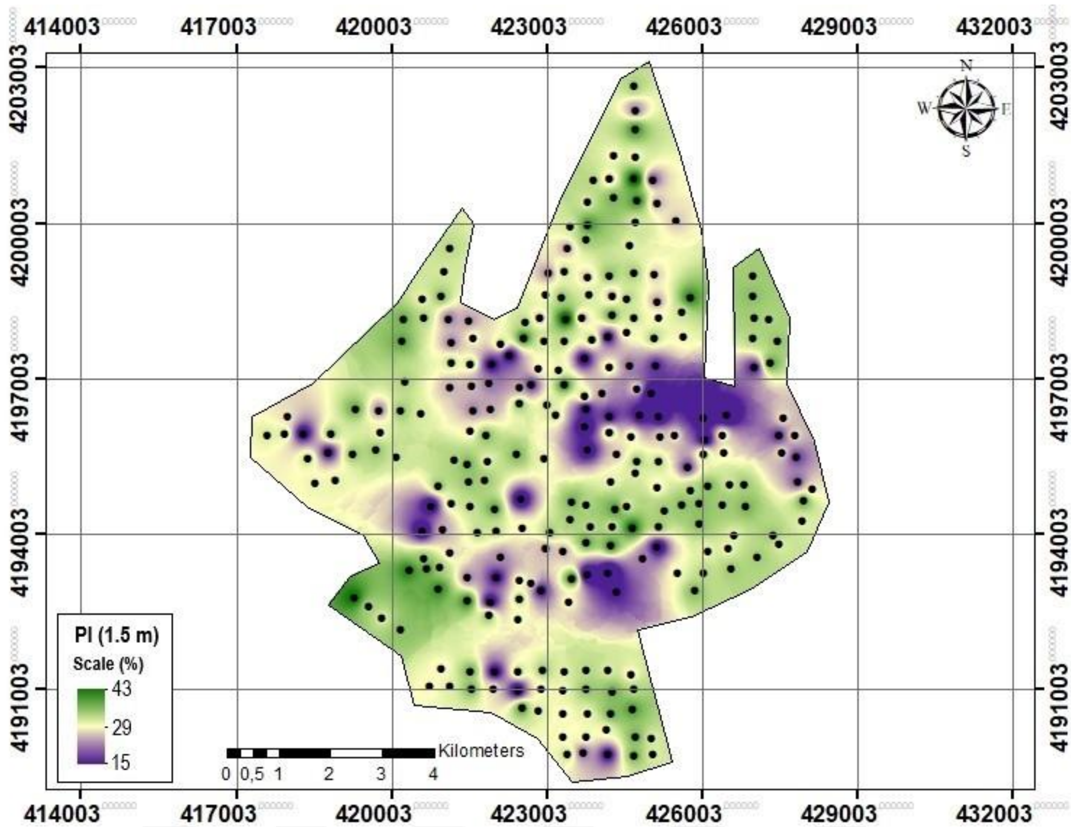

Figure 4.44. Map of plasticity index values according to 1.5 m depth.

Maps showing the change of Atterberg limits measured for 3.0 m depth of the study area were prepared. The LL distribution map created for the depth in question is presented in Figure 4.45, PL distribution map in Figure 4.46 and PI map in Figure 4.47. When these maps are analysed;

- LL values vary between 40-67% in Yediyol Village, Gültepe, Belde, Çamlıtepe and Tilmerc neighbourhoods in the north. PL values in the same region vary between 18-27% and PI values vary between 19-41%.

- The LL values in the 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur and Karşıyaka neighbourhoods in the inner parts of the study area vary between 34-60%. PL values in the same region vary between 18-27% and PI values vary between 15-33%.

- LL values in Petrolkent, Seyitler, Güneykent, Bayındır, Site and Çamlıca neighbourhoods in the south vary between 36-62%. PL values in the same region vary between 19-28% and PI values vary between 17-36%.

- In Fatih, Korik and Petrol neighbourhoods in the east, LL values vary between 38-62%. PL values in the same region vary between 18-26% and PI values vary between 20-39%.

- LL values in the vicinity of Girbereşik Neighbourhood and Yeniköy in the west vary between 40-58%. PL values in the same region vary between 20-31% and PI values vary between 20-34%.

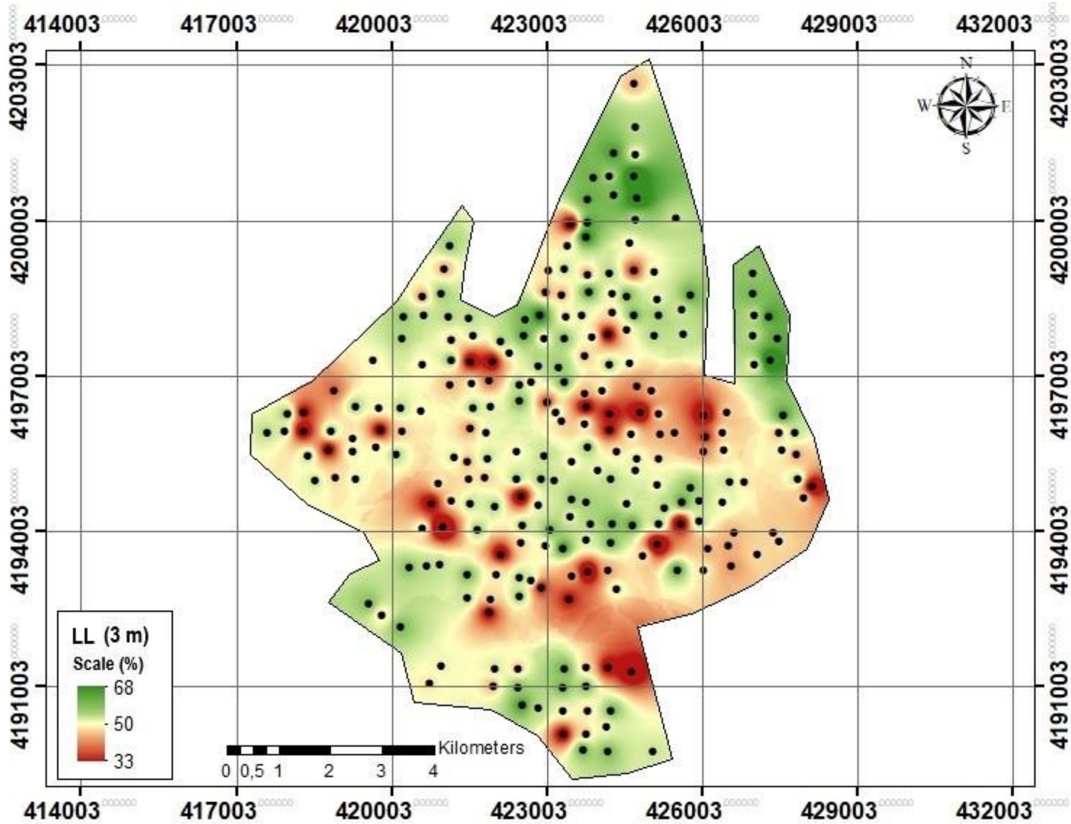

Figure 4.45. Map of liquid limit values according to 3.0 m depth.

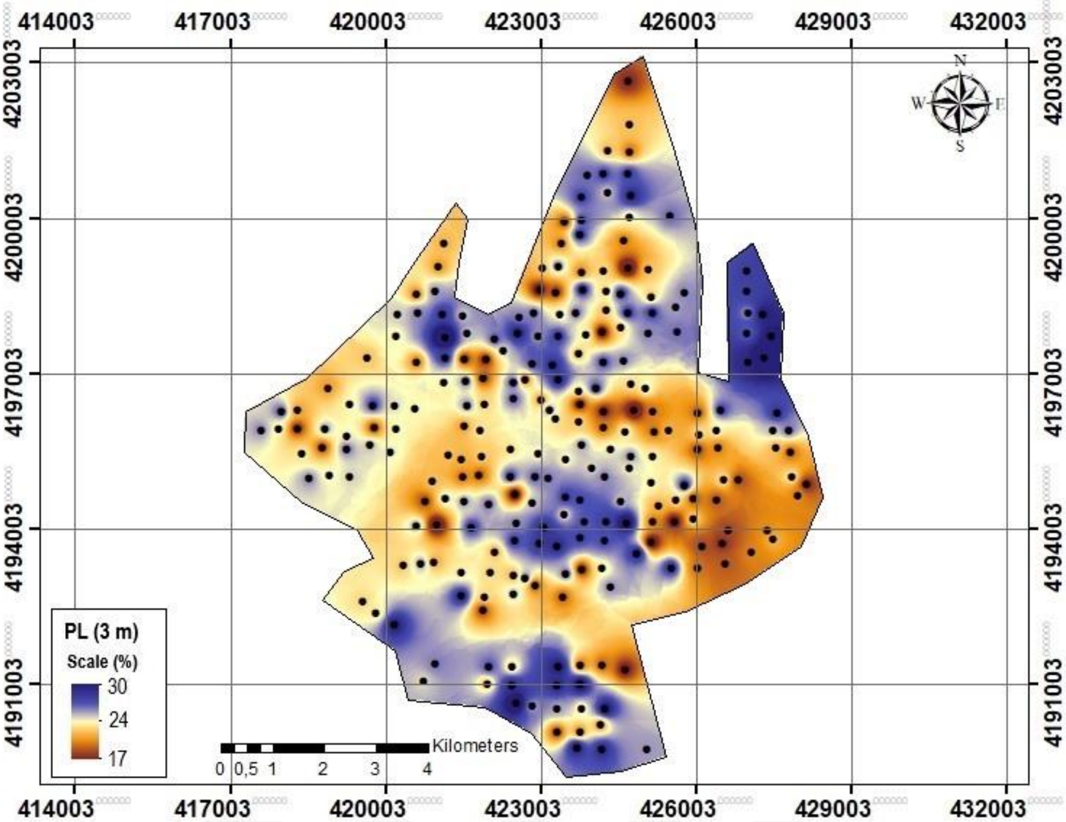

Figure 4.46. Map of plastic limit values according to 3.0 m depth.

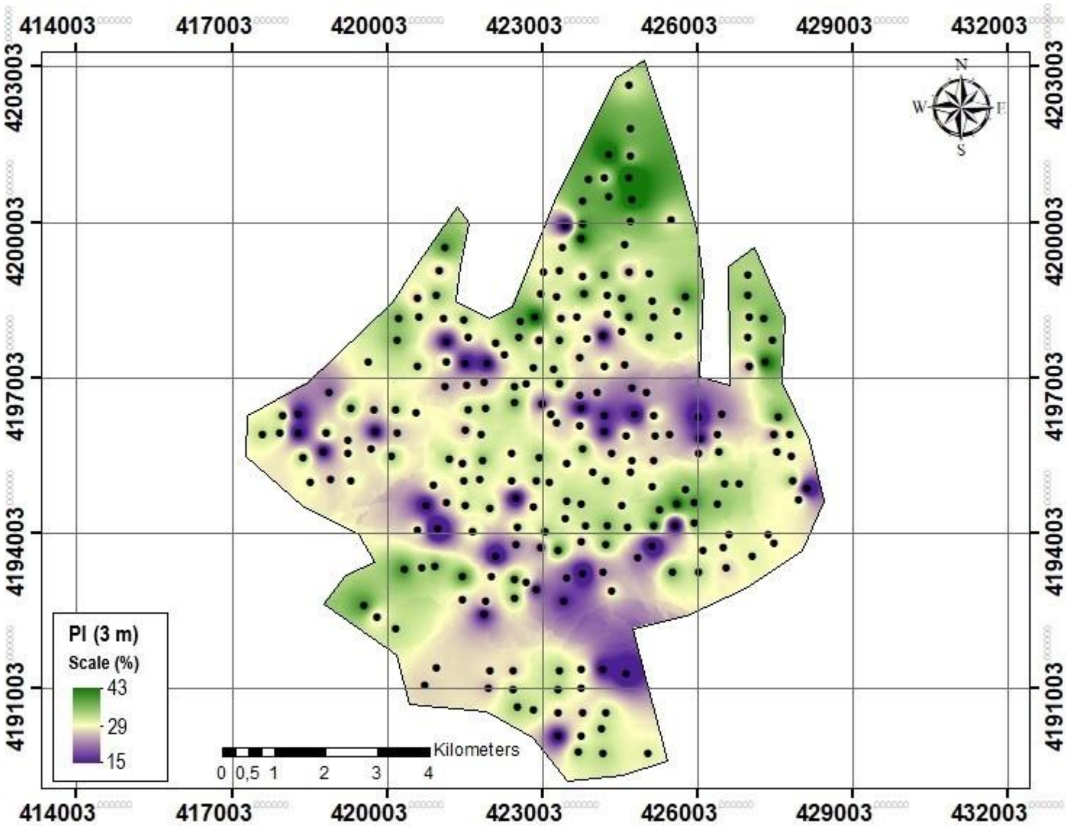

Figure 4.47. Map of plasticity index values according to 3.0 m depth.

Maps showing the change of Atterberg limits measured for 4.5 m depth of the study area were prepared. The LL distribution map created for the depth in question is presented in Figure 4.48, PL distribution map in Figure 4.49 and PI map in Figure 4.50. When these maps are analysed;

- LL values vary between 36-67% in Yediyol Village, Gültepe, Belde, Çamlıtepe and Tilmerc neighbourhoods in the north. PL values in the same region vary between 18-28% and PI values vary between 17-40%.

- The LL values in 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur and Karşıyaka neighbourhoods in the inner parts of the study area vary between 36-60%. PL values in the same region vary between 17-26% and PI values vary between 17-36%.

- LL values in Petrolkent, Seyitler, Güneykent, Bayındır, Site and Çamlıca neighbourhoods in the south vary between 37-67%. PL values in the same region vary between 19-28% and PI values vary between 18-39%.

- In Fatih, Korik and Petrol neighbourhoods in the east, LL values vary between 40-57%. PL values in the same region vary between 20-25% and PI values vary between 20-33%.

- LL values in Girbereşik neighbourhood and Yeniköy in the west vary between 40-60%. PL values in the same region vary between 20-27% and PI values vary between 20-35%.

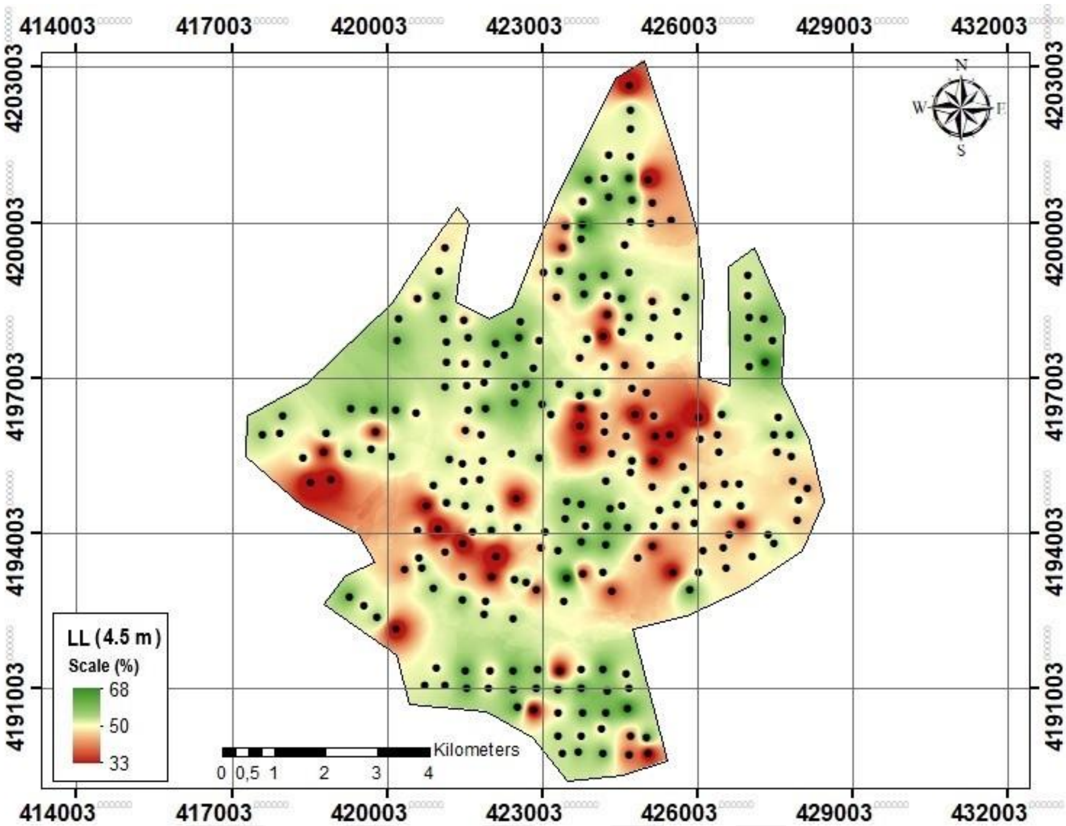

Figure 4.48. Map of liquid limit values according to 4.5 m depth.

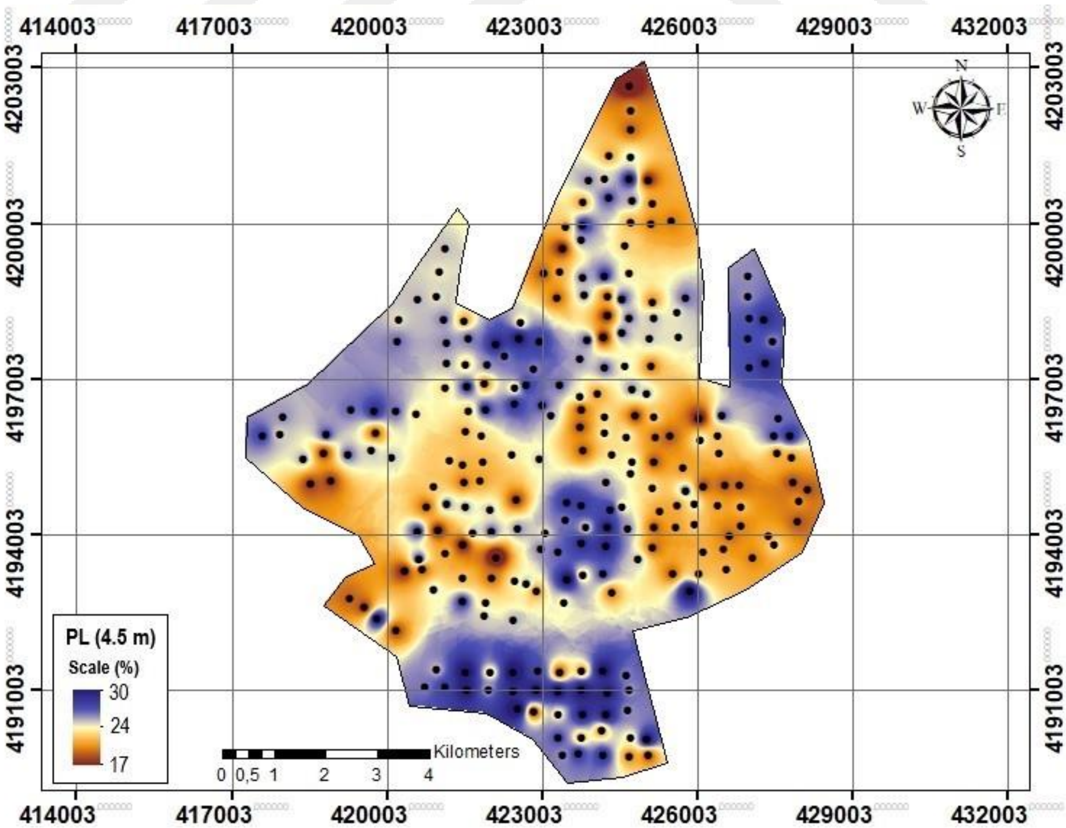

Figure 4.49. Map of plastic limit values according to 4.5 m depth.

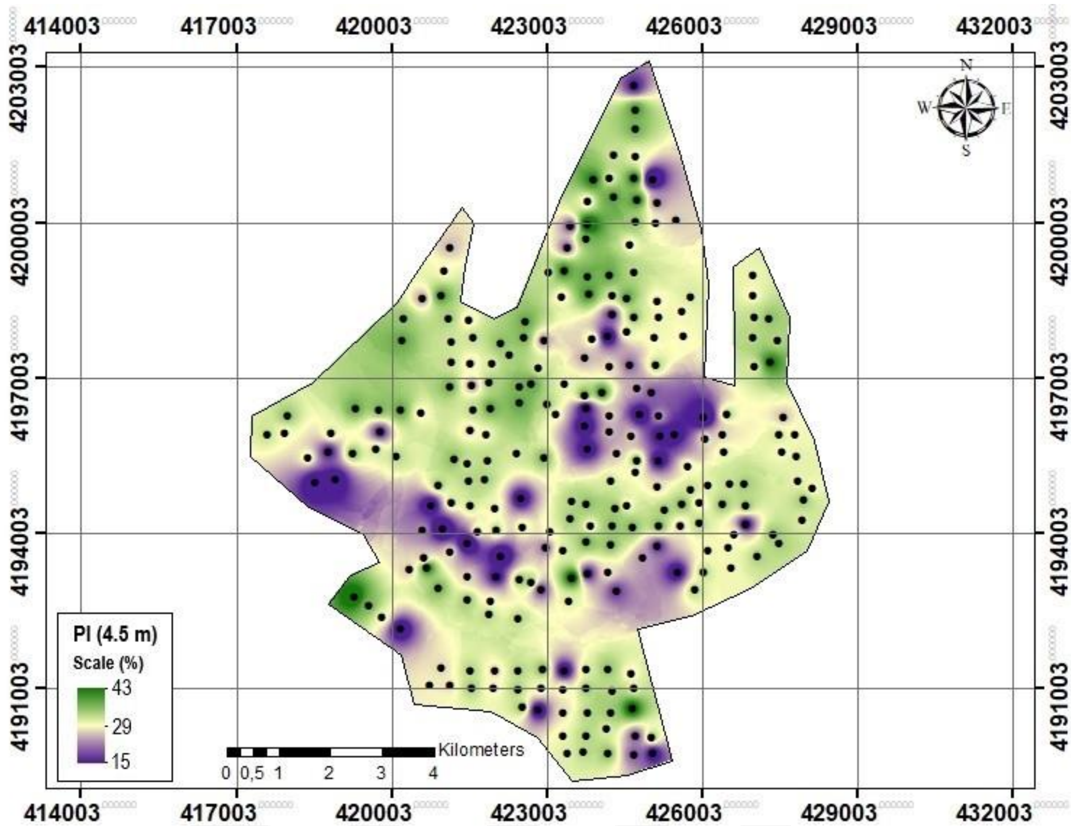

Figure 4.50. Map of plasticity index values according to 4.5 m depth.

Maps showing the change of Atterberg limits measured for 7.5 m depth of the study area were prepared. The LL distribution map created for the depth in question is presented in Figure 4.51, PL distribution map in Figure 4.52 and PI map in Figure 4.53. When these maps are analysed;

- LL values vary between 38-68% in Yediyol Village, Gültepe, Belde, Çamlıtepe and Tilmerc neighbourhoods in the north. PL values in the same region vary between 17-28% and PI values vary between 20-39%.

- LL values in 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur and Karşıyaka neighbourhoods in the inner parts of the study area vary between 33-60%. PL values in the same region vary between 17-27% and PI values vary between 15-33%.

- LL values in Petrolkent, Seyitler, Güneykent, Bayındır, Site and Çamlıca neighbourhoods in the south vary between 32-62%. PL values in the same region vary between 17-28% and PI values vary between 15-37%.

- In Fatih, Korik and Petrol neighbourhoods in the east, LL values vary between 40-59%. PL values in the same region vary between 20-26% and PI values vary between 20-34%.

- LL values in Girbereşik neighbourhood and Yeniköy in the west vary between 39-67%. PL values in the same region vary between 19-27% and PI values vary between 20-42%.

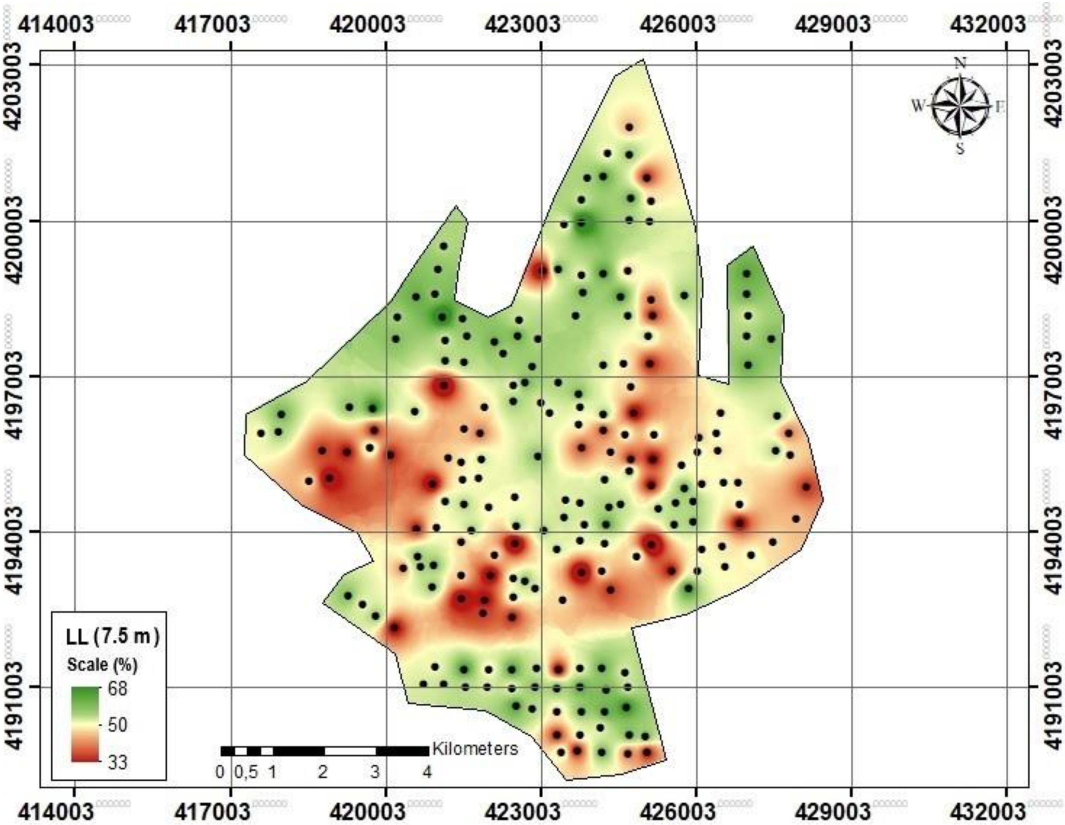

Figure 4.51. Map of liquid limit values according to 7.5 m depth.

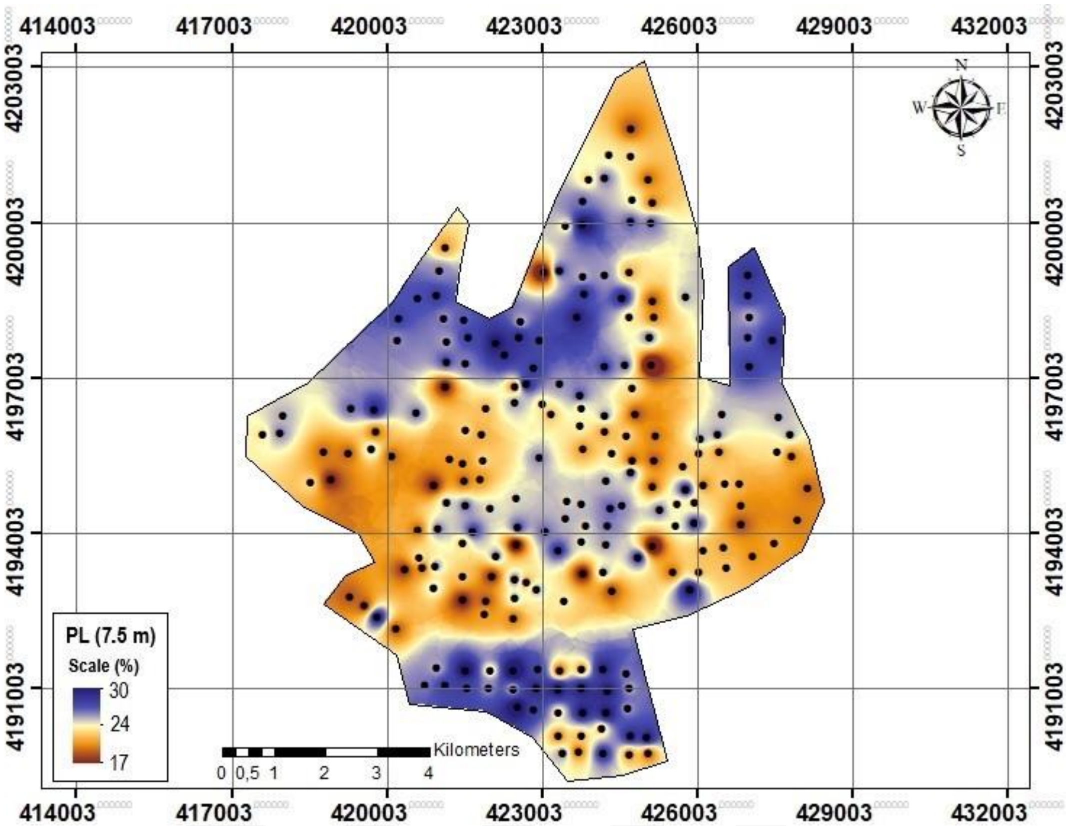

Figure 4.52. Map of plastic limit values according to 7.5 m depth.

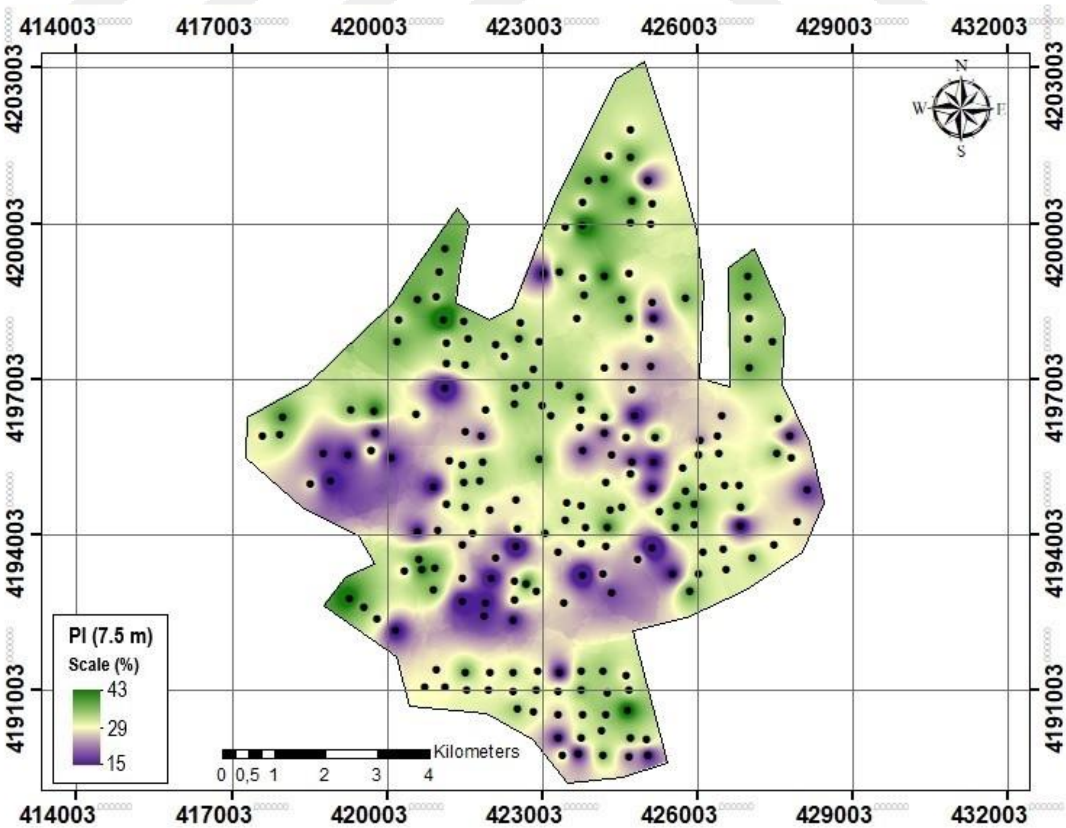

Figure 4.53. Map of plasticity index values according to 7.5 m depth.

Maps showing the change of Atterberg limits measured for 9.0 m depth of the study area were prepared. The LL distribution map created for the depth in question is presented in Figure 4.54, PL distribution map in Figure 4.55 and PI map in Figure 4.56. When these maps are analysed;

- LL values vary between 39-66% in Yediyol Village, Gültepe, Belde, Çamlıtepe and Tilmerc neighbourhoods in the north. PL values in the same region vary between 19-26% and PI values vary between 29-39%.

- The LL values in the 19 Mayıs, Aydınlıkevler, Bahçelievler, Cumhuriyet, Hilal, Kültür, GAP, Sağlık, Yavuz Selim, Huzur and Karşıyaka neighbourhoods in the inner parts of the study area vary between 38-59%. PL values in the same region vary between 18-27% and PI values vary between 20-33%.

- LL values in Petrolkent, Seyitler, Güneykent, Bayındır, Site and Çamlıca neighbourhoods in the south vary between 32-61%. PL values in the same region vary between 17-29% and PI values vary between 15-37%.

- In Fatih , Korik and Petrol neighbourhoods in the east, LL values vary between 33-59%. PL values in the same region vary between 19-25% and PI values vary between 14-34%.

- LL values in the vicinity of Girbereşik Neighbourhood and Yeniköy in the west vary between 38-60%. PL values in the same region vary between 19-28% and PI values vary between 19-33%.

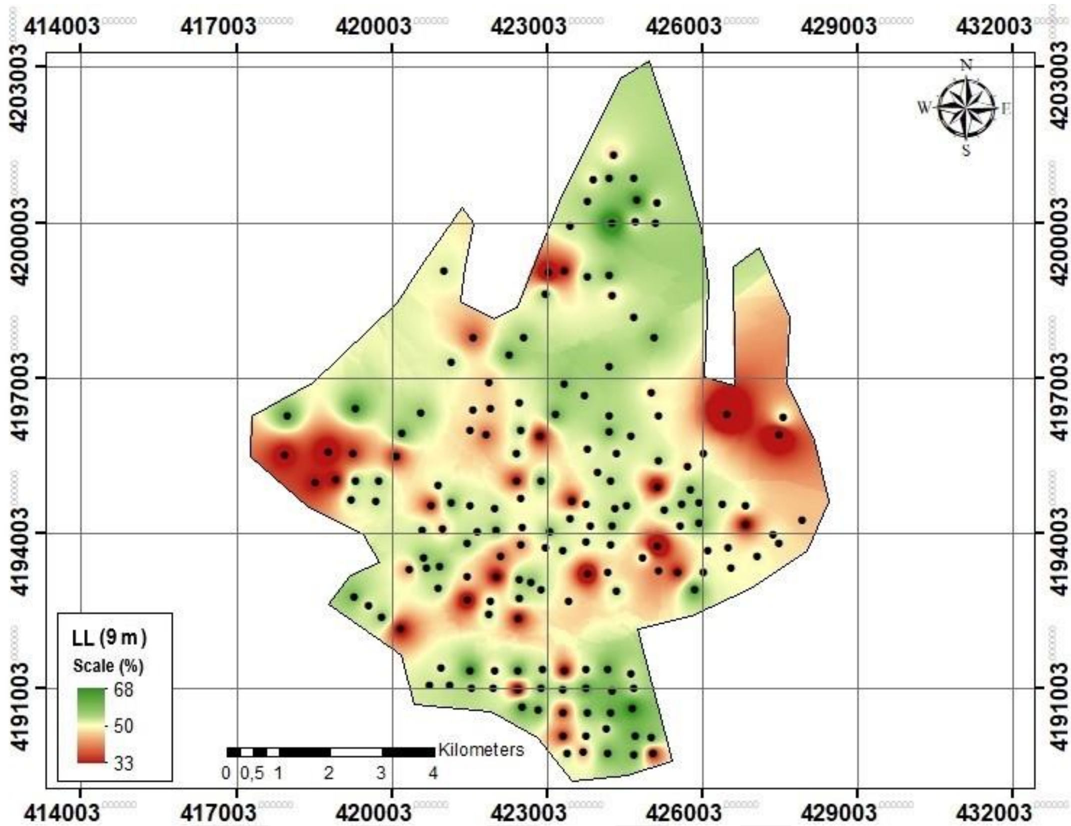

Figure 4.54. Map of liquid limit values according to 9.0 m depth.

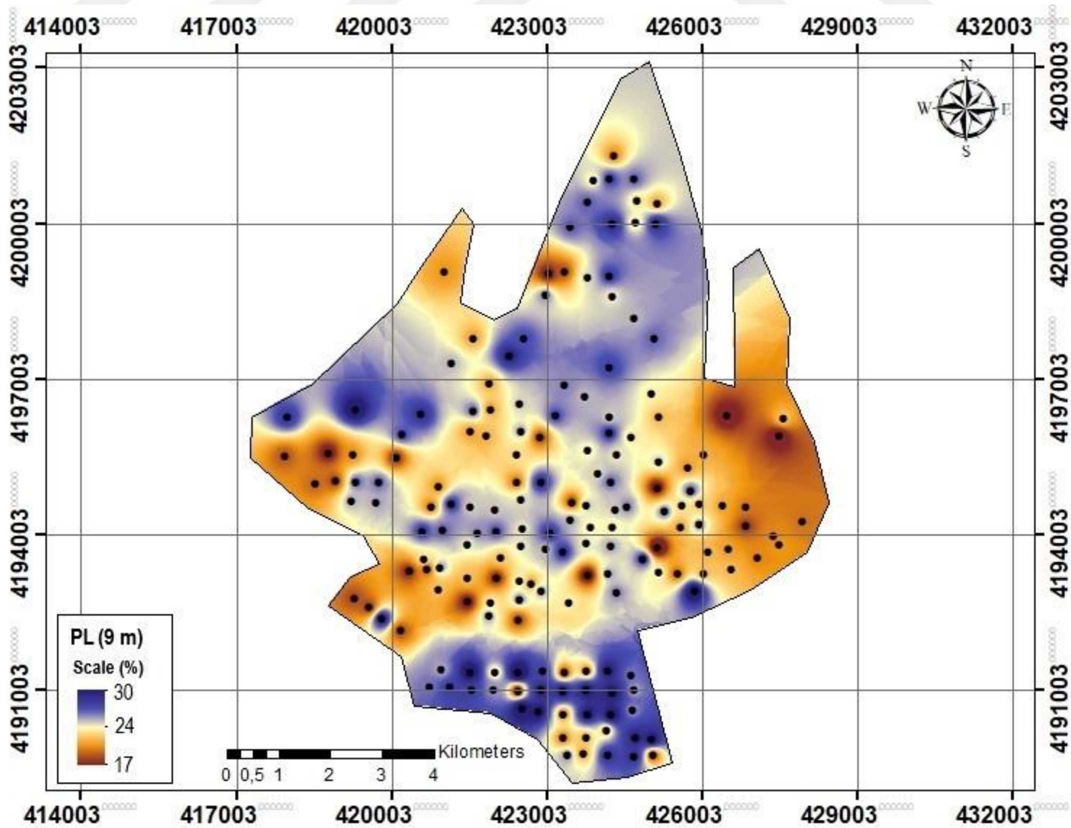

Figure 4.55. Map of plastic limit values according to 9.0 m depth.

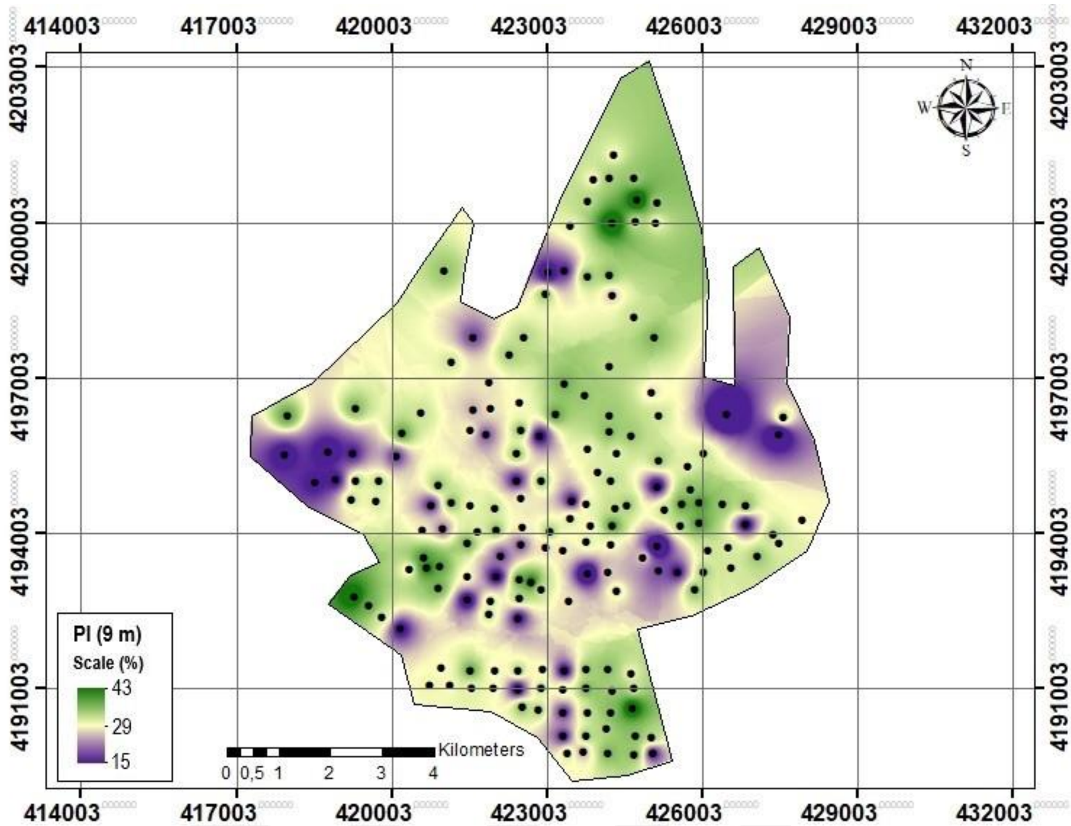

Figure 4.56. Map of plasticity index values according to 9.0 m depth.

Maps showing the change of Atterberg limits measured for 15.0 m depth of the study area were prepared. The LL distribution map created for the depth in question is presented in Figure 4.57, PL distribution map in Figure 4.58 and PI map in Figure 4.59. When these maps are analysed;

- LL values vary between 46-57% in Yediyol Village, Gültepe, Belde, Çamlıtepe and Tilmerc neighbourhoods in the north. PL values in the same region vary between 20-25% and PI values vary between 25-32%.

- LL values in 19 Mayıs , Aydınlıkevler , Bahçelievler , Cumhuriyet , Hilal , Kültür , GAP , Sağlık , Yavuz Selim , Huzur and Karşıyaka neighbourhoods in the inner parts of the study area vary between 38-59%. PL values in the same region vary between 18-26% and PI values vary between 20-33%.

- LL values in Petrolkent, Seyitler, Güneykent, Bayındır, Site and Çamlıca neighbourhoods in the south vary between 32-61%. PL values in the same region vary between 17-29% and PI values vary between 15-37%.

- In Fatih , Korik and Petrol neighbourhoods in the east, LL values vary between 33-57%. PL values in the same region vary between 19-25% and PI values vary between 14-34%.

- LL values in the vicinity of Girbereşik Neighbourhood and Yeniköy in the west vary between 38-60%. PL values in the same region vary between 19-28% and PI values vary between 19-33%.

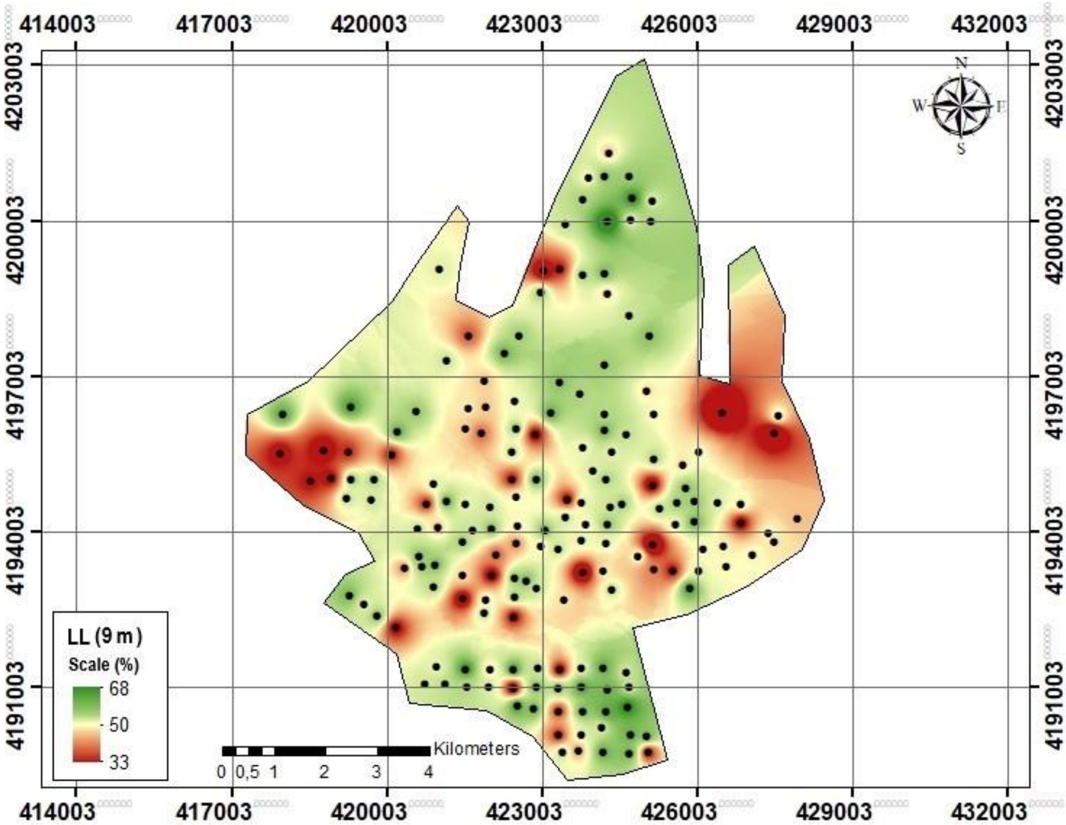

Figure 4.57. Map of liquid limit values according to 15.0 m depth.

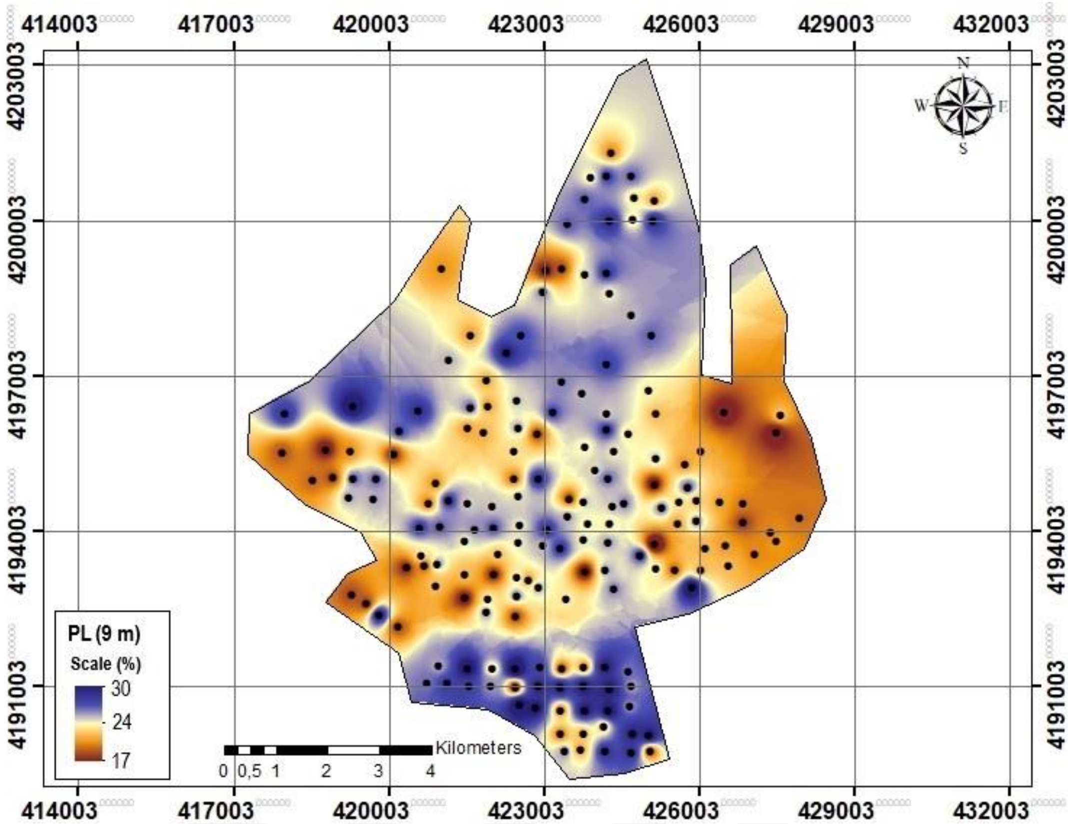

Figure 4.58. Map of plastic limit values according to 15.0 m depth.

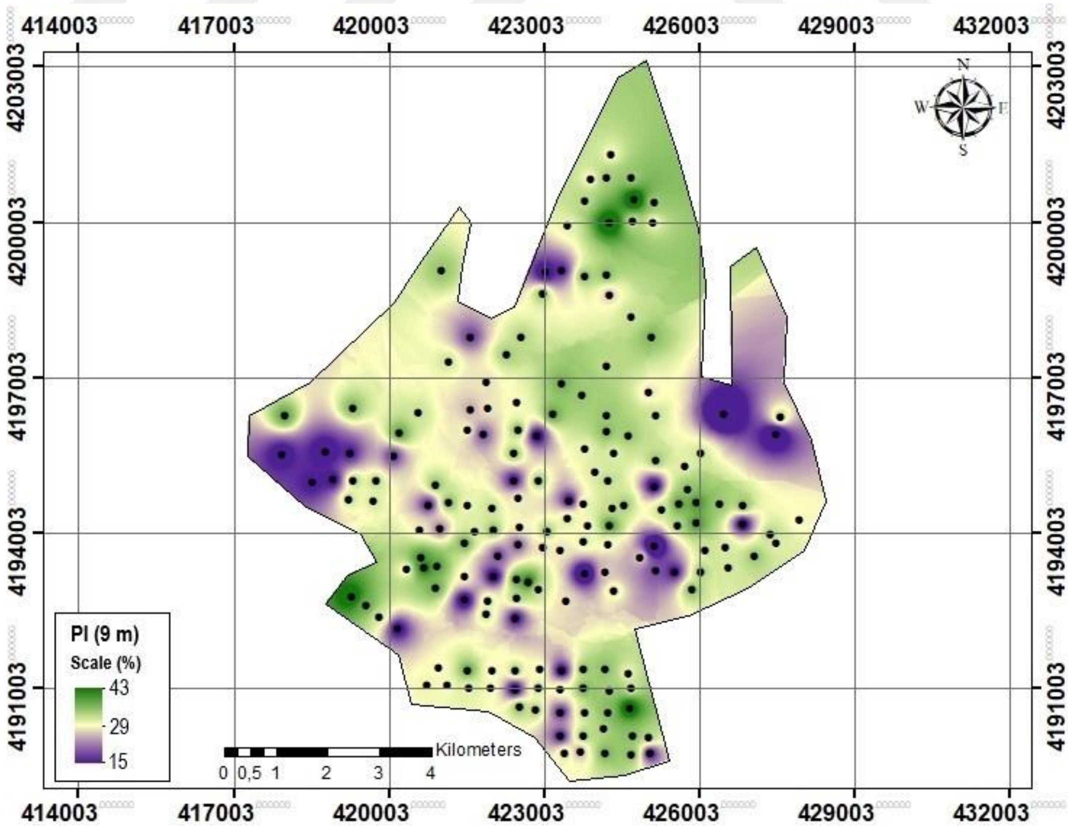

Figure 4.59. Map of plasticity index values according to 15.0 m depth.

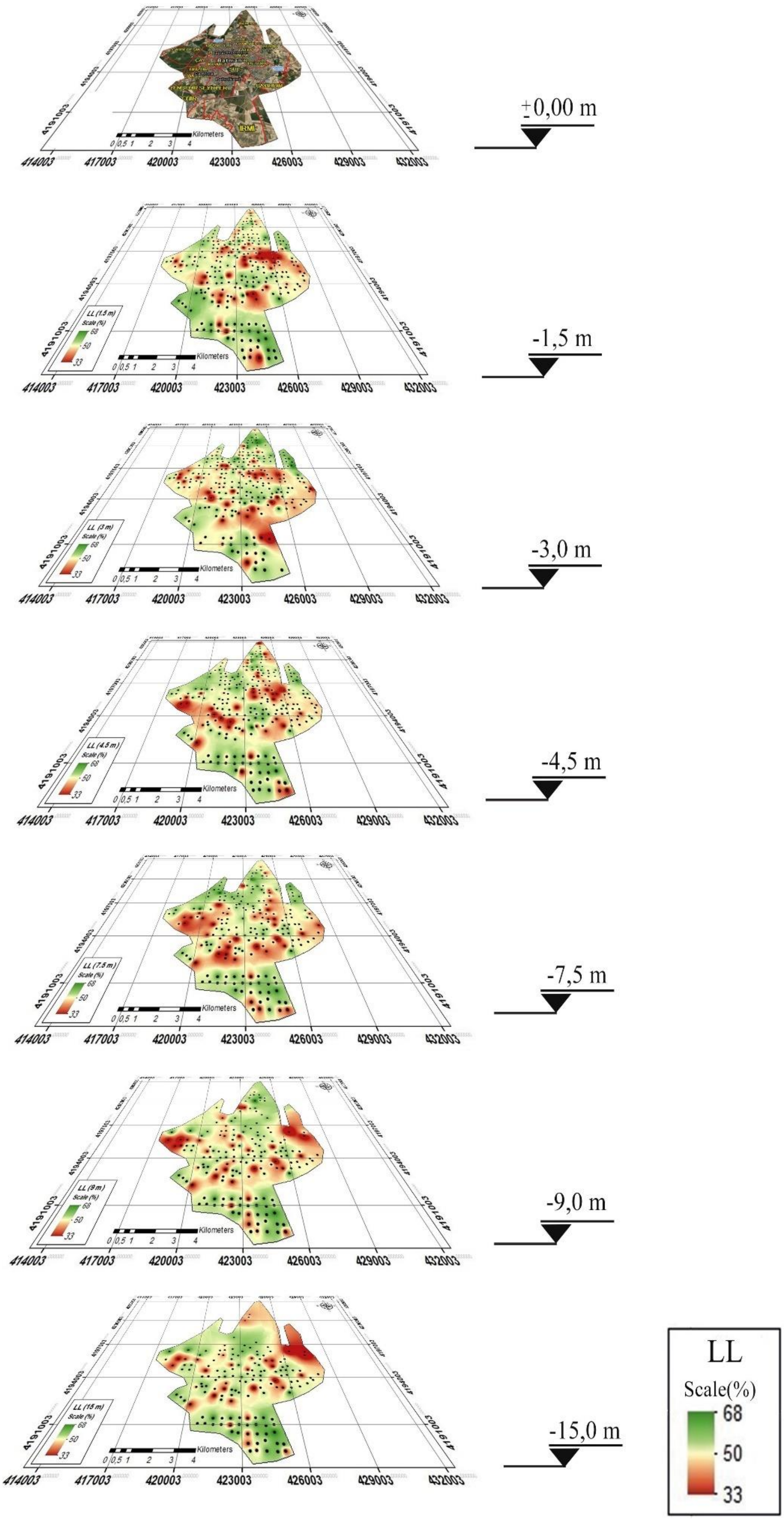

Figure 4.60. A view of all maps showing the liquid limit of the study area.

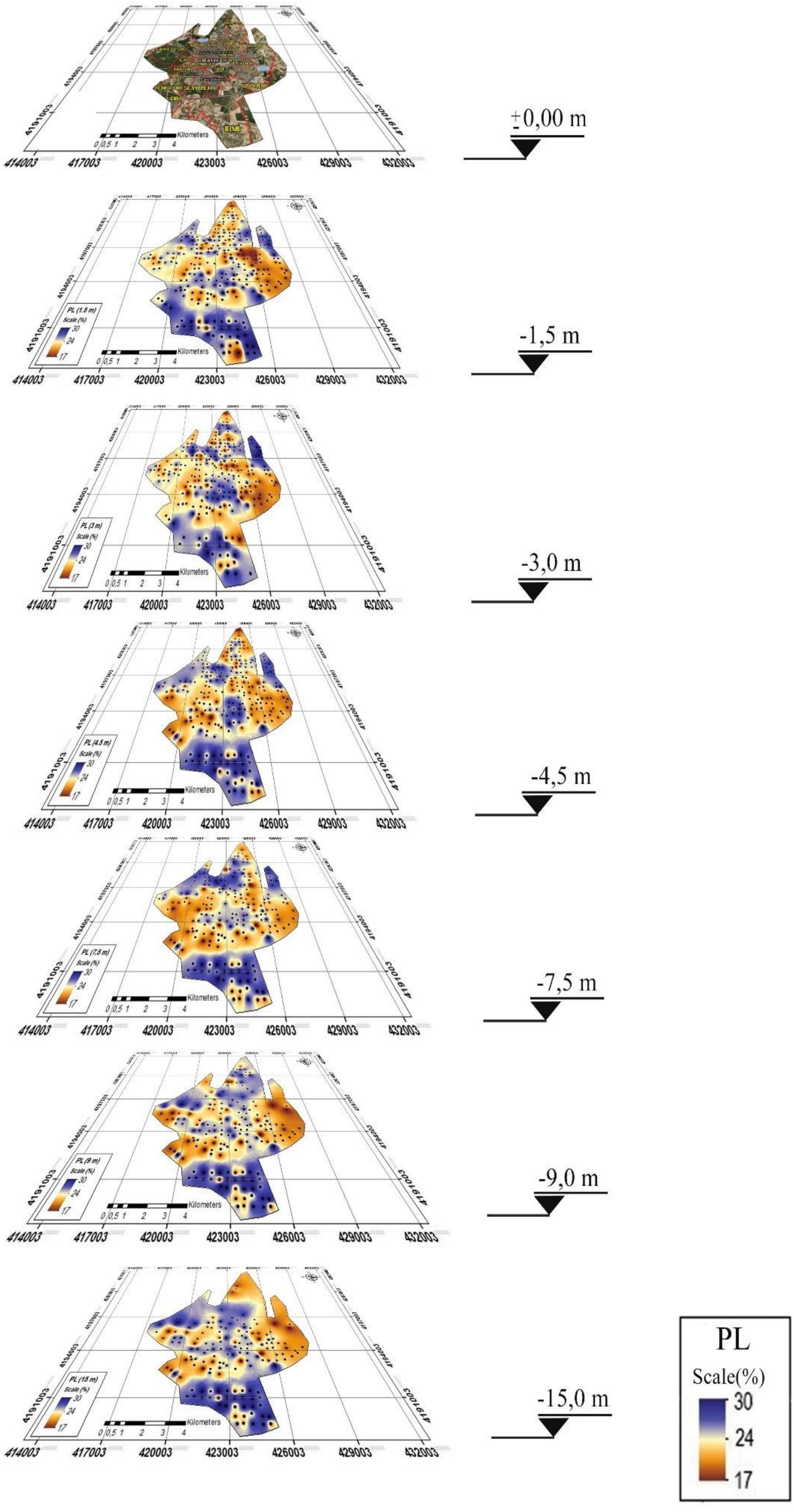

Figure 4.61. A view of all maps showing the plastic limit of the study area.

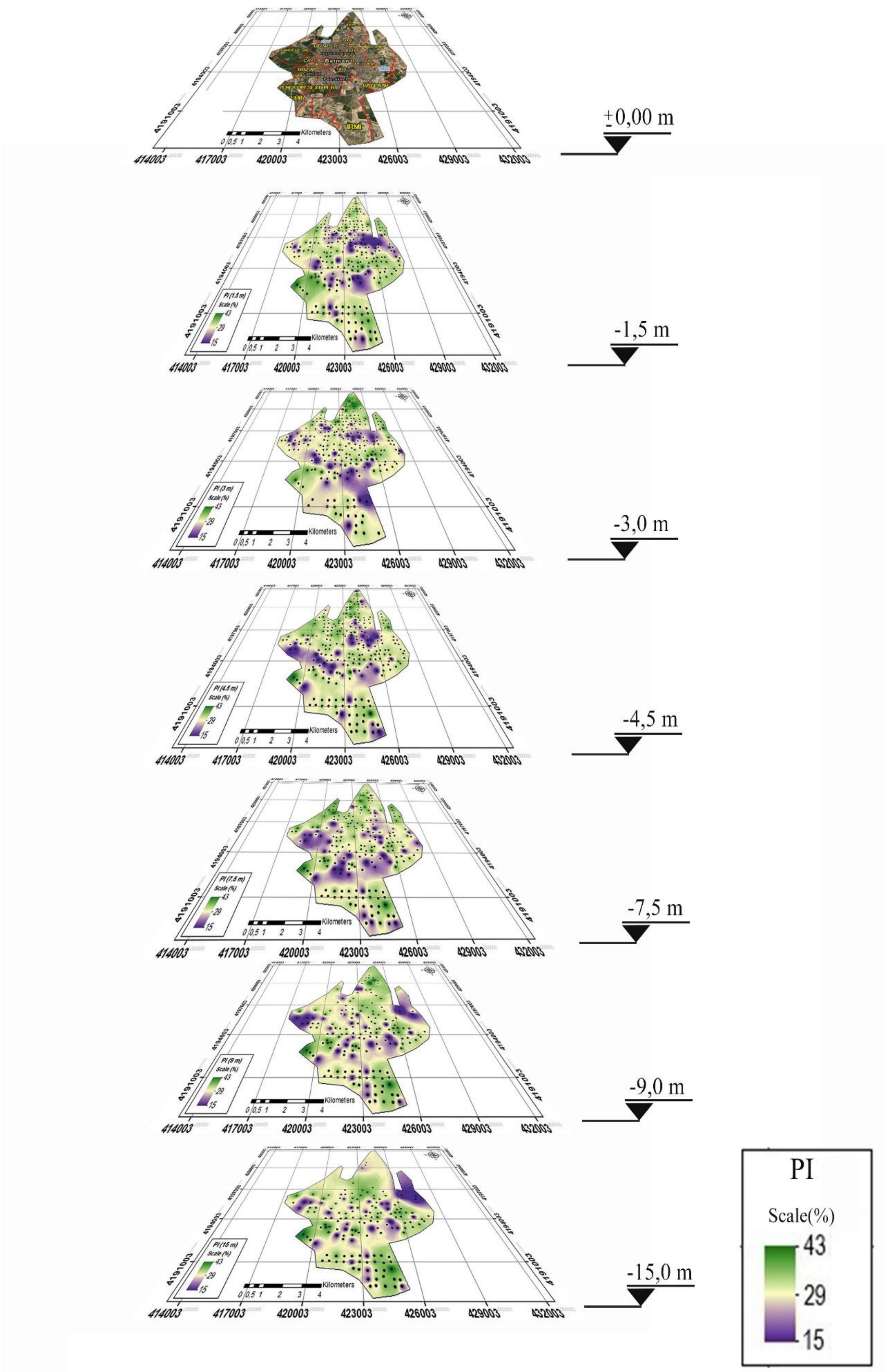

Figure 4.62. A view of all maps showing the plasticity index of the study area

4.7. Analysis of Shear Wave Velocity ($V_{S(30)}$) Maps

As part of the study, field seismic measurements were carried out using the Seismic Refraction (SR) method. Seismic refraction studies provide information about the internal structure of the ground by analysing the speed of propagation and reflections of sound waves. Using the data obtained from the seismic test results, shear wave velocity ($V_{S(30)}$) data, which contain physical information about the void, density and stress state of the soil, were obtained and a map was created for GIS analysis. The map was produced using the ArcGIS programme with estimated shear wave velocity values of 10 m square using the IDW method. It is shown on the map in Figure 4.63. In addition, the comparative graph of the distribution of shear wave velocity values in the study area according to the Vs (30 m) value described in some international and national standards is presented in Figure 4.67.

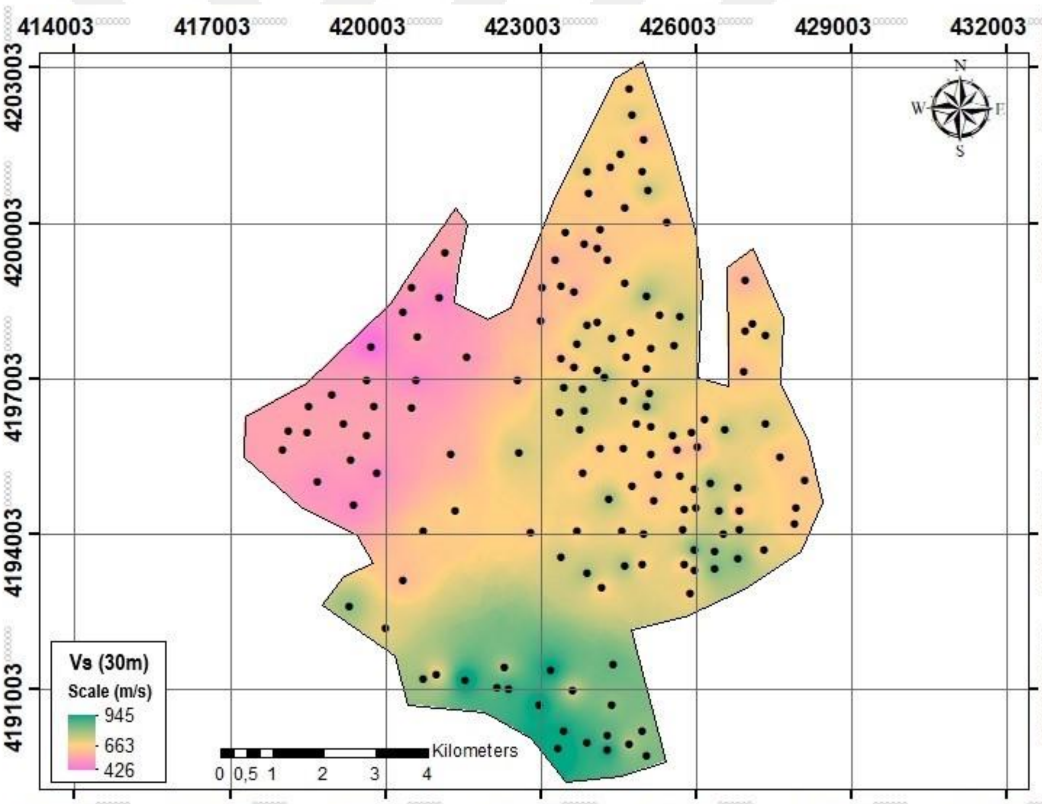

Figure 4.63. Map of shear wave velocity according to 30 m depth.

In this map, shear wave velocity values ranging from 426 m/sec to 949 m/sec have been recorded at 30 m depth. Higher velocity values are observed in the southern parts compared to other areas. When analysing the shear wave velocity data in the study area, it can be seen that the most common shear wave velocity range in the region is between 599 m/sec and 773 m/sec.

Based on the distribution map of shear wave velocity ($V_{S(30)}$) for a depth of 30 meters from the surface, the areas with the lowest values are located in the Gültepe and Girbereşik neighborhoods, which are situated in the northern and western parts of the study area, respectively. The shear wave velocity in these regions ranges from 426-591 m/s.

In Tilmerc and Çamlıtepe neighbourhoods in the north, Korik neighbourhood in the east and Site and Bayındır neighbourhoods in the southeast of the study area, the values measured between 599-772 m/s cover a wide area.

In a limited part of the study area, shear wave velocity values are in the range of 773-946 m/s and these values are generally observed in Irmi Neighbourhood in the south and in the southeastern parts of Bayındır Neighbourhood.

4.8. Soil Classification Analysis based on the NEHRP Earthquake Regulations

To determine soil class, several classification criteria are established using shear wave velocity values obtained from geophysical measurements made during field investigations. One of these is the NEHRP soil classification.

The NEHRP soil classification system categorizes soils into six different groups, namely A, B, C, D, E, and F, based on their shear wave velocity ($V_{S(30)}$) values. The hardest soils are classified as Type A, which includes soils with a ($V_{S(30)}$) value of 1500 m/s or greater. The softest soils are defined as Type E and include soils with a ($V_{S(30)}$) value of 180 m/s or less. In addition, soils with a depth of more than 36 metres and a ($V_{S(30)}$) value of less than 180 m/s are referred to as Class F soils.

A map of the NEHRP soil classification values was created for GIS analysis, using the shear wave velocity ($V_{S(30)}$) data obtained from field measurements. The maps were created by employing the IDW method on a 10-meter square grid using the ArcGIS software, and they are presented in Figure 4.64.

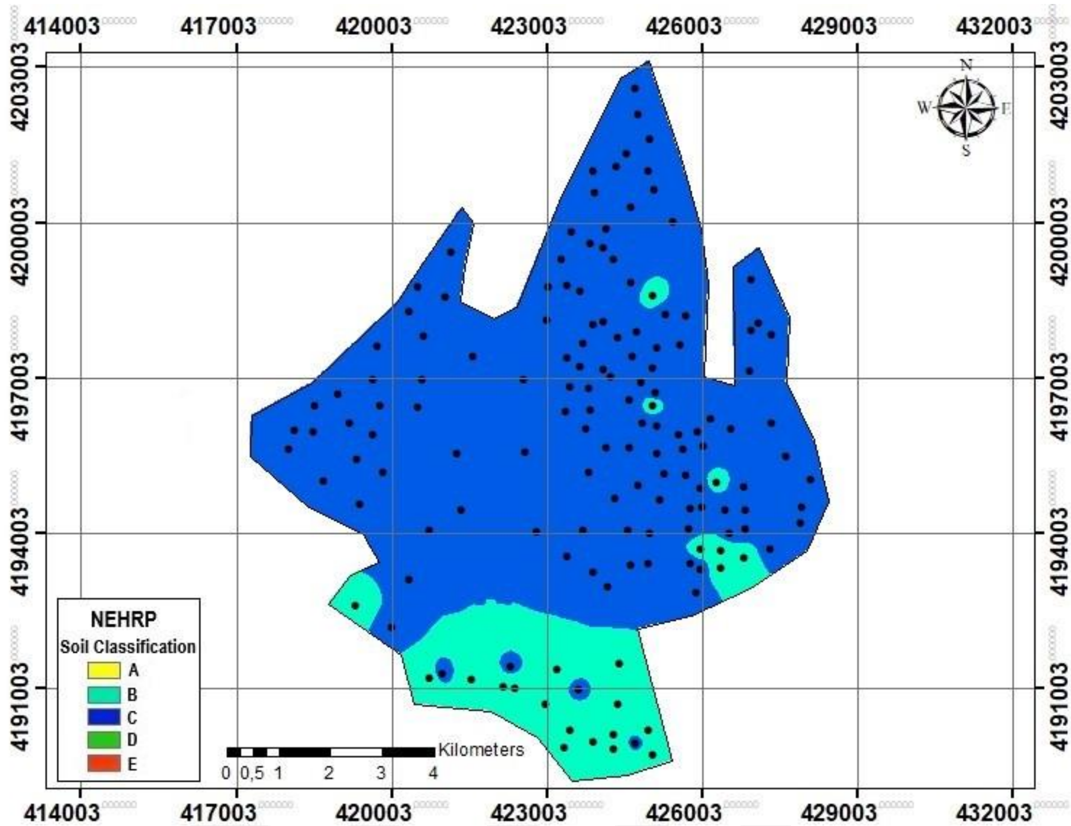

Figure 4.64. Map of soil classification according to NEHRP.

Soil classes C (dense soil, soft rock) are observed in a large part of the study area and B (firm, resistant to hard rock) in a limited part of the study area, and these values are observed in the southeastern parts of Irmi and Bayindir neighbourhoods in the south of the study area.

In addition, the graph in Figure 4.67, which compares the distribution of shear wave velocity values in the study area according to the Vs (30 m) value described in some international and national standards, clearly shows that soil class C is more dominant.

4.9. Soil Classification Analysis based on EUROCODE-8

The design codes used in Europe are called the EUROCODE series. EUROCODE-8, which is part of this series, specifies the design conditions required for the seismic design of buildings. EUROCODE-8 was approved by the European Committee for Standardisation (CEN) in 2004 and provides details for the design of buildings to resist earthquakes.

In EUROCODE-8, the soil types required for seismic design are classified into 5 basic and 2 special categories. This classification is detailed in Table 3.7 in the previous section.

The soil classes defined in EUROCODE-8 are basically labelled A, B, C, D and E. There are also special soil types in EUROCODE-8 labelled S1 and S2. These classes are determined on the basis of the strength properties and behaviour of the soil. As you move from A to E, the strength and bearing capacity of the soil decreases. Class A soil refers to hard and firm soils with the highest strength, while Class E soil refers to loose and weak soils with the lowest strength.

These soil classes are important for assessing the effects of the soil during the design process and for ensuring the seismic resistance of structures. Different design parameters and methods are used for each soil class.

EUROCODE-8 provides guidance on the determination of soil classes in seismic design and the use of appropriate design methods according to these classes. In this way, structures can be designed in accordance with local soil conditions and seismic hazard, and can be made safer.

Based on the shear wave velocity ($V_{S(30)}$) data obtained from field measurements, a map of EUROCODE-8 soil classification values was produced for GIS analysis. These maps were generated using the IDW method on a 10m square grid using ArcGIS software and are shown on the map in Figure 4.65.

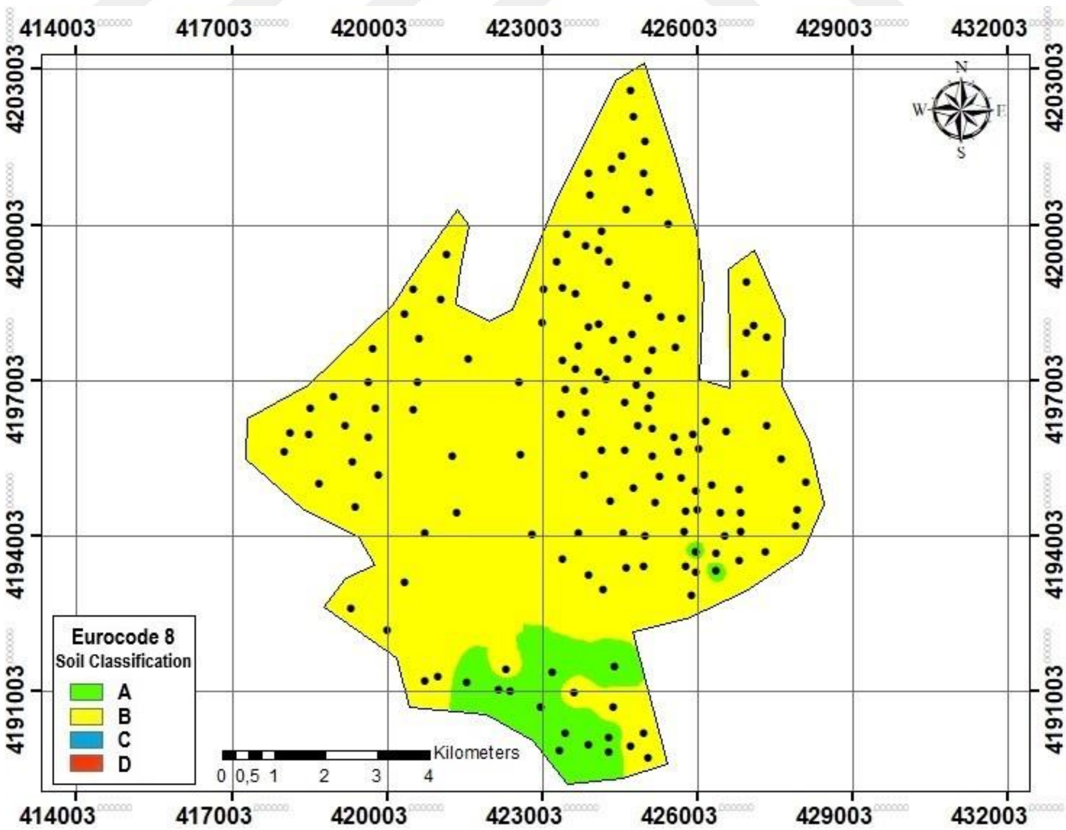

Figure 4.65. Map of soil classification according to EUROCODE-8.

Soil type B is observed in a large part of the study area and soil type A is observed in a limited part of the study area and these values are observed in the southeastern parts of Irmi and Bayindir neighbourhoods in the south of the study area.

In addition, the graph in Figure 4.67, which compares the distribution of shear wave velocity values in the study area according to the Vs (30 m) value described in some international and national standards, clearly shows that soil class B is more dominant.

4.10. Soil Classification Analysis based on TBDY 2018

Based on the shear wave velocity ($V_{S(30)}$) data determined by field measurements, a map of the TBDY 2018 soil classification values was generated for GIS analysis. These maps were produced by the IDW method on a 10 m square grid using ArcGIS software and are represented on the map shown in Figure 4.66.

Soil type ZB is observed in a large part of the study area and soil type ZA is observed in a limited part of the study area and these values are observed in the southeastern parts of Irmi and Bayındır Neighbourhood in the south of the study area.

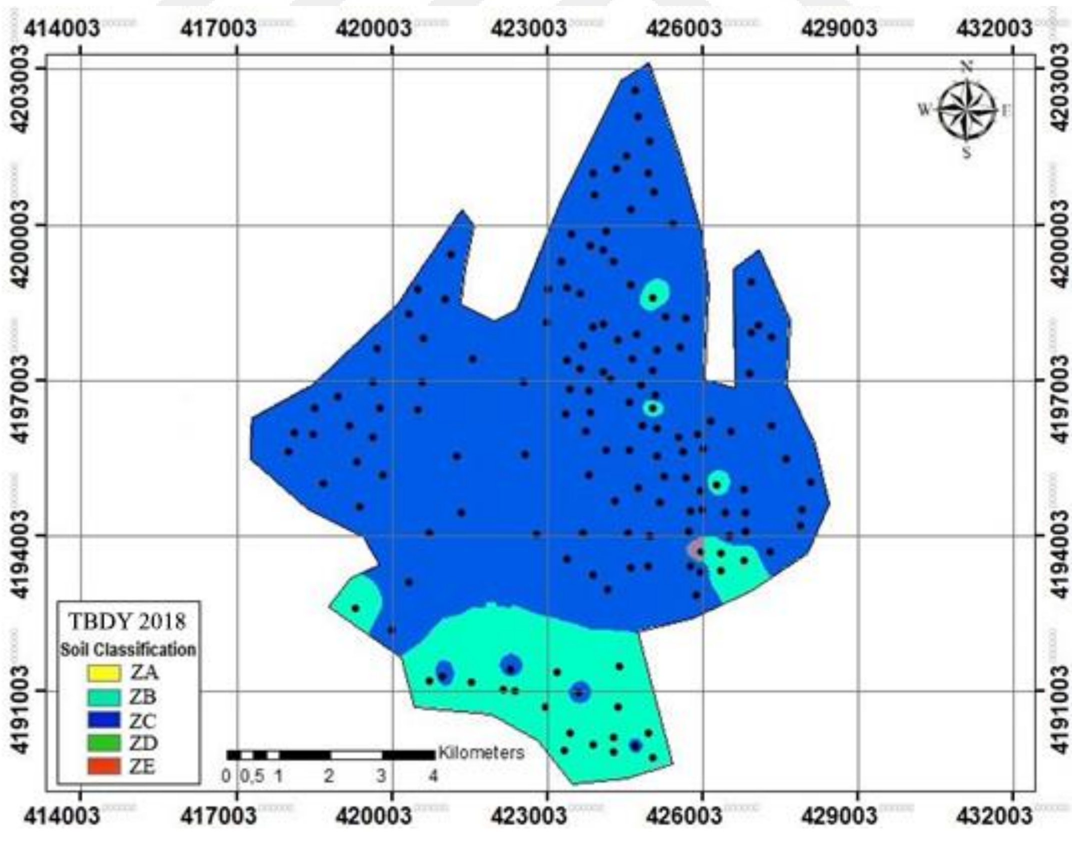

Figure 4.66. Map of soil classification according to TBDY 2018.

A comparative soil classification map according to NEHRP, EUROCODE 8 and TBDY 2018 is shown in Figure 4.66.

In addition, the comparative graph of the distribution of shear wave velocity values in the study area according to the Vs (30 m) value described in some international and national standards is presented in Figure 4.67.

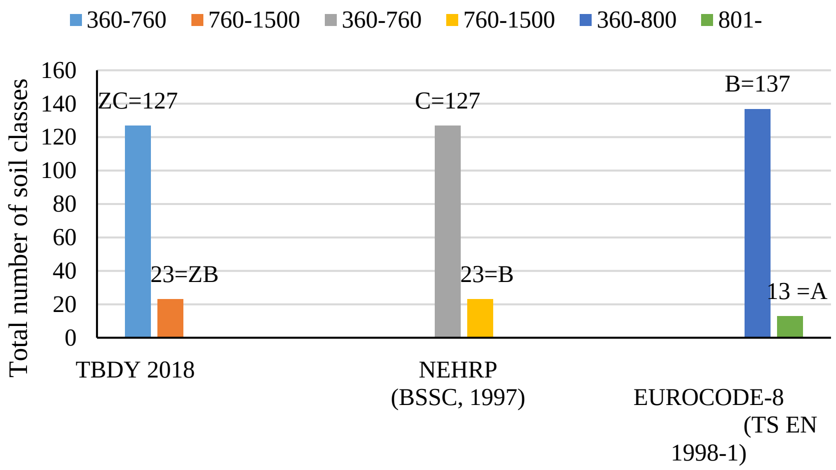

Figure 4.67. Distribution of soil classes according to the $V_{s,(30)}$ value described in some international and national standards.

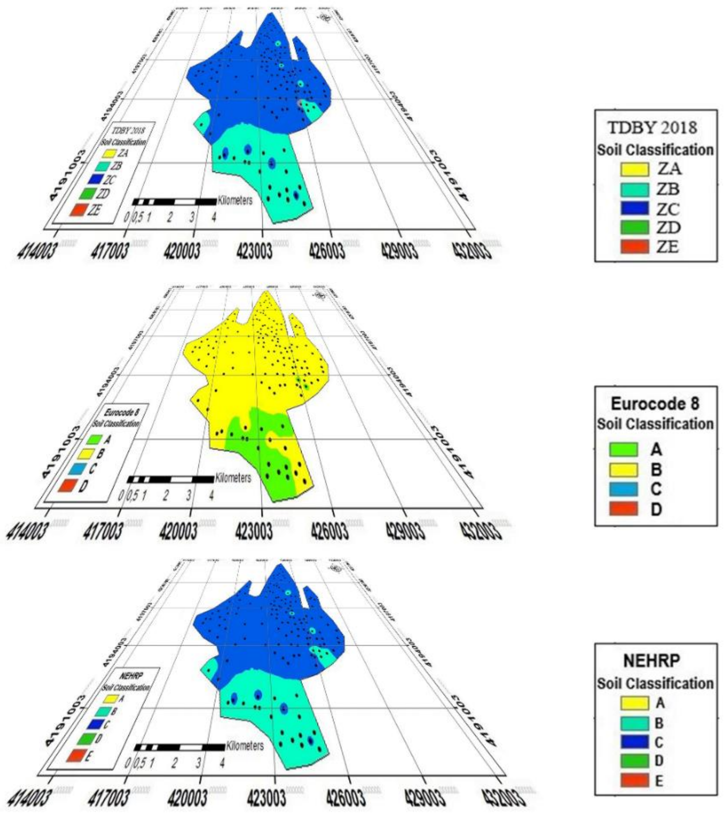

Figure 4.68. A view showing the soil classification according to NEHRP, EUROCODE-8 and TBDY 2018.

4.11. Seismic Hazard Level Analysis based on according to Soil Amplification Calculation

In order to assess the impact of strong ground motions on the ground surface, it is crucial to determine the dominant period and ground amplification values. Seismic waves passing through soil layers experience reflections and refractions, resulting in alterations in wave amplitudes and frequencies, which depend on the engineering properties of the soil. These changes lead to an increase or decrease in the effects of the earthquake on the surface, depending on the impedance properties of the soil layers, which is called ground amplification.

Ground amplification is the process of increasing or decreasing the effects of an earthquake on the surface, in a way that differs from the effects on bedrock. This depends on the dynamic properties of the soil and its structure.

The dominant period of the ground is a factor that has a direct effect on the damage to the structure. When analysing the interaction between the structure and the ground, the dominant period of the ground plays an important role in increasing the damage due to resonance effects. In other words, since resonance can occur in the interaction between the structure and the ground, the dominant period of the ground has a determining effect on the severity of the damage.

Therefore, it is of great importance to determine parameters such as ground dominant period and ground amplification in order to predict earthquake effects and determine the damage risk of structures. These parameters are used in building design and retrofit studies to make structures safer against earthquake effects.

Various methods, usually related to surface geology, are used to assess the ground amplification effect. In the study by Borcherdt ve Gibbs (1976), the amplification effect of ground motions occurring during nuclear tests in regions with different soil structures was analysed with respect to a reference point established on granite soil. As a result of this study, it was found that the soil structure is closely related to the increase in the ground motion effect and is related to the relative amplification factor.

Similar studies by Shima (1978) and Midorikawa (1987) used analytical calculations to determine the relative amplification factor values caused by different surface geologies. These calculations also took into account the seismic behaviour of the ground to determine the amplification factors associated with the surface geology.

The determination of the local soil effect is of great importance for the design of earthquake resistant structures in areas where human settlements are planned or existing.

The most common damage caused by earthquakes is caused when loose soils amplify the waves compared to hard surfaces and rocky environments. To determine the local soil effect, shear wave velocity data obtained during seismic studies in the study area were used. The Vs (30 m) data presented in Table 3.3 were utilized in the corresponding relationships to calculate the ground amplification values for the study area, using the empirical relationships developed by Midorikawa (1987). Subsequently, a map of the ground amplification values obtained from the surface was generated for GIS analysis. These maps were produced using the IDW method on a 10m square grid using the ArcGIS programme and are shown on the map in Figure 4.69.

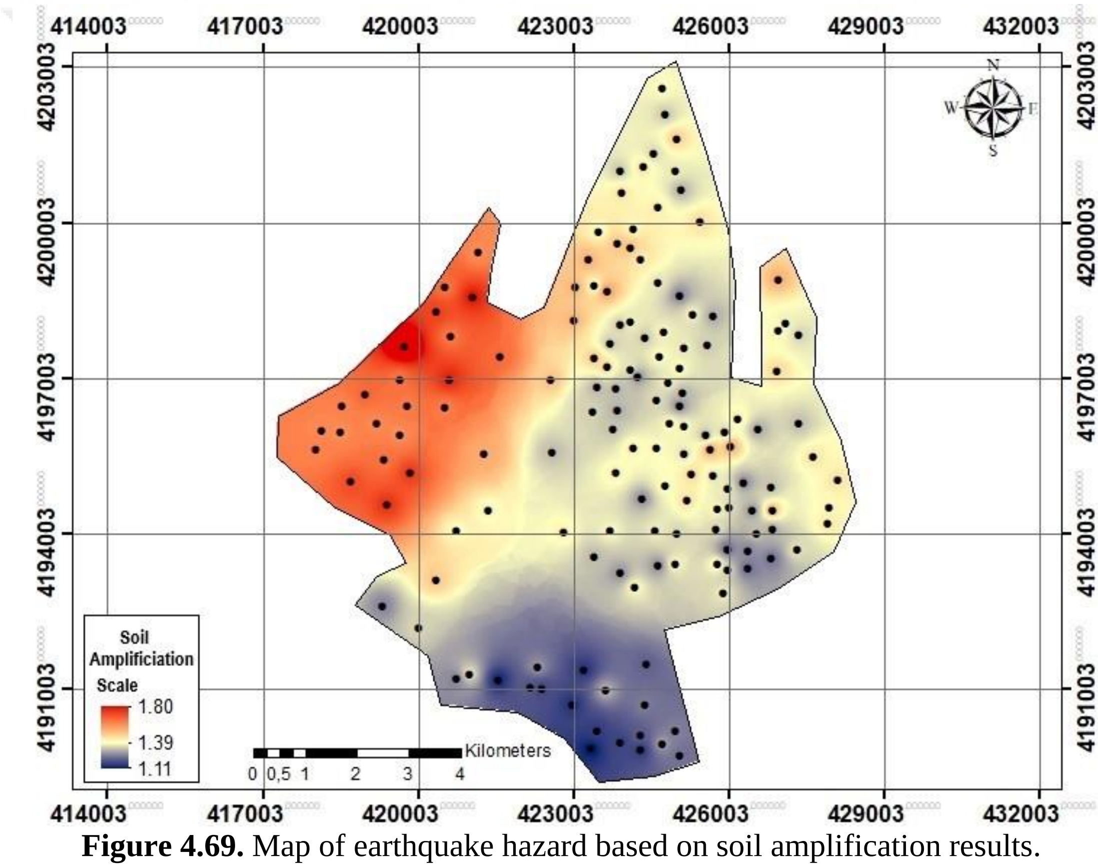

Figure 4.69. Map of earthquake hazard based on soil amplification results.

According to the distribution map of the relation developed by Midorikawa (1987) using the shear wave velocity ($V_{S(30)}$) for a depth of 30 m from the surface in the study area, the amplification values vary between 1.11 and 1.80.

The highest values were observed in the Tilmerc and Çamlıtepe neighbourhoods in the north, the Korik neighbourhood in the east, and the Site and Bayındır neighbourhoods in the southeast of the study area, while the lowest values were found in the Irmi neighbourhood in the south and in the southeastern parts of the Bayındır neighbourhood.

The soil amplification values were categorised according to the seismic hazard level. Accordingly, a amplification value of 0.0-2.0 indicates a low hazard level (C), a amplification value of 2.0-4.0 indicates a medium hazard level (B), and a amplification value of 4.0-6.5 indicates a high hazard level (A) (Kurnaz, 2011). When all the values in the study area are analysed, it can be seen that the values are in the range of 0.0-2.0 and therefore in the low hazard (C) level.

4.12. Soil Analysis based on the Unified Soil Classification System (USCS)

Soil classification was made by using the results of sieve analyses and consistency limits tests performed on 244 soil samples obtained by borehole logs in the study area. Based on these classification results, maps showing the distribution of soil classes at different depths (3 m, 4.5 m, 7.5 m, 9 m and 15 m) starting from 1.5 m in the study area were created. These maps were generated by IDW method on a 10 m square grid using ArcGIS programme and represented in Figure 4.71. Thus, it was tried to determine how the soil classes change with depth in the study area.

According to the USCS, 9 different soil classes were determined in the study area. These are named as CH, CL, GC, GM, GW, GW-GM, SC, SM and SW-SM. The graph showing the distribution of soil classes in the study area according to the USCS is presented in Figure 4.70.

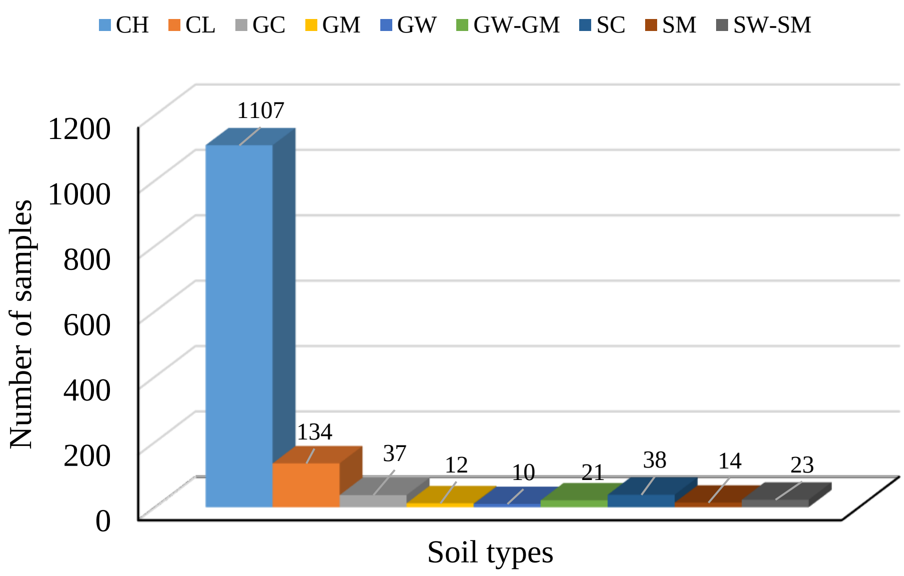

Figure 4.70. Distribution of soil classes according to USCS.

When the depth-dependent variation and distribution of soil classes throughout the study area are analyzed, the striking point is the dominance of clayey units throughout the study area. This situation shows that the study area is mostly composed of clay-containing soils. When the change of soil classes according to depth is analyzed, it is observed that clay content plays an important role at different depths. High plasticity inorganic clay (CH) and low plasticity inorganic clay (CL) soil classes are common, especially at the surface of the study area and other depths investigated. These soil classes are dominant both at the surface and at other depths and constitute the general soil characteristics of the study area.

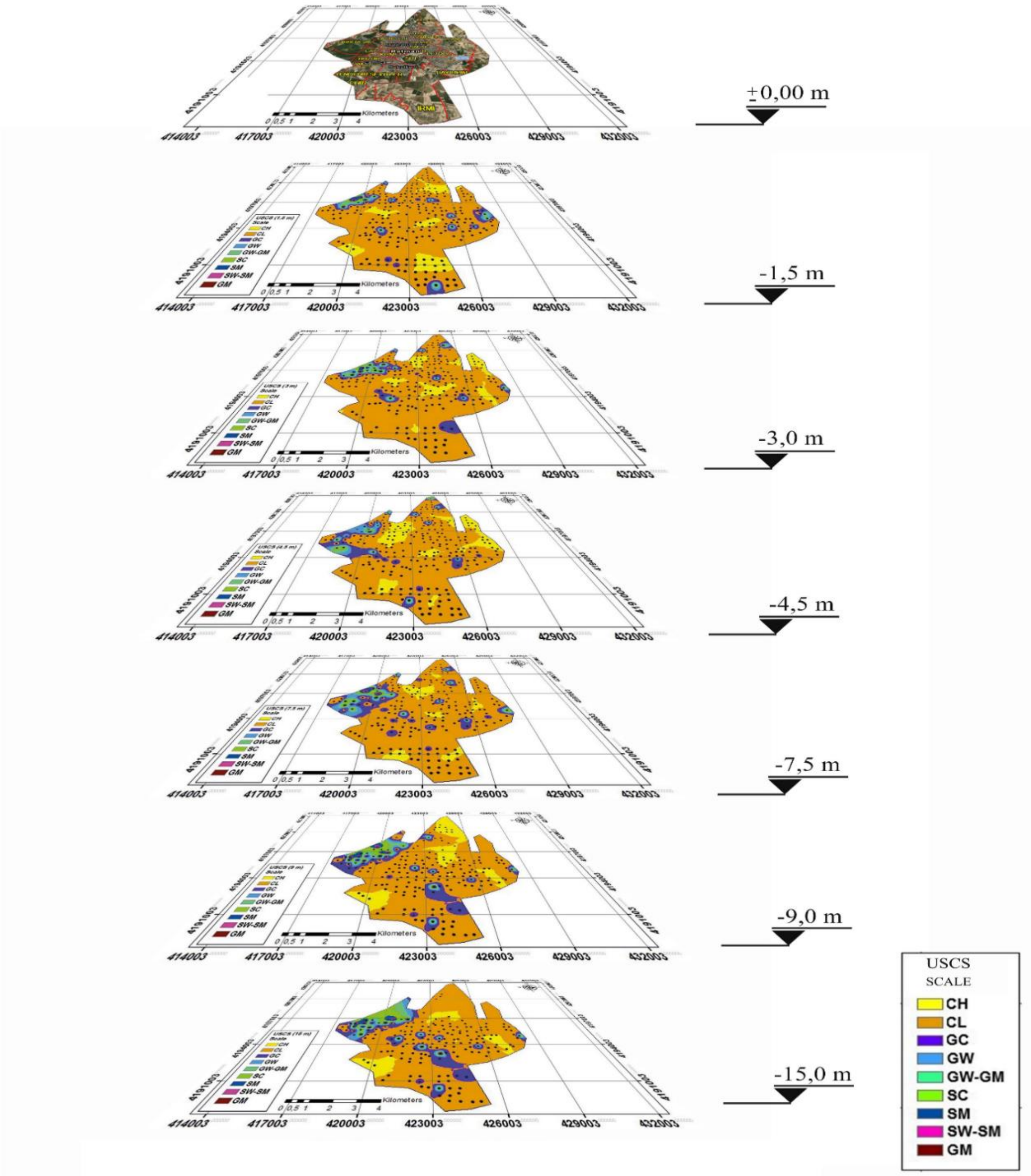

Figure 4.71. A view showing all the soil classes on maps according to the USCS.

4.13. Analysis of Site Dominant Vibration Period (To) Maps

Site dominant vibration period (To) is a measure of the frequency content of a ground motion. It refers to the vibration period corresponding to the highest value of the Fourier amplitude spectrum. The dominant vibration period of the soil usually takes a value between 0 and 1. In rock soils, the dominant vibration period is generally lower than other soil types. The dominant vibration period is calculated from factors such as the thickness of the unresisting layers over the resistant soil and the shear wave velocity.

As mentioned in the previous section, Kanai (1983) developed an equation to calculate the dominant vibration period of soil. In this equation, T is the dominant vibration period, H is the layer thickness and $V_{S,30}$ represents the average shear wave velocity at 30 m depth. In other words, according to the relation presented by Kanai (1983), the dominant vibration period of the sediment layer depends on factors such as the thickness of the layer and the velocity of the S wave and can be calculated by equation (3.6).

The natural period of vibration of the soil depends on the frequency of the earthquake waves and is also related to the properties of the soil such as its adhesion properties, compressibility and damping ratio. When an earthquake wave reaches the ground, it may resonate by vibrating with a frequency compatible with the dominant vibration period of the ground. In this case, more seismic wave energy can be transferred to the ground. However, if the vibration period of the ground is different from the frequency of the earthquake waves, the earthquake waves may be less effective in the ground and the earthquake intensity may be felt less. Therefore, the relationship between the dominant vibration period of the ground and the frequency of earthquake waves should be taken into consideration in determining the earthquake risk in a region.

Based on the shear wave velocity information obtained from the seismic studies in the study area, the dominant vibration period values of the ground were calculated and it was determined that the dominant vibration periods were in the range of 0.11 - 0.47 s. The soil dominant vibration period map of the study area is presented in Figure 4.72, which shows the distribution in the study area. In the western part of the study area, the dominant periods generally vary between 0.26 - 0.47 s, while in the remaining parts of the study area, the dominant vibration periods vary between 0.11 - 0.26 s.

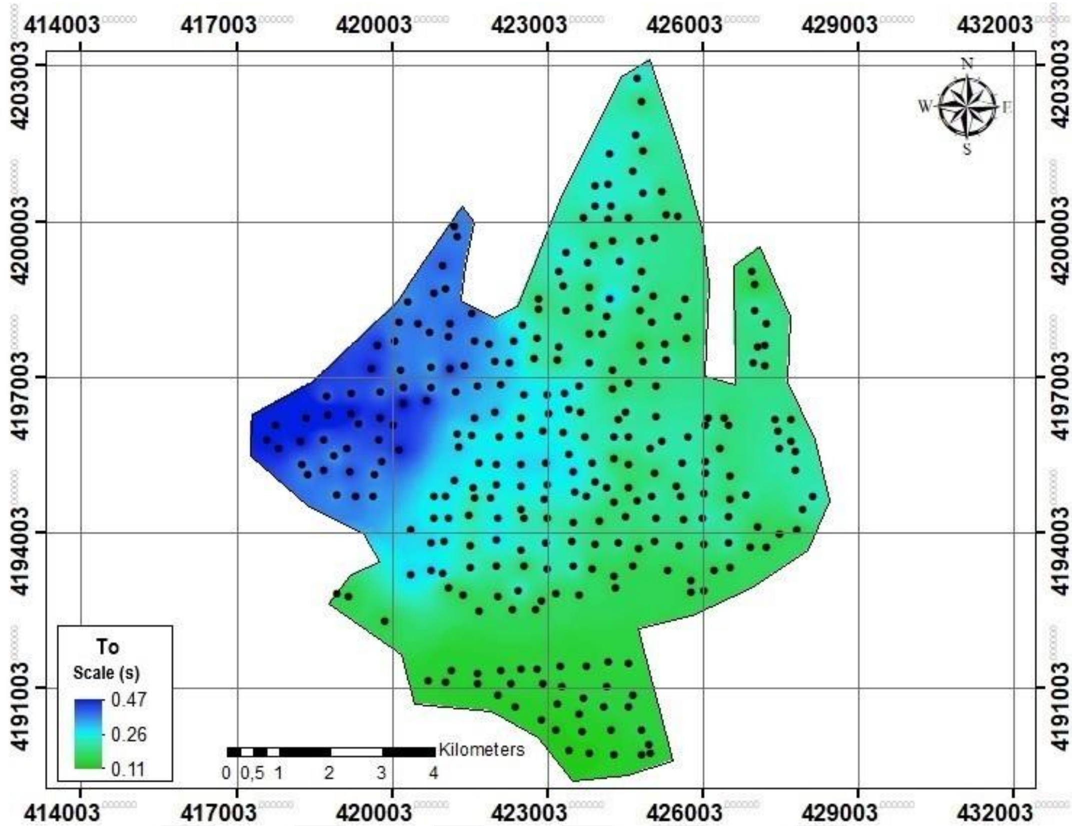

Figure 4.72. Map of site dominant vibration period (To).

4.14. Analysis of Shear (Vs) and Compression (Vp) Wave Velocity Maps

Shear wave velocity and compressional wave velocity are important parameters used in fields such as soil mechanics and earthquake engineering. These velocities are used to understand the elastic properties and behaviour of materials, to assess the dynamic response of soils and to analyse the propagation of earthquake waves.

Shear wave velocity and compressional wave velocity data were obtained from field measurements using seismic methods and a map was produced for GIS analysis. The maps were produced using the IDW method on a 10m square grid using ArcGIS. The shear wave velocity map for a depth of 6.0 m and the compressional wave velocity map for the same depth are shown on the map in Figure 4.73. Maps at different depths could not be produced due to lack of data.

According to the shear wave velocity distribution map, the lowest shear wave velocity values are observed in Girbereşik in the west and Cudi, Korik and Petrol neighbourhoods in the east of the study area. In these areas, the shear wave velocity varies between 176 and 303 m/s. In Gültepe in the north of the study area and in a limited part of Irmi neighbourhood in the south, the shear wave velocity values are in the range of 354 - 445 m/s.

According to the compression wave velocity distribution map, the compression wave velocity varies between 543 - 642 m/s throughout the study area. In a limited part of the study area, the shear wave velocity values are in the range of 647 - 788 m/s.

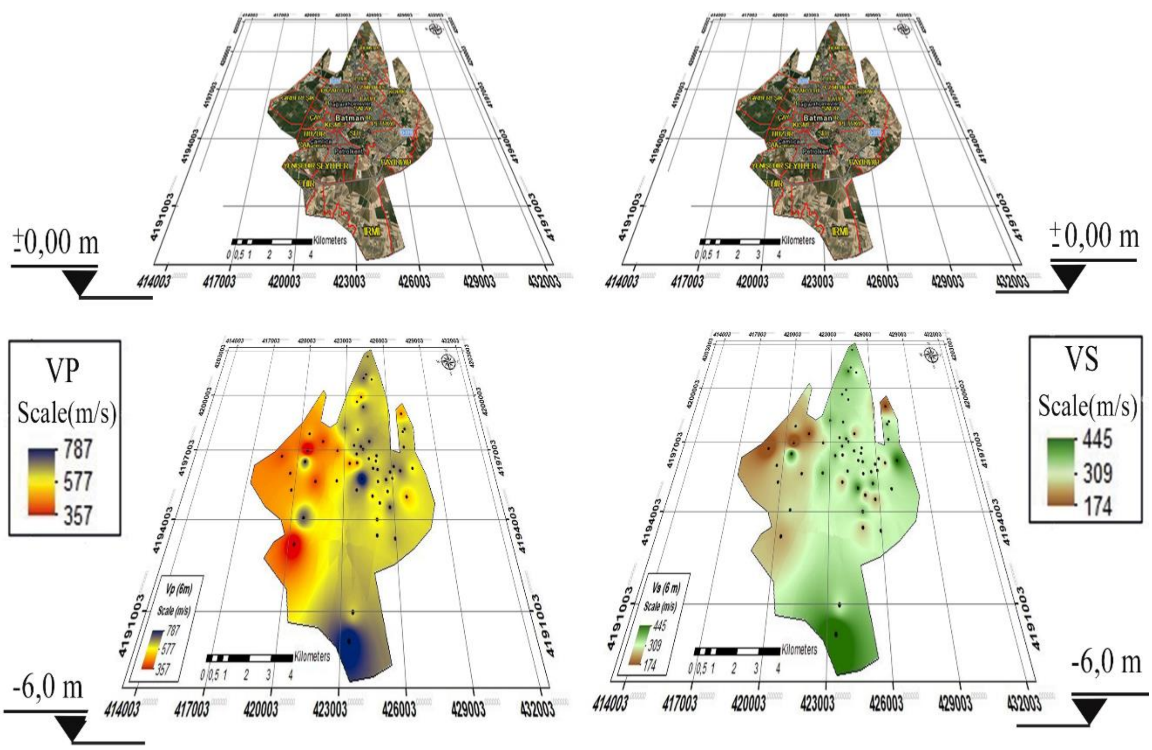

Figure 4.73. Map of shear and compression wave velocity at 6.0 m depth.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

In this study, a database was created using the data obtained from the soil investigation reports in the archives of the Batman Municipality Directorate of Zoning and Urbanization. This database allows various analyses to be carried out in the study area within the boundaries of Batman Province using geotechnical data. The analyses include standard penetration tests, bearing capacity calculation analyses, groundwater level, consistency limits, soil classification, natural water content, sieve analysis, shear wave velocity, compressional wave velocity, ground dominant vibration period, NEHRP, EUROCODE-8 and TBDY 2018 soil classification analyses, soil amplification calculations, and seismic hazard level analyses.

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

i. In the study area, SPT-N values generally increase linearly with depth.

ii. According to the values indicated on the maps produced as a result of the above SPT-N analyses, it can be seen that the soil has different properties in different parts of the study area. For example, in the northern part of the study area, the soil is generally loose, whereas in the southern part of the study area, the soil is medium. In the southwestern part, the soil has both medium and firm properties.

iii. The SPT-N values in some sections of Girbereşik and Yeniköy neighborhoods located in the western part of the study area show varying values between 3m to 7m, which can be attributed to their close proximity to the Batman stream. The obtained values suggest that the soil in coastal regions can be considered "loose," and this in turn can indicate a potential risk of bearing capacity and settlement issues in the area. Therefore, further analysis is required to evaluate potential risks such as liquefaction and loss of bearing capacity, specifically in these areas. This information can be useful for risk assessment in the region.

iv. The maps showing the shear wave velocity and compressional wave velocity indicate a comparable pattern to the SPT maps. However, certain dissimilarities can be observed in some areas resulting from the uneven proportion of boreholes and seismic data. These discrepancies can be attributed to various factors, including the changes in factors that affect the engineering properties of the soil at different depths and local variation in its composition. Thus, the similarity ratio of the two data sets does not represent a complete agreement.

v. When the SPT maps are analysed, the relationship between SPT - ($V_{S(30)}$) shows a linear fit in the parts defined as "dense, very dense or bedrock" in the and Bayındır neighbourhoods in the southeastern part of the study area where the SPT-N impact values are high.

vi. When examining the maps related to the spatial distribution of bearing capacity, it is found that around 19% of the study area has a bearing capacity below 163 kN/m². Additionally, approximately 32% of the study area exhibits bearing capacity values ranging from 163-325 kN/m², while 49% of the study area has bearing capacity values between 326-488 kN/m². The bearing capacity distribution maps generated using the Terzaghi & Peck and Meyerhof methods align well with each other, with calculated values showing close proximity. However, it is noted that as the stroke value and depth in the data increase, the Meyerhof method tends to yield higher bearing capacity values compared to the results obtained from the Terzaghi & Peck method.

vii. The groundwater levels in the study area vary between 3 to 10 meters in the western region, gradually decreasing as one moves towards the east. This variation is believed to be influenced by the presence of the Batman Stream. It is observed that the groundwater level rises to a depth of 3 meters near the Batman Stream. Consequently, the combination of high groundwater levels and the presence of silty-sandy soil classes in the study area increases the risk of liquefaction in the event of an earthquake. When the groundwater level is within 10 meters of the surface, the likelihood of liquefaction hazard becomes higher. However, if the water table is lower and the soil is less dense and compact, the potential for liquefaction decreases. Therefore, based on the findings of this study, it can be concluded that the proximity of the Batman Stream increases the risk of liquefaction. This information is significant in evaluating the seismic risks of the study area and can aid in implementing necessary precautions. Additionally, upon general examination, the study area is revealed to have a relatively limited groundwater resource.

viii. The maps produced as a result of the tests show that the water content of the soil in the study area varies between 2.5% and 40.8%. The average water content was calculated to be 19.5%. It is observed that the water content value between 11-20% is dominant in the study area. The LL varies between 32.8% and 68.1% and the average is 53.41%. The PL varies between 16.6% and 31.1% with an average of 23.58%. The PI varies between 14.5% and 42.7% with an average of 29.83%.

ix. In the course of borehole logs in the study area, 1231 soil samples were collected from the boreholes where SPT was applied. Sieve analysis and consistency limit tests were carried out on these samples and soil classification was carried out according to the Unified Soil Classification. Based on the classification results obtained, soil class distribution maps showing the spatial variation of the values at depths from 1.5 m to 3.0, 4.5, 7.5, 9.0 and 15.0 m in the study area were prepared.

x. In the study area, 9 different soil classes have been identified according to the Unified Soil Classification. These are designated as CH, CL, GC, GM, GW, GW-GM, SC, SM and SW-SM. In general, the soil classes vary and are distributed in the study area according to depth. An important finding is the dominance of clayey units throughout the study area. This indicates that the study area is largely composed of clayey soils.

xi. When analysing the change in soil class with depth, clay content at different depths was found to play an important role. The soil classes of high plasticity inorganic clay (CH) and low plasticity inorganic clay (CL) were found to be widespread, particularly at the surface of the study area and at other depths investigated. These soil classes are dominant both at the surface and at other depths and represent the general soil characteristics of the study area.

xii. Shear wave velocity ($V_{S\,(30)}$) data for a depth of 30 m from the surface were used to classify the soils in the study area. Based on these data, soil classes were determined according to NEHRP, EUROCODE-8 and TBDY 2018 standards. According to NEHRP and TBDY 2018, soil class C (dense soil, soft rock) dominates in a large part of the study area, but soil class B (firm, resistant to hard rock) is observed in the southeastern parts of Irmi and Bayindir neighbourhoods, which are located in the south of the study area. According to EUROCODE 8, soil type B dominates in a large part of the study area and soil type A dominates in a limited part. Again, this situation is clearly observed in the southeastern parts of

Irmi and Bayindir neighbourhoods in the south of the study area. In summary, according to the NEHRP seismic regulations, soil classes C and B are found in the study area, while according to EUROCODE 8, soil types B and A are observed. These classifications play an important role in the seismic evaluation of the soil properties in the study area.

xiii. Since the soil classification made by TBDY is compatible with NEHRP (US Earthquake Code), it is not necessary to make a separate map. This situation shows that the soil classification is similar between both codes and that the same classification criteria can be used. Therefore, since the soil classification maps produced based on NEHRP are compatible with TBDY, there is no need to produce a separate map.

xiv. In order to understand the effects of earthquakes caused by strong ground motions, it is important to determine the values of the ground period and ground amplification. These parameters are used to predict earthquake effects and determine the risk of damage to structures. In the studies, dominant periods between 0.26 and 0.47 seconds were generally observed in the western part of the study area. In other regions, the dominant periods vary between 0.11 - 0.26 seconds. In addition, as a result of the investigations, it was found that the soil amplification values in the study area are in the range of 1.11 - 1.80, i.e. low hazard level (C). This information can be helpful in assessing the level of seismic hazard and taking the necessary measures to improve the safety of structures.

xv. As a result of the seismic refraction studies conducted in the study area, the distribution of shear wave velocities as a function of depth was determined. While the lowest shear wave velocity values are observed in Girbereşik in the western part of the study area and in Cudi, Korik and Petrol neighbourhoods in the eastern part, the velocity varies between 176 - 303 m/s in these regions. In the north of Gültepe neighbourhood and in a limited area in the south of Irmi neighbourhood, the shear wave velocity values are in the range of 354 - 445 m/s. According to the shear wave velocity distribution map, the shear wave velocity varies between 543 - 642 m/s throughout the study area. However, in some regions the shear wave velocity values are in the range of 647 - 788 m/s.

xvi. It shows that Türkiye should take precautions against natural disasters, adopt appropriate building standards, and strengthen disaster management strategies based on the reality of earthquakes. To this end, it is important to assess the soil properties of settlement areas in order to reduce disaster damage and identify safe settlement areas. GIS analysis can be used as a tool to visualize these data on the map and to perform more detailed analyses.

xvii. As part of the objectives of the National Seismic Strategy and Action Plan 2012-2023, studies for the preparation of microzonation maps, liquefaction potential maps and earthquake hazard maps of settlement areas should be supported by relevant institutions and local administrations. Dissemination of these studies will enable more investigations and research to be carried out in earthquake-prone areas. The support of local administrations is of great importance in determining the earthquake risk and ensuring the safety of residential areas. These studies provide an understanding of the soil properties specific to the region, update seismic risk maps and allow for the necessary precautions to be taken. As a result, the studies supported make an important contribution to understanding earthquake risk and mitigating disaster damage.

xviii. By analysing the data collected, this study will provide information about the properties of the soil. In addition, the maps produced by the study can help to interpret other studies in the region more accurately. The maps, together with the visual presentation of the soil properties, are of great importance in terms of making it easier to understand the soil conditions in the region and to inspire future studies in the region. It is expected that they will help planners and practitioners to provide ideas during the planning phase. The databases and microzonation maps produced by the study provide a general assessment of the region, but detailed point-by-point studies should also be carried out, taking into account the variability of the geological units and the variability caused by anisotropy. In this way, more accurate information about the soil properties of the region can be obtained through more extensive and detailed studies.

CHAPTER 6
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