INVESTIGATION OF VEGETATION AND AGRICULTURAL SOILS IN RELATION TO GROUND WATER BY USING GEOGRAPHIC INFORMATION SYSTEMS (GIS): A CASE STUDY OF MANİSA, ALAŞEHİR BASIN

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in Urban Planning

by
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December 2018
İZMİR

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ACKNOWLEDGMENTS

First of all, I would like to thank my advisor, Assoc. Prof. Dr. Ali Can DEMİRKESEN for all his help and guidance during the entire working process. Despite the disturbances I caused in the intensive stage of the working process, I owe my endless thanks to him for his patience and attention. I would like to express my gratitude to Prof. Dr. Celalettin ŞİMŞEK for his comments and feedbacks and to Assoc. Prof. Dr. Koray VELİBEYOĞLU for his helpful suggestions.

In addition, I would like to express my gratitude to the İzmir Institute of Technology's City and Regional Planning Department academic members for their contributions to my academic development.

Additionally, I thank to the team of the TUBITAK research project, project no: 115Y065 (2018), which provided the main data sources of the study and this thesis was supported by that project.

Lastly, as every period of my life, I offer my gratitude to my parents who have always kept their financial and moral support. I would like to thank all my friends for their support and patience. I wouldn't be able to complete my M.S. program without the their efforts encouraging me.

ABSTRACT

INVESTIGATION OF VEGETATION AND AGRICULTURAL SOILS IN RELATION TO GROUND WATER BY USING GEOGRAPHIC INFORMATION SYSTEMS (GIS): A CASE STUDY OF MANİSA, ALAŞEHİR BASIN

Groundwater is a natural resource that is directly or indirectly affected by any intervention in nature that we use in all areas of our life. In this sense, the issue of the groundwater is a study-subject that interests many professions and researches. Urban planning is a profession area that is directly related to the groundwater issues as decision-making on spatial and functional decisions about the city and the natural environment. However, groundwater resources are not taken into account as above-ground natural resources during the planning phase. Plans without consideration of groundwater potential cause threatening consequences for both existing natural resources and residents in the region. For this reason, the focus point of the thesis is the groundwater and its determination and investigation of relationship among the groundwater, vegetation, and agricultural soils.

The aim of this thesis is to determine the groundwater potential (GWP) locations of Alaşehir Basin by a multi-criteria (proxies) method based on Geographic Information System (GIS) integrated with Remote Sensing (RS). The method used in this study includes 10 proxies as mult-criteria that play important roles on determination of the potential of the groundwater, combining these proxies in a digital media and illustrating output image maps of them. These proxies are: Normalized Difference Vegitation Index (NDVI), Modified Normalized Difference Water Index (MNDWI), land-use land-cover (LULC), lineament, topography (Digital Elevation Model – DEM), slope, drainage, lithology, hydraulic conductivity, and soil types. The main data sources of the study are: Landsat-8 OLI multi-spetral satellite image bands, the Aster Digital Elevation Model (DEM) of the study area and the GIS data layers from the institutions and research studies.

According to study, the most GWP locations are seen in northeast of Salihli, in southeast of Alaşehir and around Dereköy. This findings are so important for planning in terms of groundwater pollution risk management.

Key words: Groundwater, Geographic Information System (CBS), Remote Sensing (RS), Digital Elevation Model (DEM)

ÖZET

BİTKİ ÖRTÜSÜ VE TARIMSAL TOPRAKLARIN YERALTI SULARIYLA İLİŞKİLİ OLARAK VE COĞRAFİ BİLGİ SİSTEMLERİ (CBS) KULLANARAK İNCELENMESİ: MANİSA, ALAŞEHİR HAVZASI ÖRNEĞİ

Yeraltısuyu hayatımızın her alanında kullandığımız aynı zamanda doğaya yapılan herhangi bir müdahaleden doğrudan ya da dolaylı olarak etkilenen doğal bir kaynaktır. Bu anlamda, yeraltı suyu konusu pek çok meslek alanını ve araştırmayı ilgilendiren bir meseledir. Kent ve dolayısıyla doğal çevresi hakkında konumsal ve işlevsel kararlar veren bir meslek alanı olması sebebiyle kent plancılığı yeraltı suyu meselesiyle direkt olarak ilişkilidir. Fakat planlama aşamasında yeraltı suyu kaynakları, yer üstü doğal kaynaklar kadar dikkate alınmamaktadır. Yeraltısuyu potansiyeli dikkate alınmadan yapılan planlar, hem mevcut doğal kaynaklar hem de bölgede yaşayanlar için tehdit oluşturacak sonuçlara sebep olur. Bu sebeple, tezin odak noktası yeraltısuları potansiyeli olan yerlerin belirlenmesidir.

Bu yoldan hareketle, Alaşehir Havzası yeraltısuyu potansiyeli, Coğrafi Bilgi Sistemi (CBS) ile bütünleşik Uzaktan Algılama (UA) tabanlı, çok-kriterli (çok-parametreli) karar-verme aşamaları ile bütünsel olarak değerlendirilmiştir. Bu amaçla kullanılan yöntem, yeraltısularının niteliğini ve niceliğini etkileyebilecek 10 parametrenin belirlenmesini, bu parametrelerin dijital ortamda bir araya getirilip, sonuç çıktılarının oluşturulmasını ve görselleştirilmesini kapsamaktadır. Bu parametreler: Normalleştirilmiş Fark Bitki Endeksi (NDVI), Değiştirilmiş Normal Fark Su Endeksi (MNDWI), arazi-kullanım arazi-örtüsü (LULC), çizgisellik, topografya, eğim, drenaj, litoloji, hidrolik iletkenlik ve toprak türleri olarak sıralanabilir. Çalışmanın ana veri kaynakları Landsat-8 OLI multi-spektral uydu görüntü bantları, kurumlardan ve alandaki araştırma çalışmalarından alınan CBS veri katmanları ve alanın Aster Sayısal Yükseklik Modelidir (SYM).

Çalışmaya göre, yeraltısuyu potansiyel lokasyonları genellikle Salihli'nin kuzeydoğusu, Alaşehir'in güneydoğusu ve Dereköy civarinda konumlanmıştır. Bu alanlar, yeraltısuyu kirlilik risk yönetimi açısından planlama için önem taşır.

Anahtar kelimeler: Yeraltısuyu, Coğrafi Bilgi Sistemi (CBS), Uzaktan Algılama (UA), Sayısal Yükseklik Modeli (SYM)

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CHAPTER 1

INTRODUCTION

Planning a city has close relation to social, economic and natural parameters affecting the city. Unplanned cities, which are developed without avoiding these parameters, cause adverse effects for both people and their environment. The cities are home for a great many of people. In areas where there are so many living people, who inevitably affect and threaten the nature. It is important to minimize the adverse impacts that may occur in the planning of areas such as housing and residential areas, industrial facilities (waste storage, energy production, etc.) or agricultural areas. Providing this will only be possible by correctly determining and evaluating all kinds of information and the existing natural resources of the urban area. Although groundwater resources are one of the most important natural resources, the importance for planning has not been noticed for a long time, because it is not visible like above the ground natural sources. The groundwater resource is directly or indirectly affect all species living around them. Therefore, it is also directly related to urban development. This relationship, which has been on the agenda with the acceleration of urban development in the 1900s, still plays an important role today.

The aim of this study is to provide an alternative method for accurately determining the potential of the groundwater and to accelerate researches. The area chosen for the study is the Alaşehir Basin, which is a sub-basin of the Gediz Basin. The most important reason for choosing this area are the fact that the area has a rich groundwater potential (GWP) with an aquifer under fertile agricultural soils and there is a TUBITAK research project, project no: 115Y065 (2018) which is carried out as the study on the groundwater in the area. The existence of the TUBITAK project would provide some information data and ensure that the results obtained from this study by testing and comparing them with the most up-to-date data. This study was carried out independently from the TUBITAK project mentioned above. The TUBITAK project is the data source for the thesis study. The data and data sources are described in the "Material Method" chapter.

Determination of the GWP is associated with multi-proxies (parametres, mult-criteria). This situation requires the necessity of a multi-criteria decision-making method. When this situation is considered, it is the main problem to consider which multi-criteria decision-making method is the most appropriate for the study. Then, the proxies required for the analysis of the GWP are determined and the weights of each identified proxies are determined depending on the impact of the analysis. Another important stage is to determine whether the data obtained as a result of the operations are efficient and accurate. Finally, in the light of the data obtained, it is expected that the current use of the land will be examined and that it will be able to produce robust solutions for future developments.

This study involves the determination of the GWP by considering many proxies as multi-criteria used by weighted image overlay analysis. A multi-criteria evaluation approach is required to incorporate more than one proxy into the analysis. For this purpose, the method to be used in this study is a multi-criteria decision-making method. This method is based on Remote Sensing (RS) integrated with Geographic Information System (GIS). As a result of the research, all the 10 proxies were decided and selected. Each proxy was examined in terms of its impact on determination of the GWP and finally, with a combined evaluation of all the 10 proxies, a conclusion was made on the GWP of the Alaşehir Basin, Manisa which is a sub-basin of the Gediz Basin. As a consequence, the results and findings of this study employing an efficient multi-proxies method are satisfactory and consistent with previous studies and the available existing information.

According to study, the most GWP locations are seen in northeast of Salihli, in southeast of Alaşehir and around Dereköy. These findings are so important for planning in terms of groundwater pollution risk management.

Thesis structure: This thesis contains five chapters. The contents of the chapters are summarized below:

Chapter 1. Introduction: this section briefly explains the importance and necessity of groundwater potential determination in terms of urban planning. It also explains the aim, motivation, rationale, and major findings of the study in addition to details of the method used in this study and finally gives information about the general structure of the thesis.

Chapter 2. Literature Review: This chapter elaborates the urban planning and groundwater relationship by using the literature. It explains the concepts related to the thesis study. It gives information about the works that have been done before and related to the subject of this study.

Chapter 3. Materials And Method: This section gives general information about the study area (Alaşehir Basin). It explains the method of study, data sources and data used in detail. The explanations of 10 proxies used in the study are presented with thematic maps.

Chapter 4. Results and Discussions: In this section, the final groundwater potential thematic map, created by calculating 10 proxies, is interpreted in parallel with existing land-use land-cover data. It is compared with the existing graundwater level map taken from the TUBITAK project and tested for its accuracy and validation. Finally, the evaluation of the compatibility of the 10 proxies used and recommendations for future studies was made.

Chapter 5. Conclusion: This section contains a general overview of the results obtained from this study.

CHAPTER 2

LITERATURE REVIEW

2.1. Background Information of Urban Planning and Groundwater

In order to ensure the sustainable development of the city, the impact of the built environment and existing natural conditions on water resources should be examined and appropriate planning criteria should be established. Groundwater can be considered as two-way in urban planning. The first one is to minimize the adverse effects to human being and remove harmful impacts on the groundwater resources. The second is to ensure the efficient use of the existing groundwater resources Carmon et al. (1997) and Frans and Rijsberman (1999).

Carmon et al. (1997) in their study is about water sensitive urban planing, focused on what urban planners can do to reduce the negative impacts of urban development on the groundwater. Carmon et al. pointed out that urban areas are usually developing on aquifers, and that any wrong planning decision could damage the nature of quality and quantity of the aquifers and the groundwater. In the hydrological context, they defined two objectives for water sensitive urban development. These can be listed as increasing the amount of water leaked to the ground, transporting (infiltrating) it to the groundwater and reducing the pollution of the surface flow which allows refilling of the aquifer (Carmon et al., 1997). In addition, they offered several planning proposals to ensure sustainable water management:

1. To accurately and efficiently determine the quantity and quality of the groundwater, the areas where the aquifers are high level and used as natural infiltration basins; perform the potential damage analysis of the area before the planning phase.
2. Introducing the construction boundaries in areas with the high GWP and preventing pollutant structures.
3. To allocate areas of infiltration to urban open space (park, garden, recreational areas, etc.).
4. To ensure that the rain water is caught in the field before being polluted with the help of parks and gardens (Carmon et al., 1997).

Frans and Rijsberman (1999) interested in the problems created by urban development without considering groundwater resources in their study in Holland. In this context, they have identified three main problems. The first one is the negative effects on public health. De-humidification caused by improper structuring in the Netherlands and the high level groundwater level have added human health adversely (Frans and Rijsberman, 1999). Another problem is the effects of the groundwater on local hydrology. The moisture and pressure created by the groundwater have caused damage to buildings, building foundations and infrastructure units. In addition, sufficient yield was not obtained from plants in planting areas where the groundwater was insufficient (Frans and Rijsberman, 1999). The last problem is economic effects. The damages to infrastructure units caused the increase of pollutants in the groundwater have caused repair costs. The cost of the agricultural production has increased because of the higher costs to clean the contaminated water. In a sense, this study emphasizes that the way to develop the urban health and economy has passed through the plan decisions that take into account the natural resources.

Another study on the groundwater conservation in urban areas was reported by Morris et al. (2002). They conducted two examples of cities in Bangladesh and Kyrgyzstan (Morris et al., 2002). in the case of the groundwater, the lack of policy required for urban decision-makers and the reasons for this lack. The first of these reasons is the lack of current and convenient data. Another reason is that the connection of the groundwater with sustainable development is not known. The last problem is that not seeing the big picture. The groundwater is speculative in nature. It is possible that the wells drilled by special users will affect the quality and quantity of water. This will make planning decisions difficult (Morris et al., 2002).

With their study, they aimed to develop applicable policies in the field of the aquifer and groundwater conservation. In the urban area, some basic steps for the groundwater planning are defined. The most important of these are the identification and mapping of potential pollution and hazardous activity risks. Another is to ensure that the correct data is obtained and planning decisions are made in the region. In addition, Morris et al. (2002) mentioned the necessity of creating a project team and identifying the stakeholders associated with the groundwater.

2.2. Background Information of Groundwater and Aquifers

The groundwater is a natural resource that meets the water need of the settlements in terms of drinking and irrigation use and its natural environment. The groundwater is formed by the accumulation of water in the porous rocks called the aquifer. The movement and quantity of the groundwater varies according to the nature of the material through which groundwater passes over (Bear, 2007).

The rock layers where the groundwater is stored in the crust are called an aquifer. Surface water, absorbed in the ground surface, accumulates in the aquifers. In urban areas, the aquifers have three basic functions. First of all, the aquifers are one of the main groundwater sources. As a second function, the aquifers can be used as a waste water disposal areas. Finally, the aquifers can house infrastructure units under ground surface such as tunnels, subways, warehouses and foundations (Morris et al., 2002).

Failure to determine the level and quality of the groundwater in an area, wrong determination of the location and the groundwater level of aquifer areas, wrong planning and application decisions will lead to. This situation will have negative consequences such as a decrease in the groundwater due to excessive pumping or increased pollution due to incorrect spatial use. In this regard, the main objective in urban planning should be to produce solutions for the sustainable use of the groundwater. This should be the right planning decisions based on the right data to provide.

2.3. Background Information of Remote Sensing

Remote Sensing (RS) is defined as a system of obtaining information about the Earth by using sensor systems without any contact. RS data is obtained by satellites. These satellites can collect different types of data according to their characteristics. RS can provide positional image data for large areas (Schowengerdt, 2007).

RS can be used in many areas such as hydrology, transportation, mining, hydro-geology, agriculture, mapping, urban planning and meteorology. RS data allows determining the right method to minimize the environmental damages in the plans and applications, to use the space efficiently and to reduce the cost.

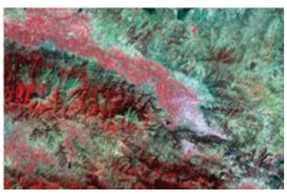
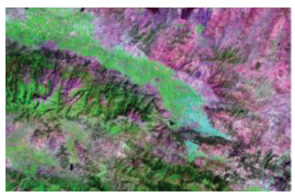
RS used in this study is associated with optical data of the Landsat-8 Operational Land Imager (OLI) (2018). Optical sensing is performed by detecting the electromagnetic energies of the objects by the receivers and recording them to the tapes according to their reflection values. These bands come together separately or in various combinations to create images. These image data are provided by optical detection satellites (Schowengerdt, 2007). Table 2.1. below contains information about the bands provided from the Landsat-8 OLI multi-spectral satellite image bands.

Table 2.1. Characteristics of Landsat-8 OLI multi-spectral satellite image bands.
Source: Barsi et al. (2014)

Landsat-8 Operational Land Imager (OLI) Multi-spectral Image Bands		Wavelength (micrometers)	Resolution (Meters)
Band 1	Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
Band 2	Blue	0.452 - 0.512	30
Band 3	Green	0.533 - 0.590	30
Band 4	Red	0.636 - 0.673	30
Band 5	Near Infrared (NIR)	0.851 - 0.879	30
Band 6	Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
Band 7	Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
Band 8	Panchromatic	0.503 - 0.676	15
Band 9	Cirrus	1.363 - 1.384	30
Band 10	Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
Band 11	Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

The bands obtained from Landsat satellite images are combined in different combinations and images are generated about the area studied. Different band combinations provide different types of information and can be used in various studies according to the type of information it provides (Barsi et al., 2014). The information about the combinations to be used in this study is shown in Table 2.2. (Landsat-8 OLI, 2018)

Table 2.2. Landsat-8 OLI Composite Images of the Study Area.

Red, Green, Blue (RGB) Band Combination, Composite Images	The Standard Color Infrared Composite Image 	The Natural Color Composite Image 	A False Color Infrared Composite Image 
Landsat-8	R,G,B = 5,4,3	R,G,B = 4,3,2	R,G,B = 7,5,4

The color infrared combination (R,G,B = 5,4,3) is usually used in soil, vegetation and drainage studies. Vegetation is seen in red shades, urban areas and stony areas are seen in blue shades and soil areas are seen in brown shades. The darkest areas of red represent the healtiest vegetation, while the most light blue areas represent the most dense residential areas. (http://www.usgs.gov 2018 and and https://eos.com 2018).

The combination of natural color (R,G,B = 4,3,2) is not very useful in distinguishing the diversity of vegetation. Colors and tones are in the form perceived by the human eye. Green shades refers to healthy plant cover, brown shades refers to unhealthy plant cover and gray shades refers to roads, coastlines, stony and concrete areas (http://www.usgs.gov, 2018 and https://eos.com, 2018).

The combination of false color (R,G,B = 7,5,4) is generally used for research on agriculture and vegetation. Healthy vegetation is seen in bright green shades, areas with no soil and vegetation are seen in purple shades (http://www.usgs.gov, 2018 and https://eos.com, 2018).

2.4. Literature Review of Previous Studies on Determination of the GWP

There are many multi-variate studies used to determine the GWP. One of the examples of these studies is the work done by Ramu and Vinay in 2014 in Karnataka. In this study, they used a GIS-based multi-criteria method to determine the GWP. In the study, 9 different variables were used. These proxies (parameters, variables) can be listed as drainage density, elevation, geology, geomorphology, land-use and land-cover (LULC), lineaments, dykes, rainfall pattern, slope gradient and soil texture. In this study, they used SATTY's analytic hierarchy process (Ramu and Vinay, 2014) to determine the effects of variables.

Similarly, Fashae et al. (2013) investigated the GWP in Southwest Nigeria with using multi-criteria decision analysis. The variables used in this study are; geology, rainfall, geomorphology, soil, drainage density, lineament density, landuse, slope and drainage. Also, Mandal et al (2016) conducted a study using the similar multi-criteria decision analysis technique in the basin of the Balasore region of India.

In another study, Waikar and Nilawar (2017) used GIS and remote sensing techniques to determine the potential of under groundwater in India. They have used 6 parameters. These include geomorphology, slope, drainage density, lineament density, land use land cover and geology. In order to identify the under groundwater potential, they have divided the final map into five categories: excellent, good, moderate, poor and very poor.

One of the variables that are most related to groundwater is vegetation. Normalized Difference Vegetation Index (NDVI), which is an important part of this study and which can be obtained by remote sensing techniques, is a data that is commonly used in groundwater and surface water detection. Fu and Burgher (2015) analyzed the 23-year period variation of climatic factors and groundwater in the study of semi-arid ripian field in the Naomi Bvadasin of Australia. They used Landsat-7 and Landsat-5 satellite imageries (image bands) between 1987 and 2010 to make NDVI calculation.

In another study that focused on the NDVI variable, Hughie et al. (2016) used GIS and remote sensing techniques, too. They used 5 basic parameters to determine groundwater potential. These parameters can be listed as lithology, geomorphology, slope, NDVI and NDWI. They created a thematic map for each parameter and divided each map into 4 classes. These are: “Very Good”, "Good”, “Moderate” and “Poor”. They used QUEST (Quick, Unbiased, and Efficient Statistical Tree) (Huajie et al., 2008) to determine how and to what effect each variable will have on the result map. As a result, a thematic map of Chaoyang province, which provides insight into the potential of groundwater, was created.

Another important variable in the literature is hydraulic conductivity. Although this variable is more commonly used in groundwater pollution potential detection studies, it is possible to say that it has a significant effect on groundwater potential. Ahmed et al. (2017) used DRASTIC model which is a type of method to determine groundwater pollution potential in Saudi Arabia. Expansion of the word DRASTIC depth to groundwater, recharge, aquifer media, soil media, topography, impact of the vadose zone and conductivity. The DRASTIC model is a multi-critera decision method that is very often used to detect groundwater presence and potential pollution hazards.

When analyzed studies for Turkey, studies which is about groundwater potential determination with using multi-criteria methods are not founded in website of the national thesis center (https://tez.yok.gov.tr, 2018). However, it is possible to talk about several similar studies using the DRASTIC model for detecting groundwater pollution risk. As an example of these studies, the phd study carried out by Nesrin Barış in the

Tahtalı Dam Basin in 2008 can be given. In this study, Nesrin Barış used DRASTIC model to determine groundwater pollution risk and integrated water quality in the basin. In the mapping phase, GIS methods were used (Barış, 2008). Another similar study on this subject was the study by Ahmet Atlı (2010) based on the DRASTIC model to determine the groundwater pollution risk in the Erzin Plain.

In this study, in addition to the parameters from the DRASTIC model used in previous studies, the variables obtained by remote sensing methods (NDVI, MNDWI) were used together. Unlike previous studies, in this study, more variables were used and each variable was classified and visualized by assigning indexes from 1 to 5 according to groundwater potential. Also a weighted image overlay process was employed for each variable. In addition, no other studies related to city planning have been found in the studies on this subject. In this sense, this study can be regarded as a pioneering work for urban planning in Turkey.

CHAPTER 3

MATERIALS AND METHOD

3.1. Data and Sources

In this study, theree fundamental data types that are required for this study are listed as auxiliary GIS data, Aster DEM data (2018) and Landsat-8 Operational Land Imager (OLI) multi-spectral image data (2018). The Aster DEM data of the area and the image data of the Landsat-8 OLI can be accessed from the official site of the United State Geological Site (usgs.com). Auxiliary GIS data comes from two basic sources. One of these sources is the Computing Department of General Directorate of State Hydraulic Works which is an official institution and the other one is the project called with the number 115Y065 which is a TUBITAK research project carried out in the Alaşehir Basin. The data types used in this study are as below:

- Auxiliary GIS data (the TUBITAK research project, project no: 115Y065) for Hydraulic Conductivity Map, Lithology and Average Groundwater Level Map.
- Auxiliary GIS data (DSI – State Water Works, Turkey): Soil Type, 3D images and general map of the study area
- Aster DEM data: Drainage, Slope, Topography (DEM), Lineament (asterweb.jpl.nasa.gov/gdem.asp, 2018)
- Landsat-8 OLI multi-spectral satellite image bands: Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Water Index (MNDWI), Land-Use Land-Cover (LULC), RGB combination images (earthexplorer.usgs.gov/, 2018)
- ED50 Datum, UTM Projection with 35N Zone, and 30 m grid size resolution for all kinds of images and DEMs were used for georeferencing.

3.2. Case Study Area: The Alaşehir Basin, Manisa

The Alaşehir Basin (Figures 3.1 and 3.2) is one of the sub-basin of the Gediz Basin. The Gediz Basin is located in the west of Turkey in the Aegean Region. The

Gediz Basin covers an area of 1,713,697 Ha. and is located between 38°04' 39°13'north latitudes and 26°42 - 29°45' east longitudes. (Gediz Master Plan Report, 2016)

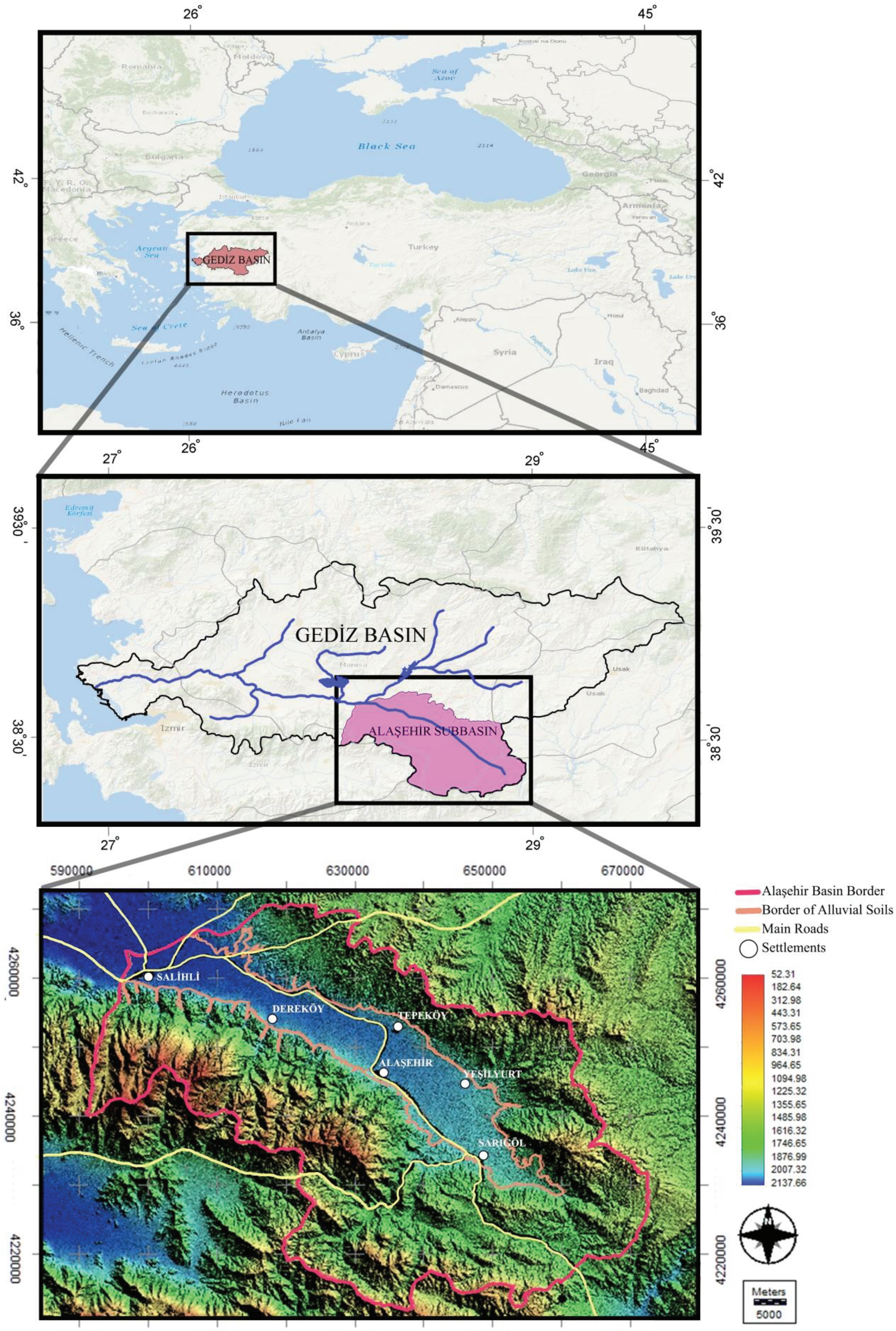


Figure 3.1. Location map of the Alaşehir Basin created from the Aster DEM.

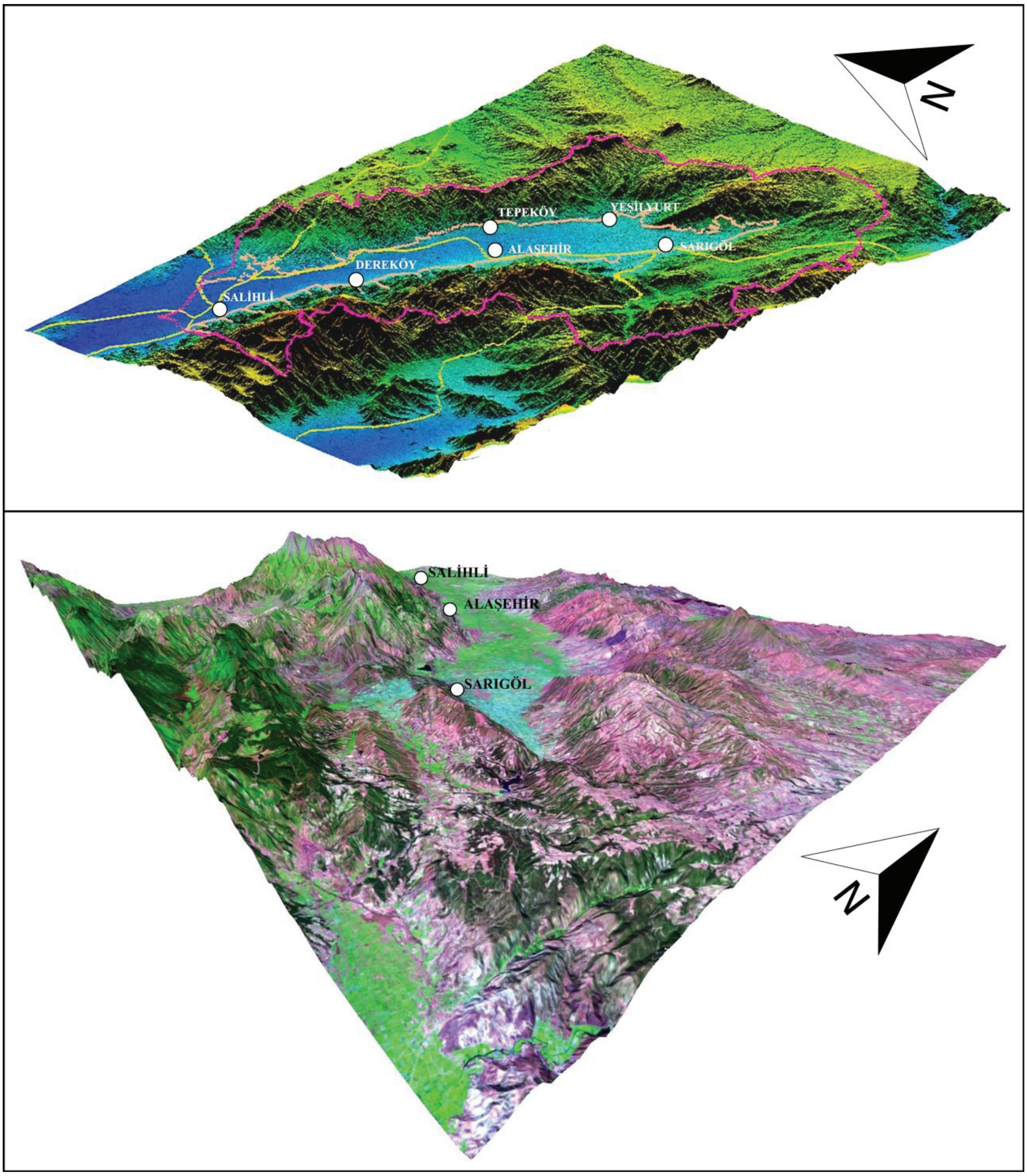


Figure 3.2. 3D images of the Alaşehir Basin.

Mediterranean climate type is seen in the Alaşehir Basin, a sub-basin of the Gediz Basin. The average temperature of the basin is 15.1 ^{o}C. The average daily temperature difference is 25.8 °C. According to the observations of the meteorological station in the basin, the total annual rainfall varies between 450 and 800 mm. Summers are dry and winters are rainy. Most of the rain falls during the winter months (Gediz Master Plan Report, 2016).

The Gediz River, which gives its name to the basin, is 275 km long and feeds on a 17.137 km^2 precipitation area in Western Anatolia. It drains the waters of the basin into the Aegean Sea. The Gediz Basin has 5 sub-basins:

1. Demirköprü Barrage Sub-basin,
2. Alaşehir Sub-basin
3. Kemalpaşa Sub-basin
4. Gediz Main Tributary Sub-basin
5. Kum Çayı Sub-basin (Gediz Master Plan Report, 2016)

The sub-basin, which is focused in this study, is the Alaşehir Basin. The Alaşehir sub-basin is located to the south-east of the Gediz Basin. The length of the Alaşehir Creek is 115 km. The basin has a 2,680 km^2 drainage basin. Alaşehir Creek flows in the southeast-northwest direction and joins with Gediz River near Salihli (Gediz Master Plan Report, 2016).

The settlements in the Alaşehir Stream Basin: Alaşehir, Salihli, Sarıgöl districts and villages of the Manisa province, Kiraz district villages of the İzmir province and Buldan, Kuyucak and Nazilli districts of the Aydın province. There are 115 hectares of organized industrial side in the Salihli district within the borders of the basin. In the industrial area, there are mainly food, construction materials, textile and machinery manufacturing facilities. Water consumption of existing facilities in organized industrial area is 2,100 m^3/day. (Gediz Master Plan Report, 2016). There are rich mineral resources in the region, including mercury, copper, lead and zinc deposits (Gediz Master Plan Report, 2016).

The highest wind velocity measured in the Gediz Basin was determined as 3.6 m/s in Akhisar and Alaşehir. The Alaşehir Stream Basin Natural Surface Water Potential in the period 1980-2013 was calculated as 327.58 hm^3 on an annual basis. The Alaşehir Basin hosts the most important geothermal systems and especially arsenic and boron pollution is observed in the basin. In this context, a total of 12 observation wells have been proposed for monitoring of the groundwater in terms of level and quality. The proposed wells were placed in order to determine the effect of the geothermal system in the region in addition to the determination of the level and quality of the granular units, neogene and basement rocks (Gediz Master Plan Report, 2016).

Geology of the study area: The geological structure of the basin (Figure 3.3) gives an idea about the potential of groundwater. The basement of the Gediz Basin consists of gneiss, schist and marble. (Baba and Sözbilir, 2012). Paleozoic-aged Menderes metamorphic is the main rock in the study area (Figure 3.3). The Alaşehir Plain is full of Neogene sedimentary rocks which is contains sandstone, conglomerate, claystone, limestone and volcanic layers (Seyidoglu et al., 2002). Quaternary-aged unconsolidated sediments cover these units along the plain (Figure 3.3). This alluvium material consists mostly of gravelly and clayey sands. (Rita et al., 2017).

Permeability of Neogene sediments is low. It contains sandy and clayey levels. In particular, claystone levels are very thick and impermeable layers for the geothermal system. The alluvial layer is the most important and most suitable aquifer for groundwater. Groundwater is provided by deep wells with depths ranging from 120 m to 150 m from this aquifer. The groundwater discharge rate of these wells is 5.0 to 30 L/s (Ozen et al., 2010; Baba et al., 2015; Rita et al., 2017). The general groundwater flow direction in the alluvial aquifer system is from west to east. The groundwater flow path is determined by the alluvial sediments with a high permeability value.

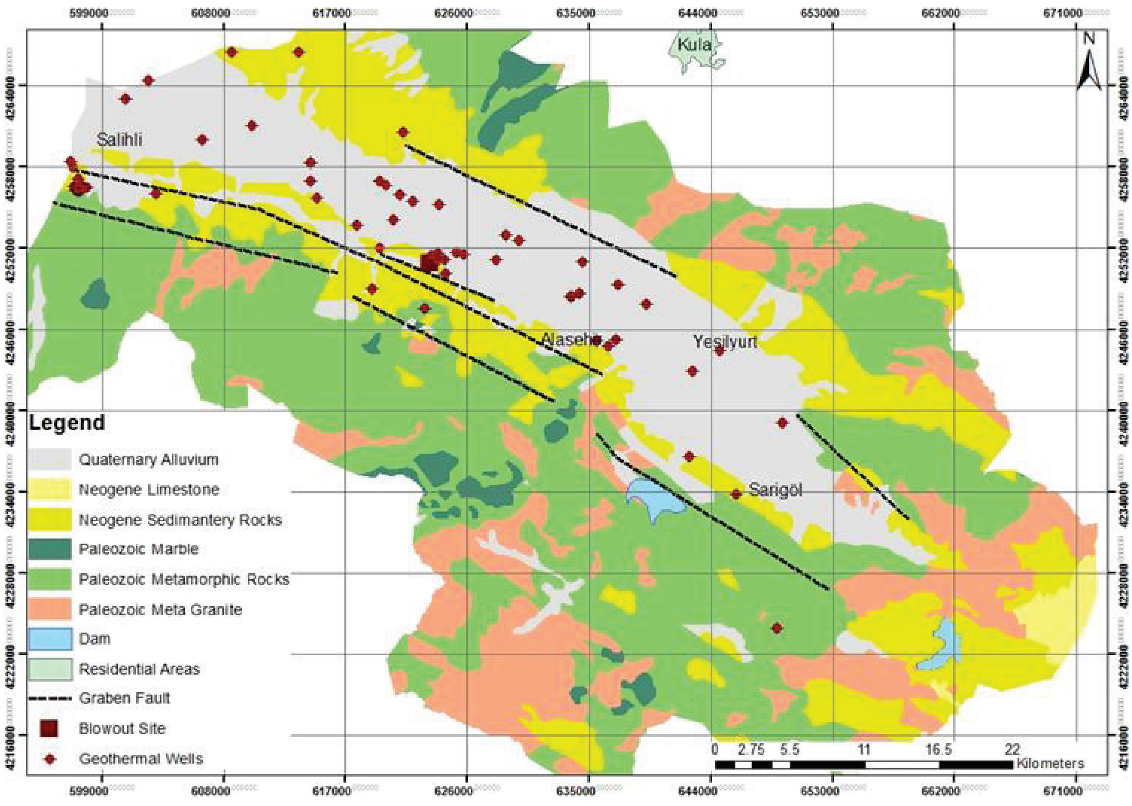


Figure 3.3. The geology map of Alaşehir Basin.

Source: Rita el al., 2017

Vegetation and land-cover of the study area from Landsat-8 OLI satellite image combinations: In Figure 3.4, color infrared vegetation and forest areas appear in red color. The regions where the red is the darkest represents the most healthy vegetation.

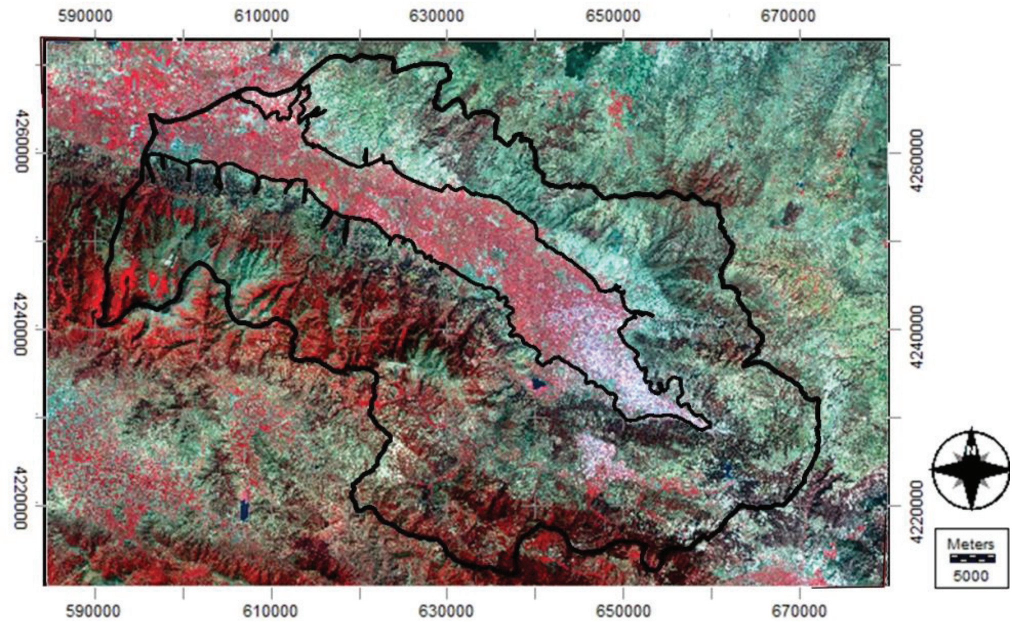


Figure 3.4. RGB = 543, the standard color infrared composite image of the study area.

In Figure 3.5, the combination of false color, agricultural areas and healthy vegetation cover appear in green and bright tones. Purple color refers to areas that do not contain vegetation. The false color combining image of the area displays a parallel image with the color infrared combination.

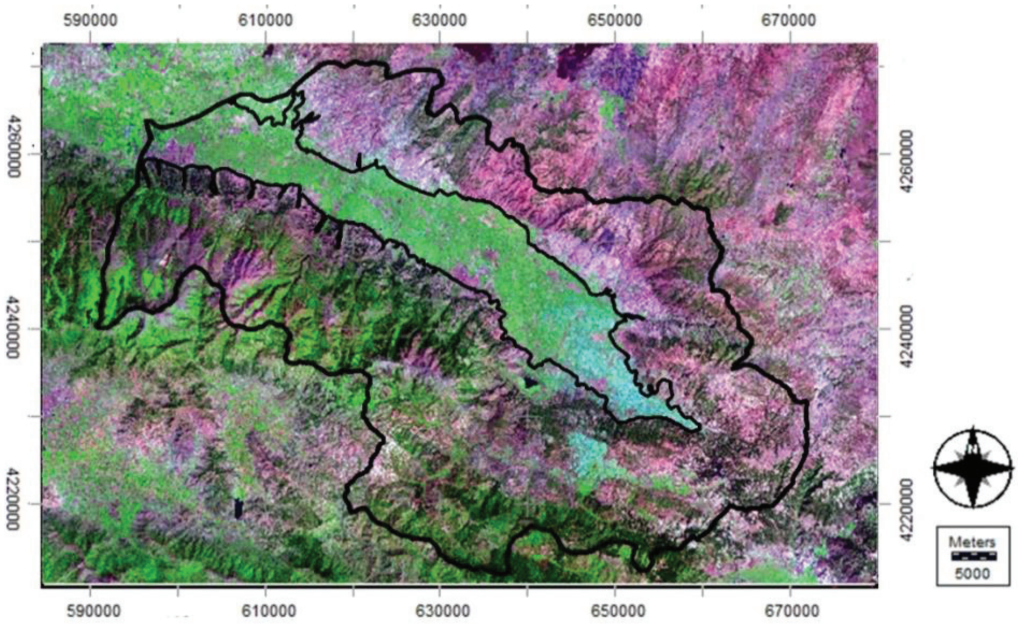


Figure 3.5. RGB = 754, a false color composite image of the study area.

In Figure 3.6, when we look at the RGB combination images of the area, it is possible to say that the vegetation is generally in the forest areas in the southwest of the basin area and in the area within the alluvial border. The most unhealthy vegetation is located in the northeast part of the area. In addition, there are urban areas within the alluvial boundary.

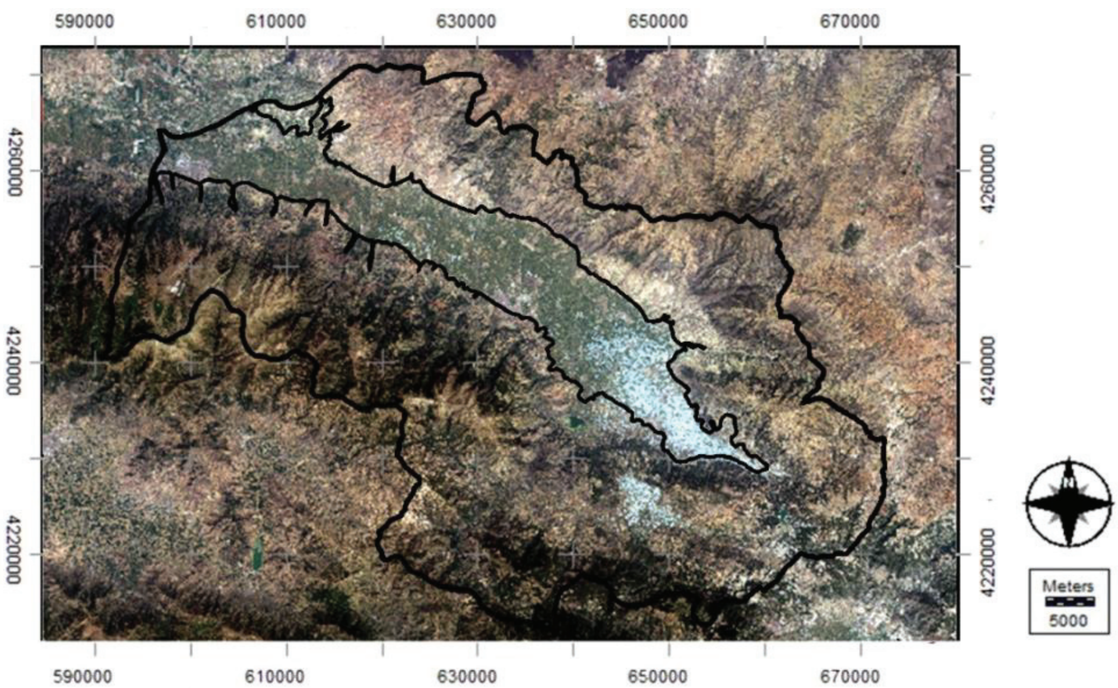


Figure 3.6. RGB = 432, the natural/true color composite image of the study area.

3.3. Data Processing

The main purpose of the study; to determine the GWP in the Alaşehir Basin with using a multi-criteria approach that focuses on a RS integrated with GIS method and test the accuracy anf efficiency of the results obtained at the end of the study. In this context; The data used, the sources of the data and the procedures applied to the data are summarized in Figure 3.6.

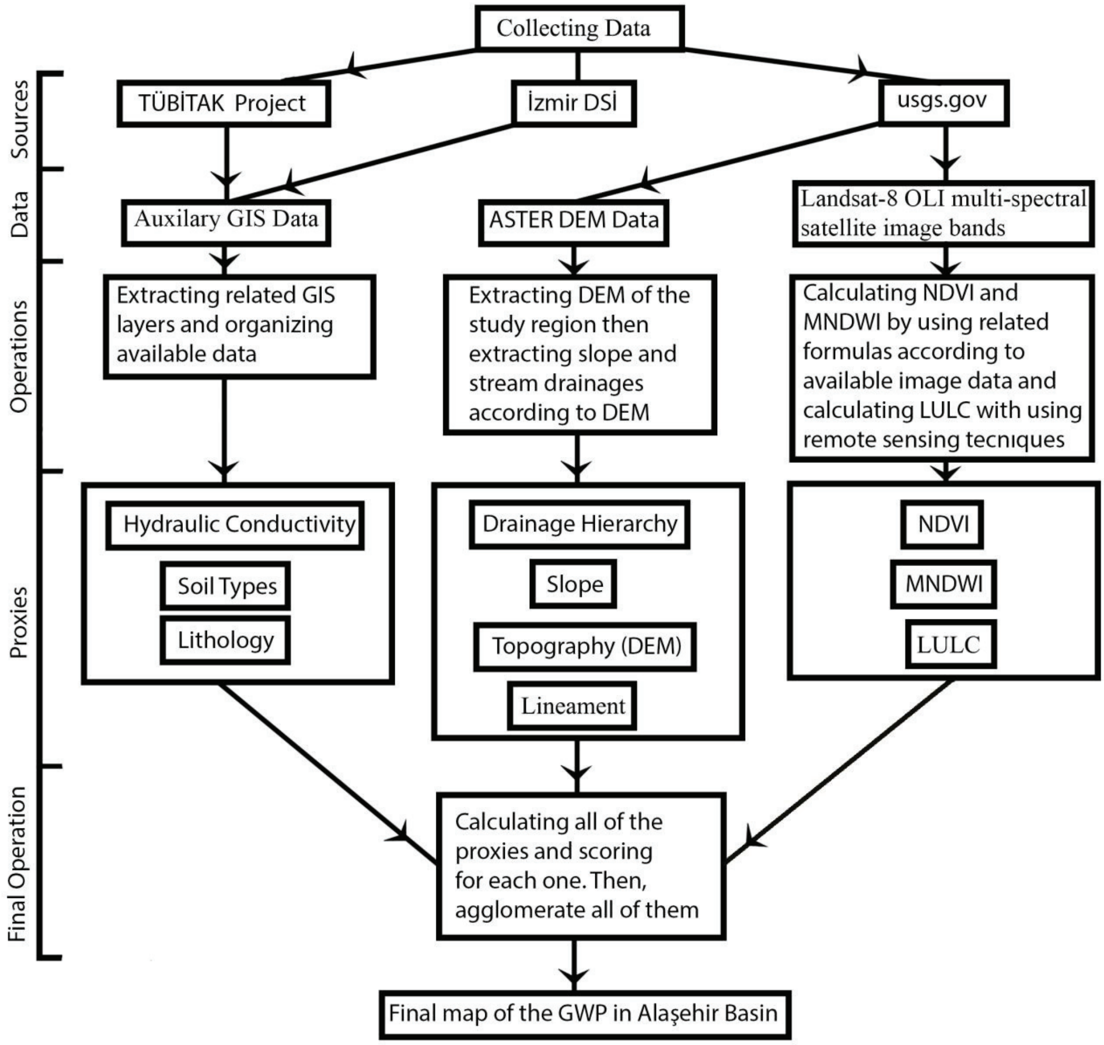


Figure 3.7. The data processing diagram

The steps of the study methodology can be listed as follows:

1) The Alaşehir Basin Border was used as the study area and the necessary data was collected from the relevant institutions, organizations and projects.

2) Research was conducted to determine the GWP by using the most appropriate proxies for the study area.
3) The data required to create the proxies were identified and collected and the results of each proxy were generated by using the collected data.
4) The GWP in the study area was mapped for each proxy and prepared legends according to each proxy.
5) The legends of each proxy were scored from 1 to 5 according to the effect on the GWP, successively. The value of 1 represents the least potential and the value of 5 represents the most potential. In this case, for each proxy, each pixel of the resultant map has a value ranging from 1 to 5 as index values of the GWP.
6) After the scoring process, the weight coefficients from 1 to 5 the GWP index values were assigned according to the significance for each proxy to the GWP as an user-defined weights. Then, each proxy was recalculated by multiplying its own weight coefficient.
7) Thematic maps of 10 proxies, which have been recalculated by the user-defined weight coefficients, were put on top of each other as weighted image overlay, and all values corresponding to each pixel were summed. Then, resultant summed image was reclassified into 5 GWP index values, again.
8) The resulting final thematic map was interpreted by comparison with land-use land-cover (LULC) and average the groundwater level data of the date 2014.

3.4. Proxies Used in the Study

In this study, it was decided to apply a multi - criteria approach by examining the samples examined in the literature review. While determining these criteria, variables that may be most related to groundwater were selected. In order to determine the significance weights of the selected variables, 2 studies with similar variables were inspired by this study. The first of these is the groundwater potential analysis of Waikar and Nilawar in India (2014). The second is the groundwater pollution potential analysis carried out by Ahmad et al. (2017) in Saudi Arabia. The method used to obtain the groundwater potential is expressed by the formula (weighted image overlay):

$$\text{GWP} = \sum_{i=1}^{n} W_i P_i = \text{W}_1\text{P}_1 + \text{W}_2\text{P}_2 + \ldots. + \text{W}_{10}\text{P}_{10}$$

Where: GWP → Groundwater potential

n =10 → The number of the proxies.

P_i → Proxies. i = 1....10

W_i → Weights of the proxies, weight coefficients range from 1 to 5. These range values are assigned as user-defined according to significance to the GWP searching the literature review.

In this section, all the 10 proxies and their weight coefficients were determined by the literature search and the method of calculation of these proxies will be explained, later on. For details of the legend values ranges of the resultant maps can be seen in the Table 4.1 which can be examined simultaneously with this section. Table 4.1 illustrates the detailed characteristics of all the 10 proxies and their classification class-intervals.

3.4.1 Normalized Difference Vegetation Index (NDVI) – Proxy 1

Vegetation in the study area can give an idea about the richness of groundwater potential. If the amount of the groundwater in the study area is high, this will have a positive effect on the vegetation that continues its development on the soil in that area. It is possible to observe vegetation dynamics by using remote sensing methods. One of the most common RS methods used for this purpose is NDVI (Normalized Difference Vegetation Index) (Figure 3.8).

- General NDVI formula: NDVI = (NIR - RED) / (NIR + RED) (Huajie et al., 2016).
- For Landsat-8 OLI: NDVI image map = (Band 5 - Band 4) / (Band 5 + Band 4)
- Calculation method: Bands obtained from Landsat-8 OLI multi-spectral satellite images were operationalized according to the formula in Idris Selva system which is software of RS integrated with GIS.

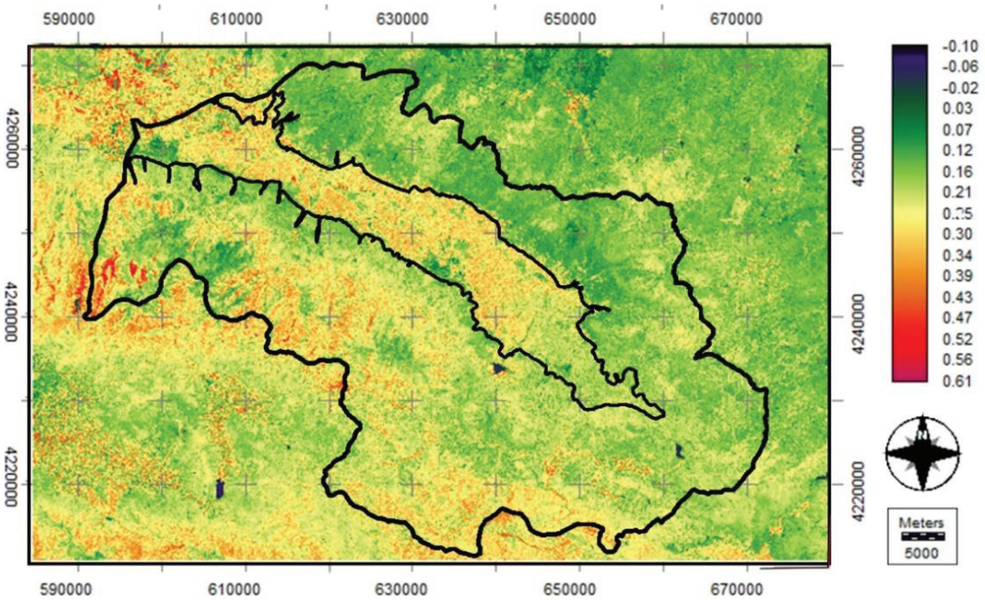
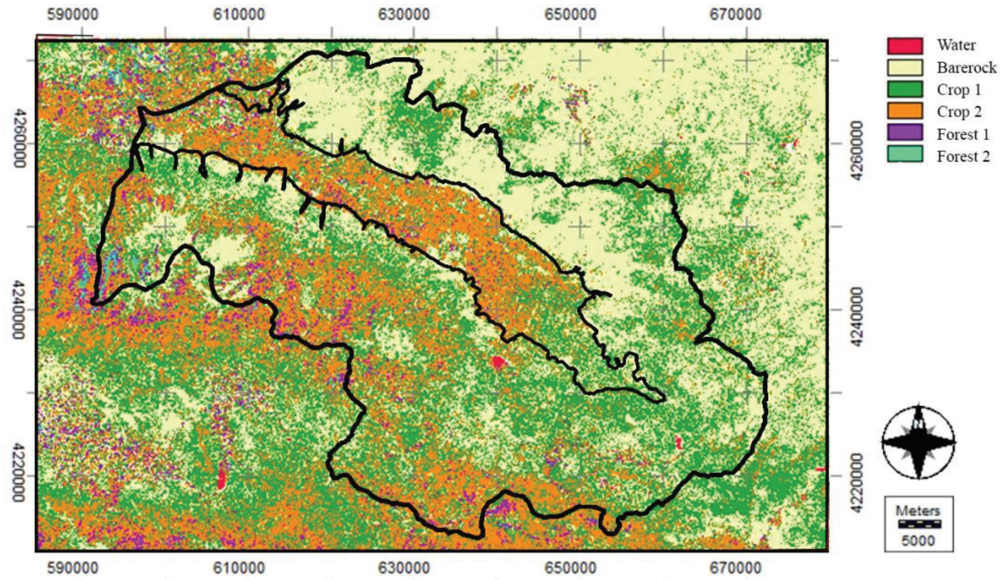


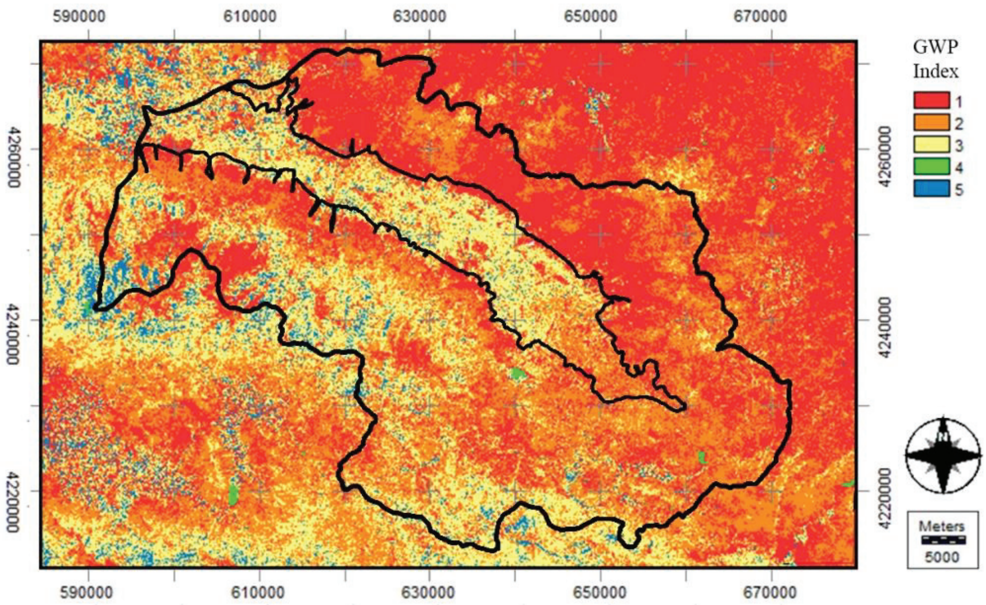
Figure 3.8. NDVI thematic map.

Basically, NDVI is dependent on the reflectance of the infrared rays of the vegetation in a region. Green leaves, which are healthy and more dense, reflect Near Infra Red (NIR) Band energy and absorb the red light (RED Band) by means of the chlorophyll it contains in order to prevent the plant from overheating. (Fu and Burgher, 2014). In an unhealthy vegetation, this will be the opposite. In an area, when the NDVI formula is applied, higher values will express a healthier vegetation. NDVI values vary ranges between -1 to +1 and NDV1 (Figure 3.8). Negative values can be identified with the water surface. (M. Jin et al., 2010).

As the NDVI value decreases, the groundwater potential decreases. The highest NDVI values were determined as 5 point of the GWP index value and the lowest NDVI values were determined as 1 point of the GWP index value . However, as the negative values indicate lakes and surface water deposits, negative values were assigned to 4 points as exceptional. The weight coefficient of the NDVI proxy was assigned as 2 (W_1=2) according to significance to the GWP (Figures 3.9 and 3.10).



Figüre 3.9. NDVI thematic map with the defined legend.



Figüre 3.10. Reclassified NDVI thematic map with the index values of the GWP.

3.4.2 Modified Normalized Difference Water Index (MNDWI)- Proxy 2

MNDWI (Modified Normalized Difference Water Index) (Figure 3.10) is a remote sensing method like NDVI. The purpose of this index is to distinguish water areas and build up areas. MNDWI is a modified version of NDWI (Normalized Differnce Water Index) developed by Mc Feeters (1996) for the Middle Infra Red Band (MIR) (Xu, 2006).

The MIR band used in the MNDWI calculation provides a more pronounced contrast than the NIR band used in the NDWI calculation. The positive values will show the water areas and the most negative values will show the build up areas. Soil and vegetation will take the remaining values (Xu, 2006).

- General MNDWI formula: MNDWI = (GREEN - SWIR) / (GREEN + SWIR) (Ko et al., 2015).
- For Landsat-8 OLI: MNDWI image map = (Band 3 - Band 6) / (Band 3 + Band 6)
- Calculation method: Bands obtained from Landsat-8 OLI multi-spectral satellite images were operationalized according to the formula in Idris Selva software.
- The highest values represent the maximum water potential and the lowest values indicate the least water potential. For this reason, the lowest-rated pixels were scored 1 point as the GWP index value and the highest-rated pixels were scored as 5 points. The weight coefficient of the MNDWI proxy was assigned as 2 (W_2=2) according to significance to the GWP (Figures 3.11 and 3.12).

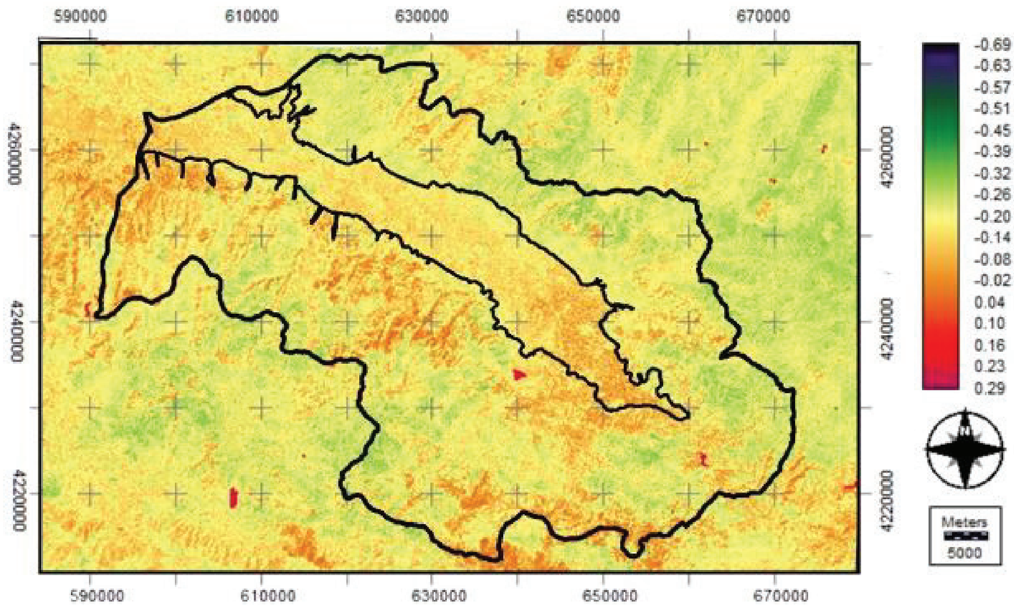


Figure 3.11. MNDWI thematic map.

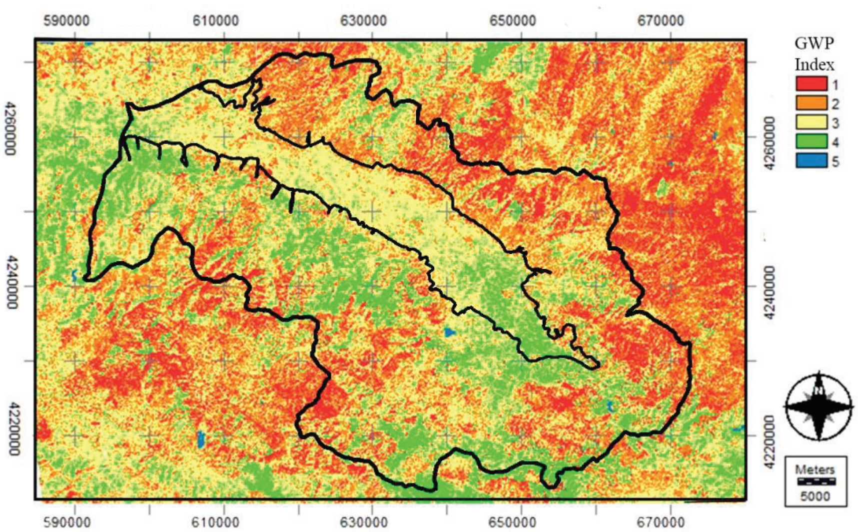
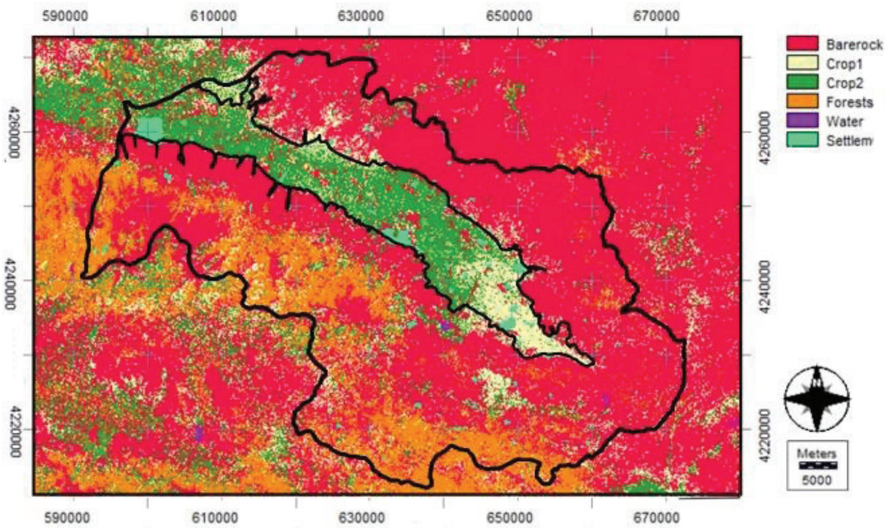


Figure 3.12. MNDWI classification map with the index values of the GWP.

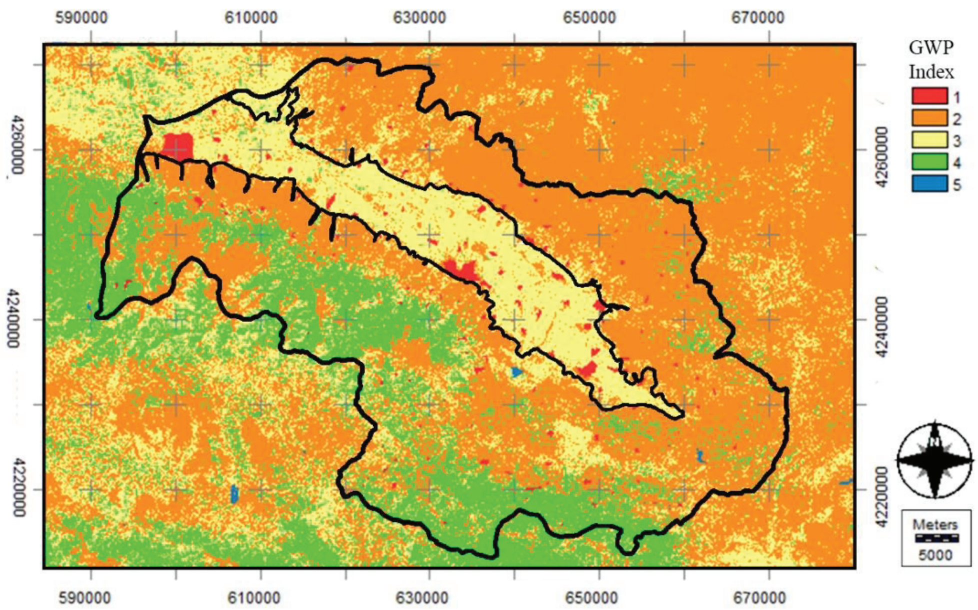
3.4.3 Land-Use Land-Cover (LCLU) – Proxy 3

Land-use land-cover (LULC) data (Figures 3.13 and 3.14) gives information about the use of general landfill. Uses such as the existing settlements, forest and agricultural lands in an area affect the water permeability, soil and surface texture in the area, so land use provides information about the ground water potential (Mandal et al. 2016).

Calculation method: The data obtained from Landsat-8 OLI multi-spectral satellite imagery was classified using the maxike tool in Idrisi Selva software as maximum likelihood supervised classification method (Idrisi Selva, 2018).



Figüre 3.13. Land-use land-cover (LULC) thematic map.



Figüre 3.14. Land-use land-cover (LULC) classification map with index values of the GWP.

The areas with the highest and qualified water potential are designated as forest and water and the highest scores are assigned to these areas. The lowest scores were assigned to settlements and barerock areas. The weight coefficient of the LCLU proxy was assigned as 2 (W_3=2) according to significance to the GWP.

3.4.4 Lineament – Proxy 4

Lineaments (Figures 3.15, 3.16, and 3.17) are seen in rocky regions on the earth. They may occur naturally, such as fault lines, drainage networks, and main stream channels. In general, lineaments are caused by increased permeability and porosity in areas exposed to localized weather conditions. Lineaments, due to their high porosity and permeability, are suitable flow areas for groundwaters. (Ndatuwong and Yadav, 2014)

- Calculation method: the shaded Aster DEM and satellite image data were used to determine the lineaments (Figure 3.14).
- The proximity to lineaments refers to an increase in the groundwater potential. For this reason, the GWP index value 5 was assigned to the regions closest to lineaments and 1 point was assigned to the farthest regions. The weight coefficient of the lineament proxy was assigned as 3 (W_4=3) according to significance to the GWP.

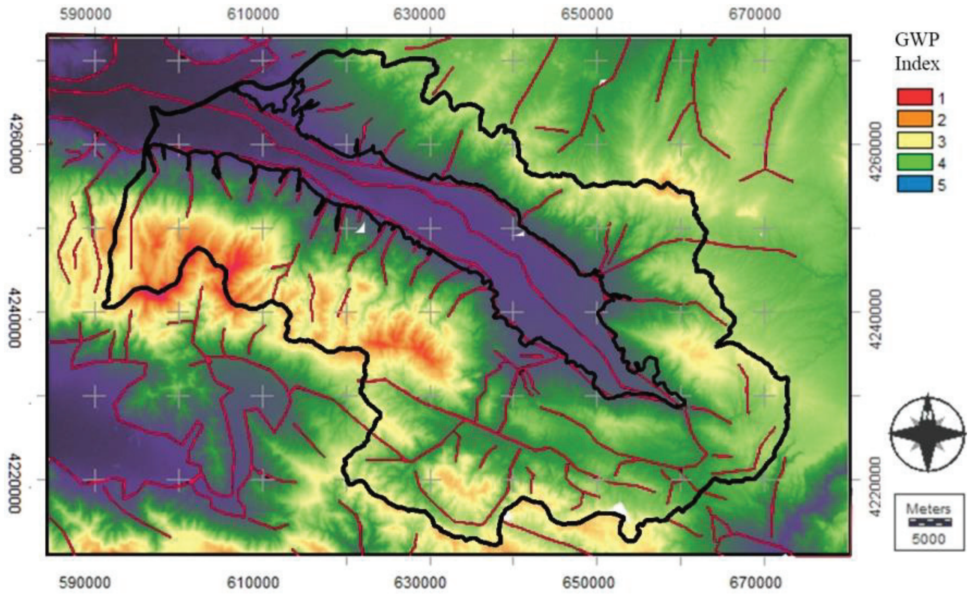


Figure 3.15. Lineament thematic map.

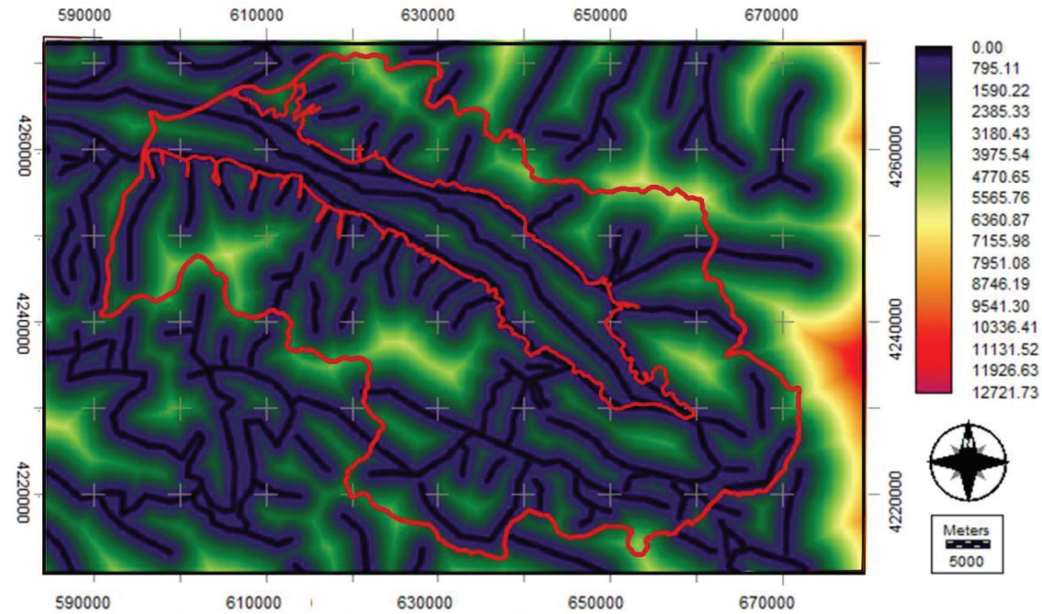


Figure 3.16. Distance from lineaments.

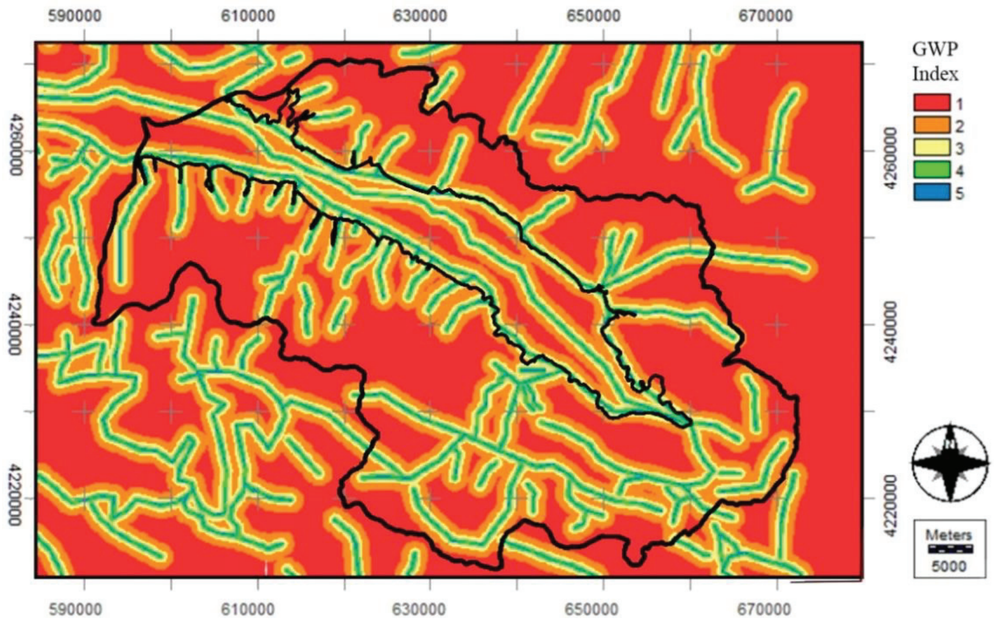


Figure 3.17. Lineament classification map with index values of the GWP.

3.4.5 Topography – Proxy 5

The DEM (Figure 3.17) indicates the topography, which controls the surface flow direction and humidity of a region (Ardakani and Ekhtesasi, 2016). When it rains, the water flows from high elevation to lower elevation. Therefore, water tends to accumulate at low heights. (Ghodratabadi and Feizi, 2015)

- Calculation method: the Aster DEM data was classified into the 5 GWP index values by considering the elevations that show the topographic characteristics (Figures 3.18 and 3.19).
- While the topographic map was scored for the potential of groundwater, the GWP index value 5 was assigned to the lowest elevations (heights) and the 1 point was assigned to the highest elevations. The weight coefficient of the topography proxy was assigned as minimum value, 1 (W_5=1) according to significance to the GWP.

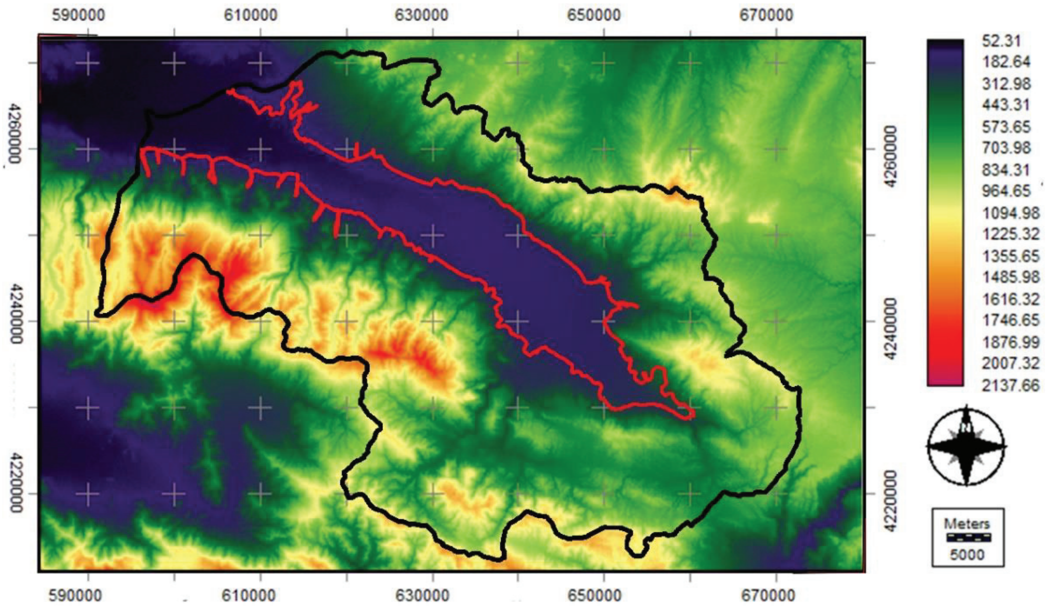


Figure 3.18. Topography (DEM) thematic map.

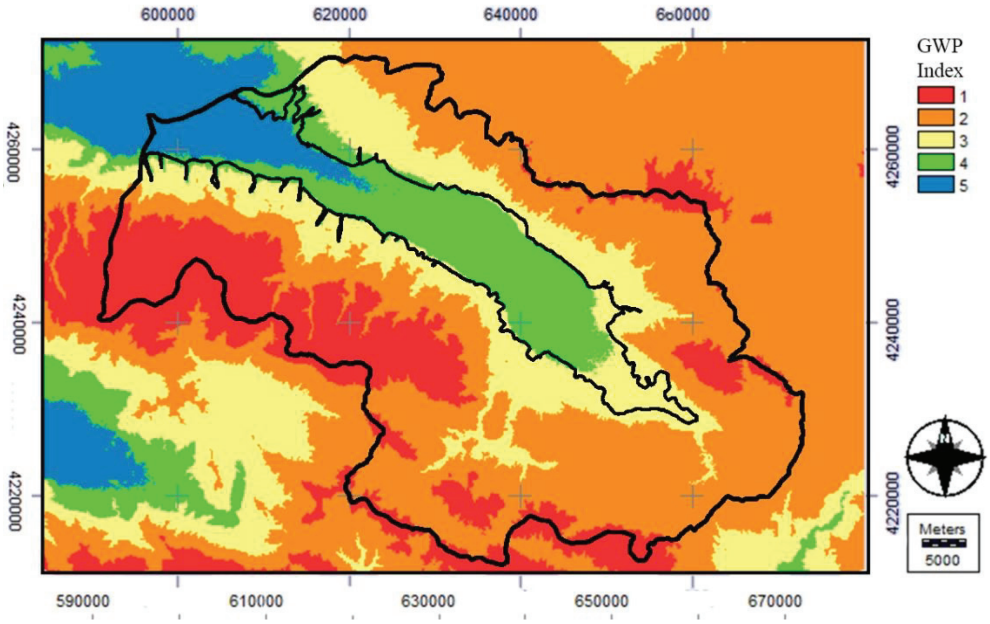


Figure 3.19. Topography (DEM) classification map with index values of the GWP.

3.4.6. Slope – Proxy 6

The slope degree (Figure 3.20) has effects on the flow of water and the discharge of groundwater. It causes the soil surface to be too inclined and the water to flow without being absorbed by the soil. Thus, the surface water in the sloping area is not stored too much. Therefore, groundwater potential is expected to be high in flat and pit areas (Huajie et al., 2016).

- Calculation method: the Aster DEM data was used for finding slope degrees and their analysis for classification (Figures 3.20 and 3.21).
- The GWP decreases as the slope increases. For this reason, the GWP index value 5 was assigned to the lowest slope degree values and 1 point was assigned to the highest slope degree values. The weight coefficient of the slope proxy was assigned as 4 (W_6=4) according to significance to the GWP.

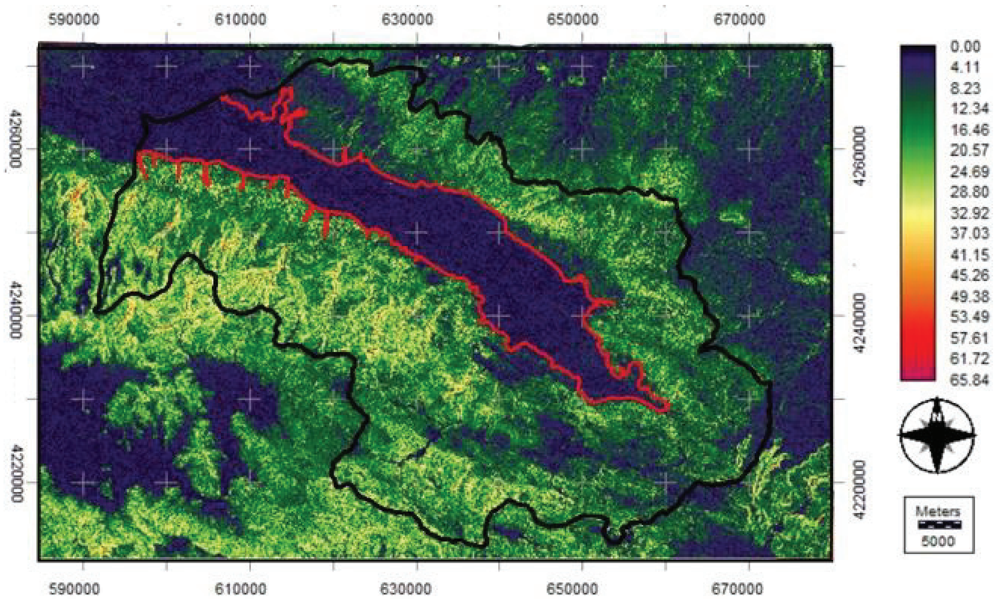


Figure 3.20. Slope thematic map.

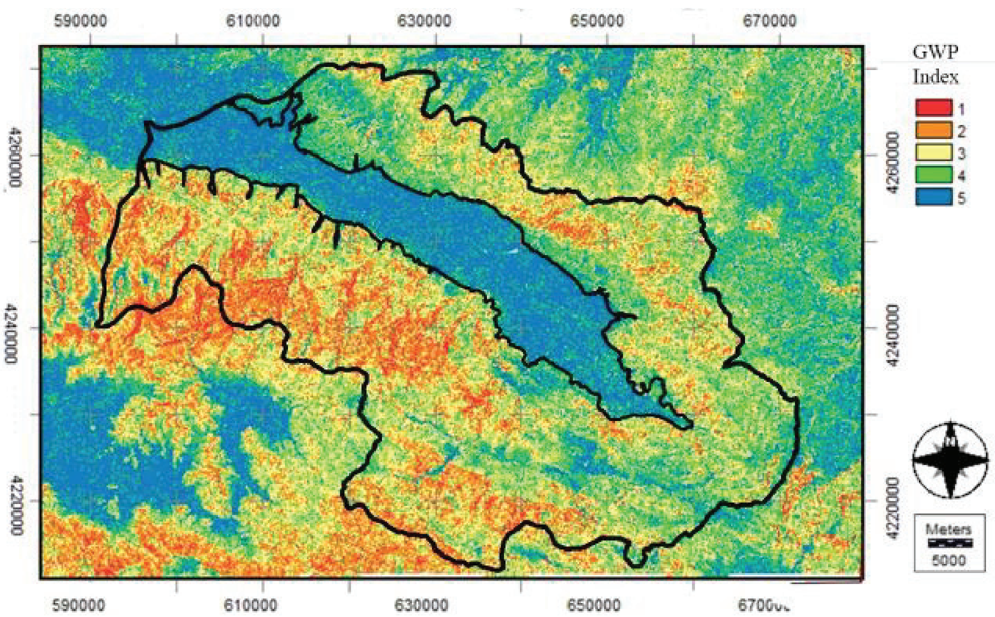


Figure 3.21. Slope classification map with index values of the GWP.

3.4.7. Drainage – Proxy 7

Drainage networks (Figures 3.22, 3.23 and 3.24) help identify the watershed and give an idea about the surface properties and determine the direction of the water flow. The type and density of the drainage gives information about the permeability of the soil. Thick drainage tissue is formed in porous and permeable rock formations and thinner drainage tissues are formed in less permeable rocks (Waikar and Nilawar, 2014).

- Calculation method: the Aster DEM data were used to extract the drainages using by the Hydrology Analysis Tool in ArcGIS software.
- The Gediz River and its surroundings have a GWP index value of 5, which is the highest value in the scoring because it is 1st degree drainage order hierarchy. After that, the Alaşehir Creek and its surroundings come with 4 points. The score decreases as the stream order degree increases. The remaining areas have a value of 1. The weight coefficient of the drainage proxy was assigned as 4 (W_7=4) according to significance to the GWP. Also, note that drainage lines were buffered with 200 m before the process.

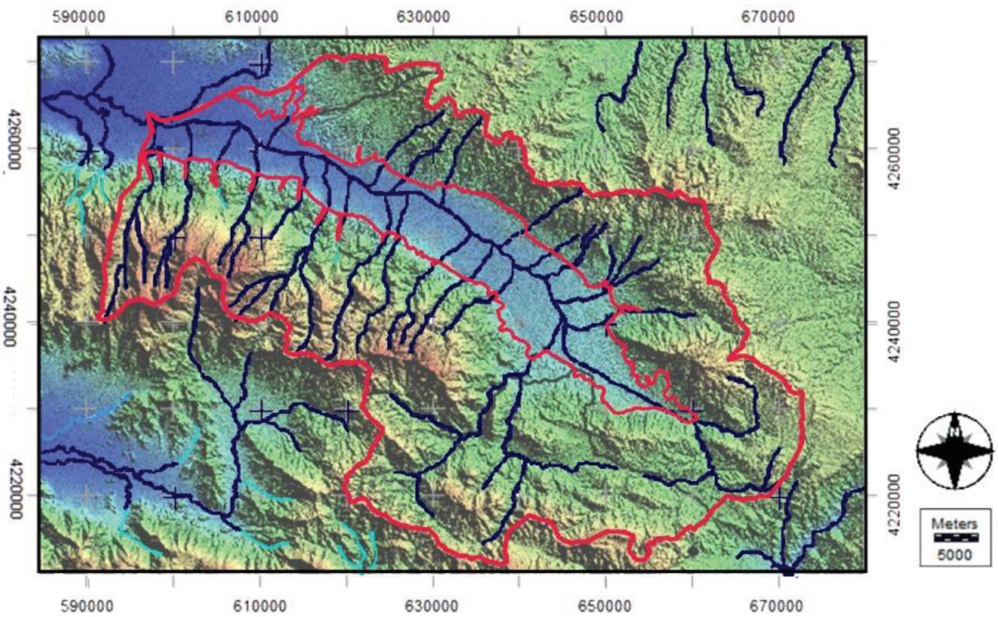


Figure 3.22. Drainage thematic map

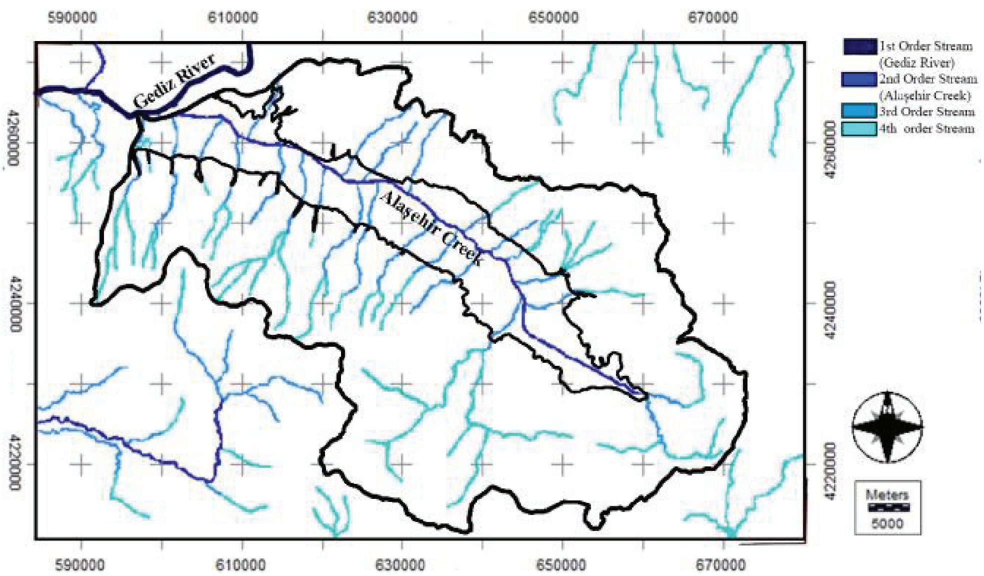


Figure 3.23. Drainage thematic map in a hierarchical order.

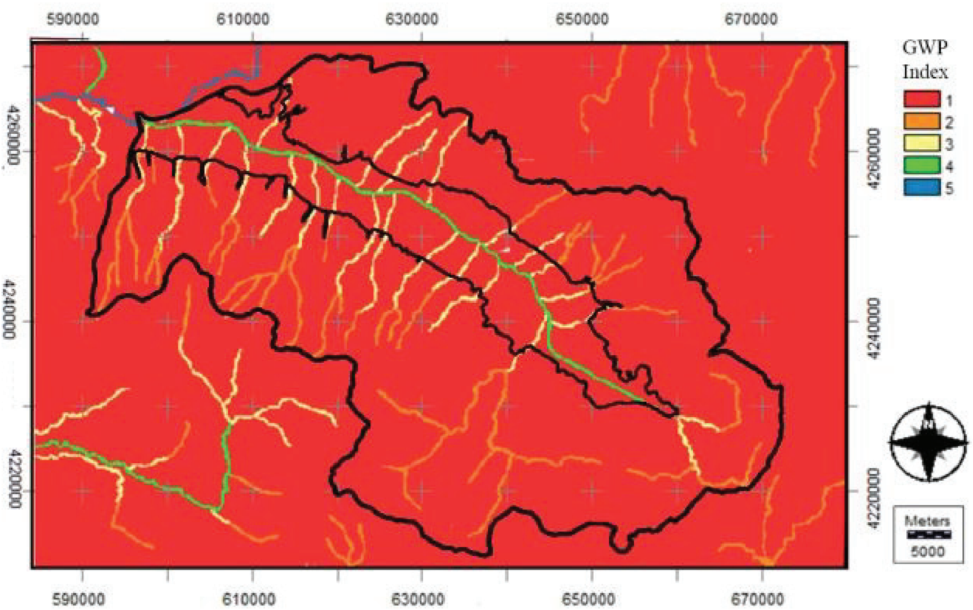


Figure 3.24. Drainage classification map with index values of the GWP.

3.4.8. Lithology - Proxy 8

Lithology (Figures 3.25 and 3.26) describes the physical properties of the surface such as texture, color and grain size. Physical properties will affect the ability to infiltration, the amount and quality of the groundwater. Lithology, in a sense, defines the porous permeability of the geological formation (Aneesh and Deka, 2015). For example, while granular structures show more permeable properties, structures such as rock and clay soils will show less permeable property.

- Calculation method: It was obtained by classifying GIS layers related to lithology (source of data: the TUBITAK project no: 115Y065).
- Because of rocks have less permeability, the GWP index value 1 was assigned to rocks with paleosic and neogene features. 2 points were assigned to cracked rock. Areas with lakes and puddles were assigned to 5 points and 4 points were assigned to granual units. The karstic rocks were assigned to 3 points. The weight coefficient of the lithology proxy was assigned as maximum value, 5 (W_8=5) according to significance to the GWP.

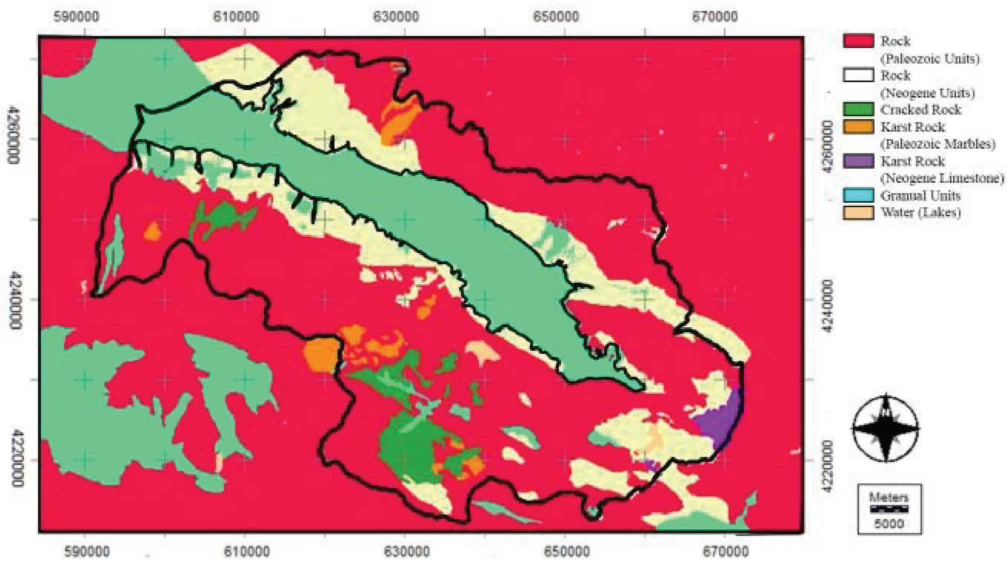


Figure 3.25. Lithology thematic map

Source: TUBİTAK project no:115Y065 (2018).

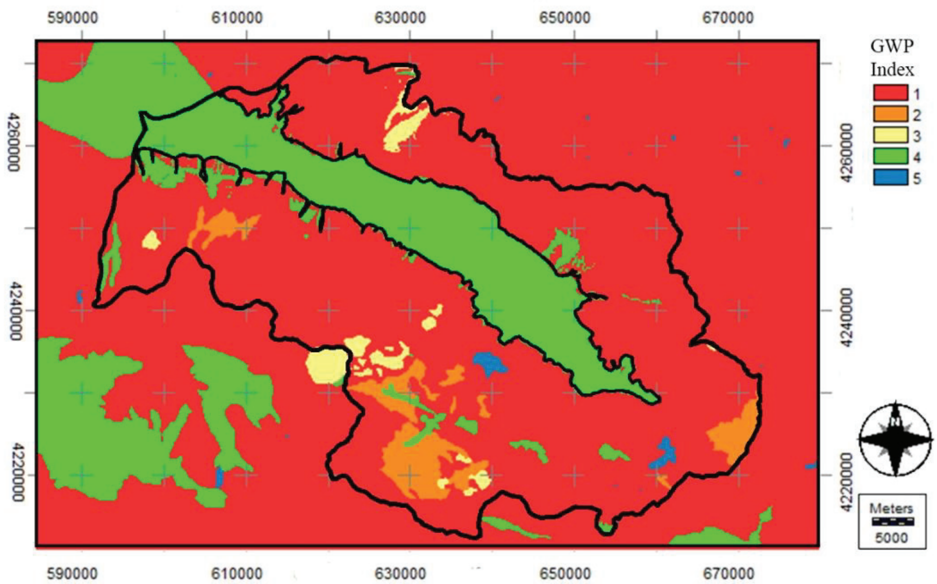


Figure 3.26. Lithology classification map with index values of the GWP.

3.4.9. Hydraulic Conductivity – Proxy 9

The hydraulic conductivity (Figures 3.27 and 3.28) is the proportionality constant that defines the liquid flow in an environment dependent on permeability and the physical properties of the aquifer. Hydraulic conductivity determines the movement speed of groundwater in the region and the water conductivity of the aquifer material (Ahmadet al., 2017). Therefore, the high hydraulic conductivity value will mean more groundwater potential in the region. particular, the high hydraulic conductivity value lie in the border of the alluvial soils, which can be called as the aquifer border.

- Calculation method: It was obtained by classifying GIS layers related to hydraulic conductivity (source of data: the TUBITAK Project No: 115Y065).
- The highest hydraulic conductivity values were assigned to the GWP index value 5 and the smallest values were assigned to 1 point. The weight coefficient of the hydraulic conductivity proxy was assigned as 4 (W_9=4) according to significance to the GWP .

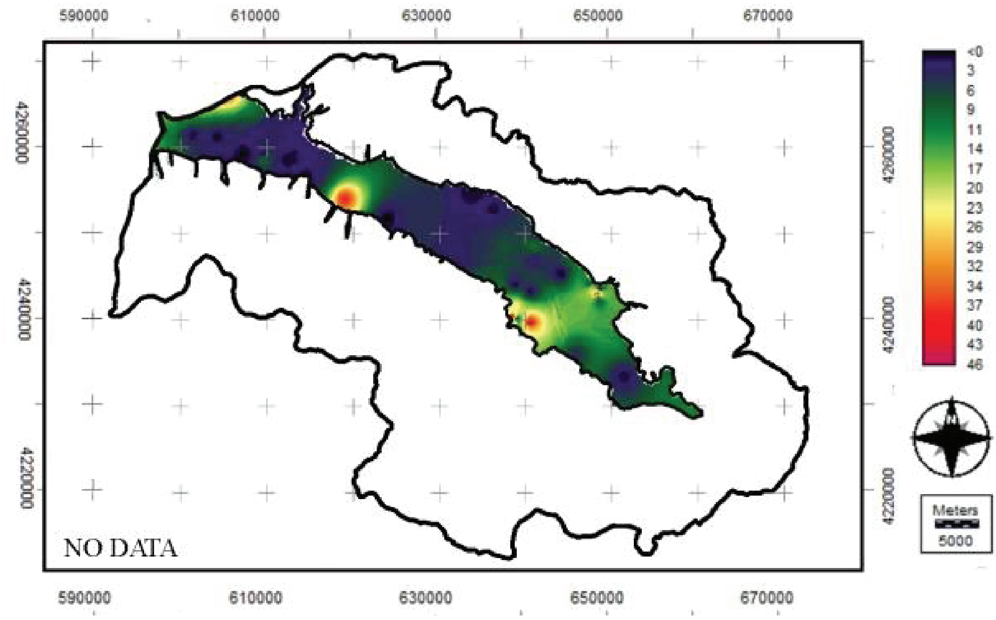


Figure 3.27. Hydraulic thematic map
Source: TUBITAK project no:115Y065 (2018)

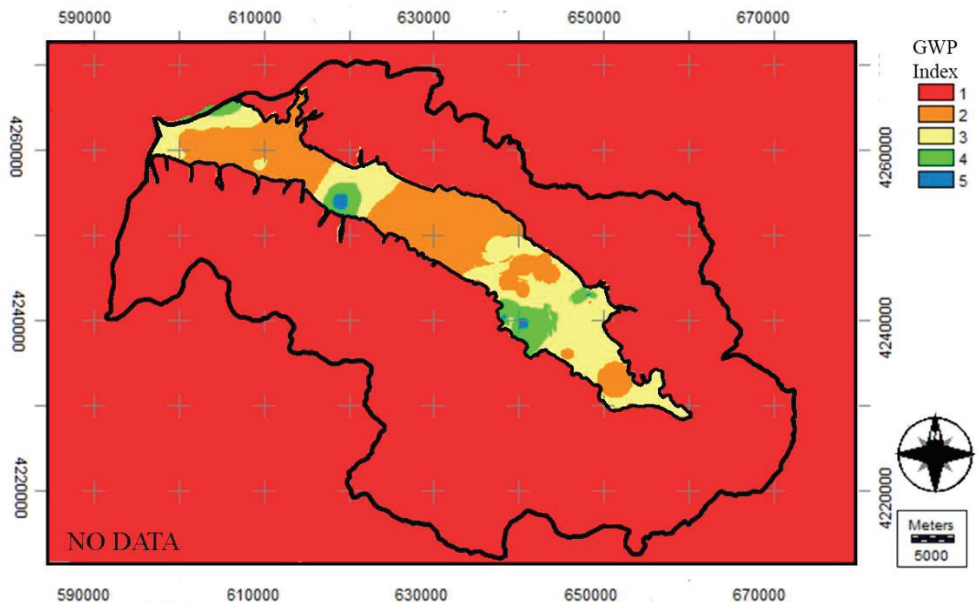


Figure 3.28. Hydraulic classification map with index values of the GWP.

3.4.10 Soil types – Proxy 10

Different types of soils (Figures 3.29 and 3.30) have different permeability, structure and drainage. This affects groundwater levels. Soil classification in this section is based on land-use capability classification system.

The first class soils have less slope than 1% and have good drainage, permeability and water holding capacity. The second class soils are slightly more inclined than the first class soils. The third class soils have a moderate slope but the water holding capacity is lower than the first and second class soils. The fourth grade soils are highly inclined and have poor drainage. The fifth class soils are soils that have a slope of less than 1% and can be found in forested areas. The sixth grade soils are too sloped, too wet or too dry. Seventh grade soils are more sloping, dry or swampy soils. Eighth grade soils serve as a catchment basin.

- Calculation method: It was obtained by classification of the GIS layers related to soil types (State Water Works – DSI, 2018)
- The first, fifth and eighth class soils have the GWP index value 5, the second and the third class soils have 4 points, the fourth and sixth class soils have 3 points, the second class soils have 2 points and the remaining areas have 1 points. The weight coefficient of the proxy of soil types was assigned as 2 (W_{10}=2) according to significance to the GWP

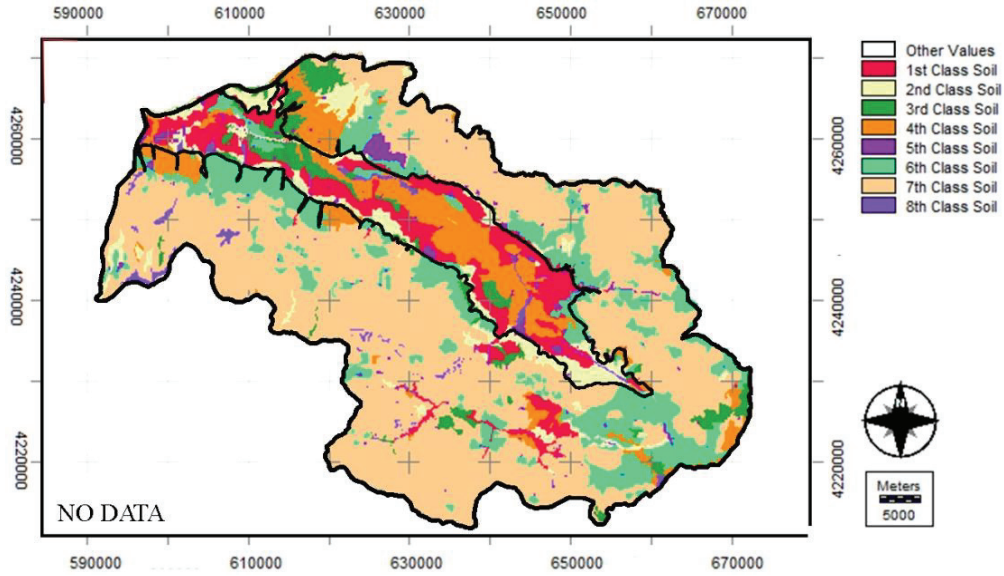


Figure 3.29. Soil types thematic map

Source: State Water Works – DSI (2018).

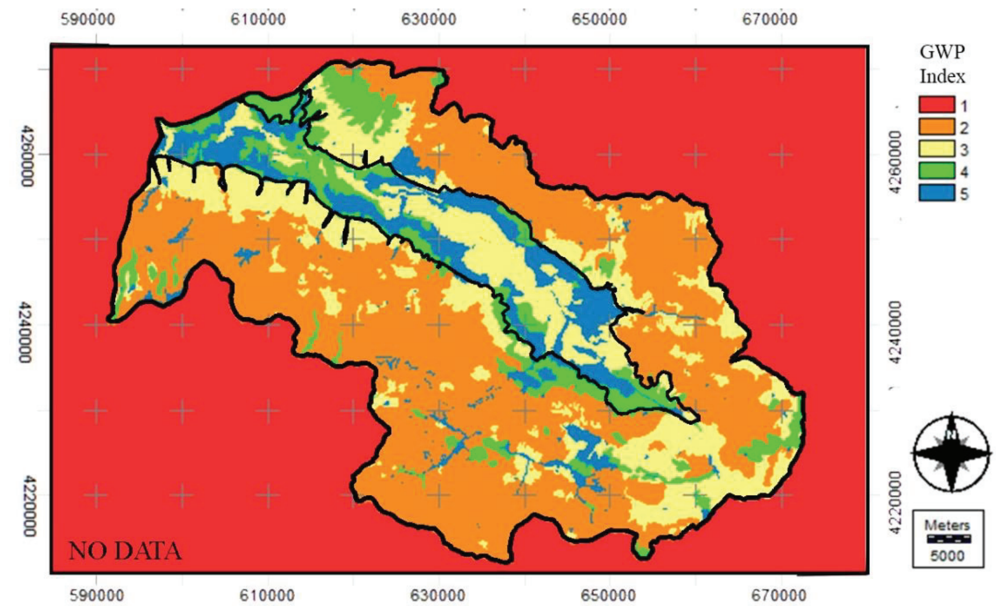


Figure 3.30. Soil types classification map with index values of the GWP.

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CHAPTER 4

RESULTS AND DICUSSION

In this section, the final output image of the spatial operations for finding the GWP is interpreted. Comparing the final image with the available existing groundwater level data (2014), the accuracy and efficiency of the method is inferred.

The GWP map was generated by using all the 10 proxies (parameters, criteria) and the weights of all the proxies. The computation of the GWP was performed as below. Where the weights of the proxies are user-defined ranged form 1 to 5 according to significance to the GWP. And, they are placed in the formula (weighted image overlay) as follows:

$GWP = \sum_{i=1}^{n} W_i P_i = 2*P_{NDVI} + 2*P_{MNDWI} + 2*P_{LULC} + 3*P_{Lineament} + 2*P_{Topography} + 4*P_{Slope} + 3*P_{Drainage} + 5*P_{Lithology} + 4*P_{Hydraulic\ Conductivity} + 2*P_{Soil\ Types}$

Where: GWP → Groundwater potential

n =10 → The number of the proxies

P_i → Proxies,

W_i → Weights of proxies, which ranges from 1 to 5

The GWP map was generated and visualized. All the 10 thematic maps of the proxies have the same legend indicating the GWP index values from the lowest potential index value 1 to the highest potential index value 5, as of Figure 4.1 below:

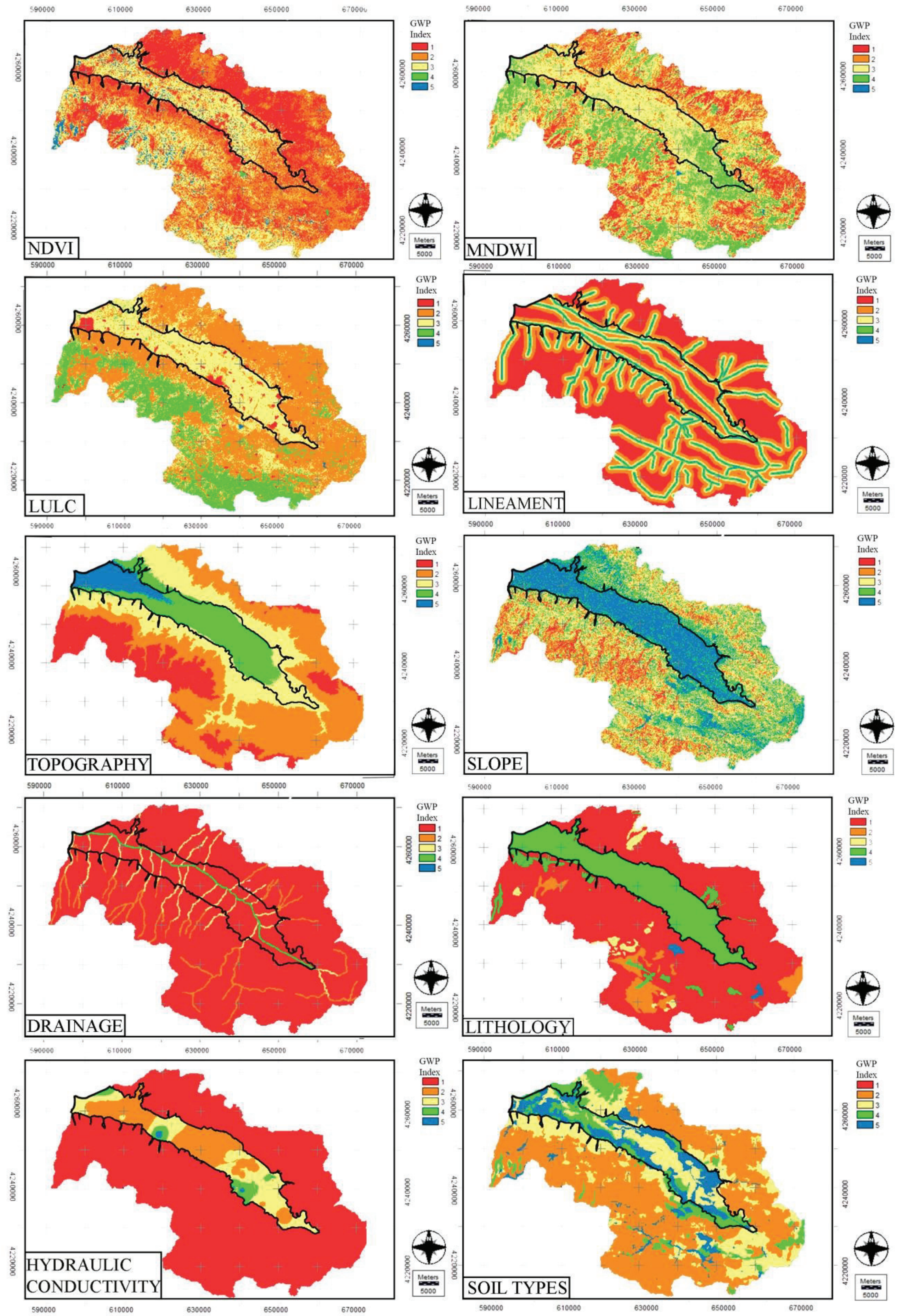

Figure 4.1. Classification maps of all the 10 proxies with sub-basin border and index values of the groundwater potential (GWP).

4.1 Comparison of the final GWP Map with the LULC Thematic Map

In the resultant final GWP map (Figures 4.2 and 4.3) was obtained by summation of the image maps of all the 10 proxies weighted, where the pixel values range from 30 to 121 (Figure 4.2). The pixels with a value of 30 indicate areas with the lowest groundwater potential, and those with a value of 121 indicate areas with the highest groundwater potential. Therefore, we reclassified this final image into 5-indexed GWP values as categories of (1) very low, (2) low, (3) moderate, (4) high, and (5) very high (Figure 4.3).

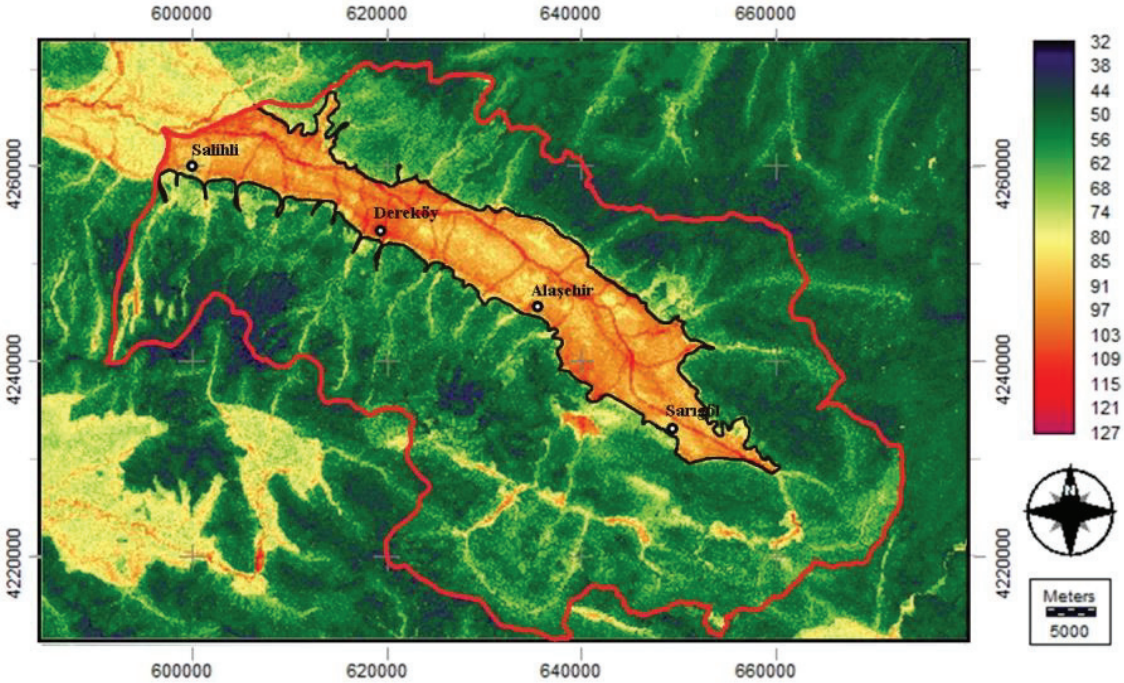

Figure 4.2. Groundwater potential (GWP) thematic map.

When we interpreting the final GWP map, we may say that the areas with the highest GWP according to the final GWP image map are the drainage areas within the alluvial boundary, namely the aquifer and the Alaşehir Creek surroundings. In the majority of areas within the alluvial boundary, high or highest values are observed. For comparison of the GWP map with the land use classification image map (Figure 4.4), when interpreting the output images of the study, the land use classification image map of the study area is quite comprehensible and consistant with previous information data.

Currently, the settlements in the area have been established within the alluvial boundary, namely the aquifer where the GWP is high. These regions can be listed as northeast of Salihli, southeast of Alaşehir and around Dereköy. Generally, agricultural lands are concentrated in the areas within the alluvial border. It is seen that the most productive agricultural lands are located near the settlements of Salihli and Alaşehir. These areas have the highest groundwater potential. Although the area to the northwest of the Salihli district is similar to the other areas within the alluvial border, the potential for groundwater is low. This can be explained by the fact that the available data does not cover this area when taking the hydraulic conductivity parameter into account.

In addition, in the south of the area, there is high groundwater potential in the region outside the Alasehir Basin. In this area, just like areas within the aluvial border, the ground consists of granule units. Besides, elevation and slope are suitable for groundwater.

In the south of the alluvial boundary, it is observed that the forested areas are dense. Although the forest areas are dense, the groundwater potential in this section is lower than the area within the alluvial boundary. This is because the slope and elevation in this region is higher. Besides, it is possible to mention the effect of soil types and lithology in this area.

Areas with the lowest groundwater potential are marked as barerock in the land-use map. These areas are poor in vegetation. In addition, the soil is weak in terms of permeability, and surface texture are not very valuable to accumulate groundwater.

The classification process applied for all parameters was also made for the final map. The pixel values specified in the thematic map are divided into 5 groups and a groundwater potential classification map is created (Figure 4.3). The value ranges of the legend are indicated in Table 4.1.

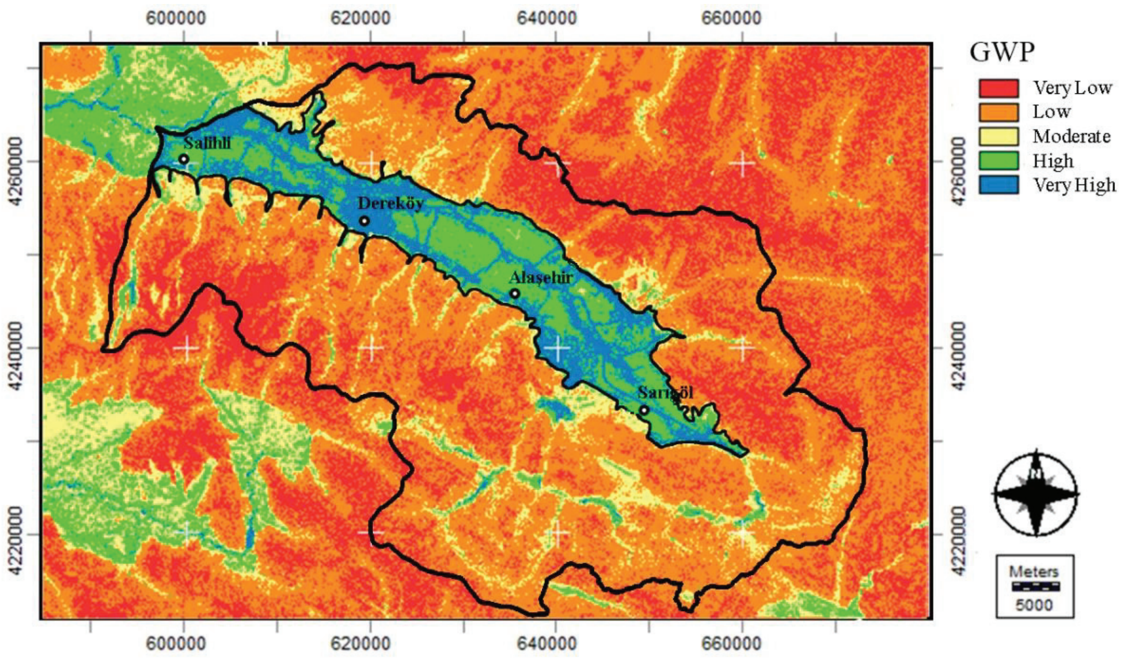

Figure 4.3. GWP classification map with index values of the GWP.

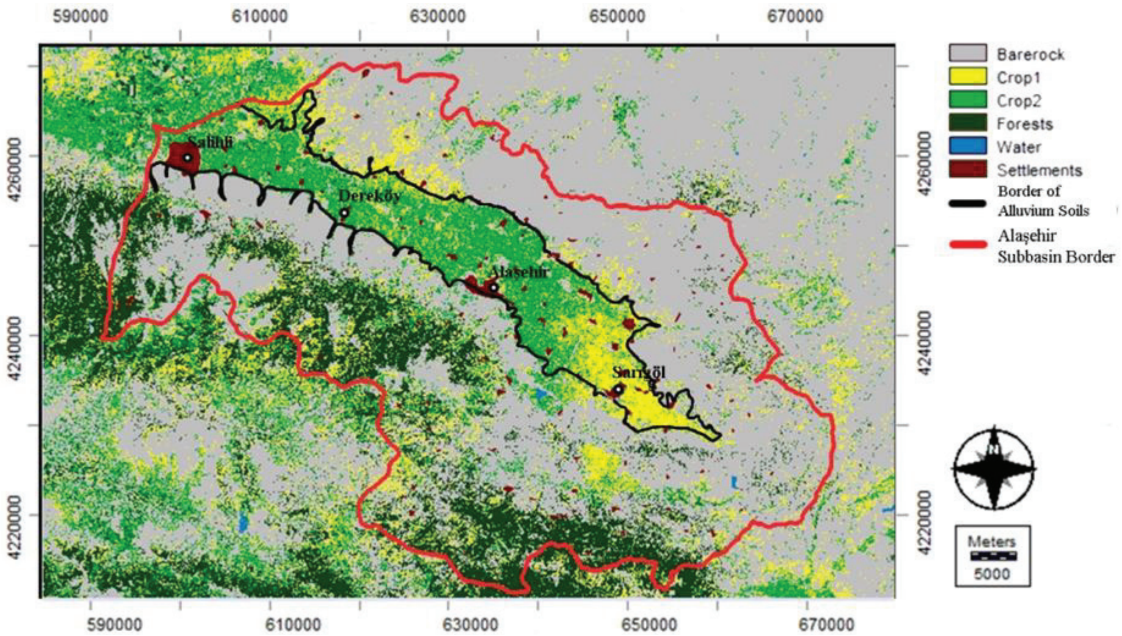

Figure 4.4. Land-use land-cover (LULC) thematic map.

There are Salihli, Alaşehir and Dereköy districts within the alluvial border where the under groundwater potential is highest. These settlements are urban areas that have an impact on water resources. In particular, the 115 hectare organized industrial zone located in Salihli district is an important element of the potential for consuming and polluting water (Figure 4.5). Besides, the villages, agricultural lands and forest areas in the region are directly related to the water condition. Degradation of the quality of the groundwater presence and excessive consumption of water under the pressure of settlement and industry in the region will also reduce the quality and quantity of agricultural products. In addition, as a result of the plans and applications made without considering the presence of groundwater, damage will occur in buildings and infrastructure units, which will increase the cost. In this case, the prerequisite for ensuring the sustainability of economic development, agricultural production and efficient use of water in the region that has high GWP in the Gediz Basin is to carefully evaluate the existing GWP.

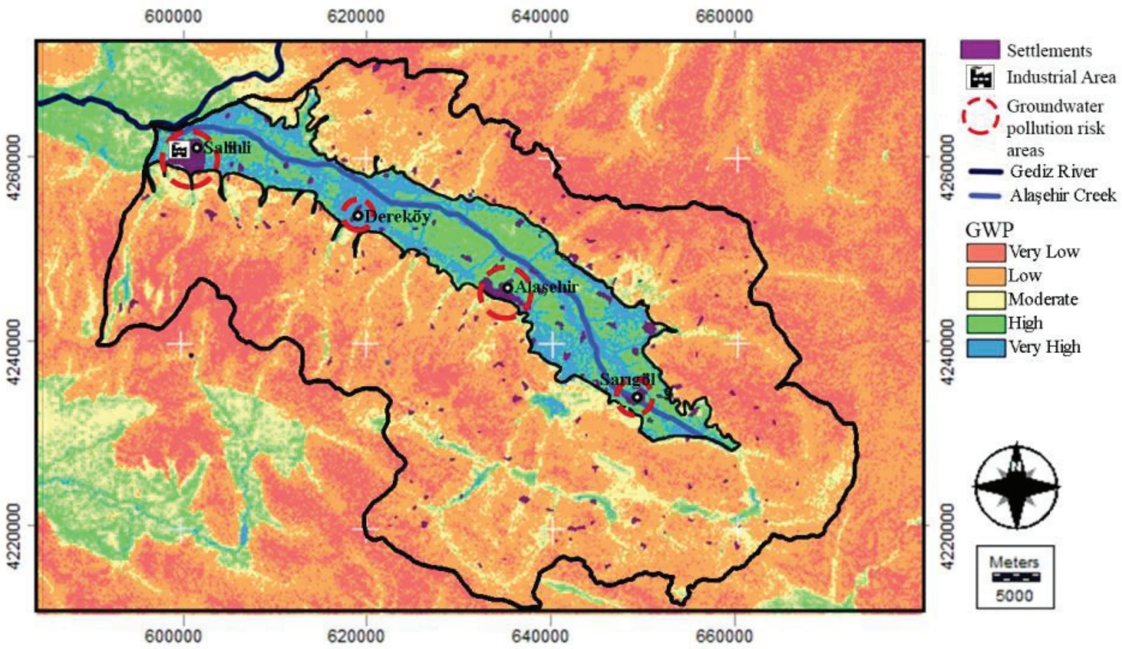

Figure 4.5. Groundwater pollution risk map.

4.2 Comparison of the final GWP Map with the Groundwater Level Map (2014) of the Study Area

In order to determine the accuracy of the work done so far, the stage of comparison with the available data has an important role. In this section, the final output of this study (Figure 4.6) and the average groundwater level map (2014) (Figure 4.5) obtained from the TUBITAK project, project no: 115Y065 are compared and interpreted.

When the final output of the study is compared to the average under groundwater level thematic Map taken from TUBITAK 115Y065 project, it is possible to talk about a similarity between the two maps. The areas with the highest groundwater potential are the areas that remain within the alluvial boundary on both maps. The potential of groundwater has increased especially in the vicinity of Dereköy and northeast of Salihli, where the Alaşehir Creek and Gediz River meet. In the general view, the groundwater potential seems to be decreasing as it moves away from the alluvial border. But it is possible to talk about a relatively high groundwater potential, which can be seen in both images in the southeastern part of the basin.

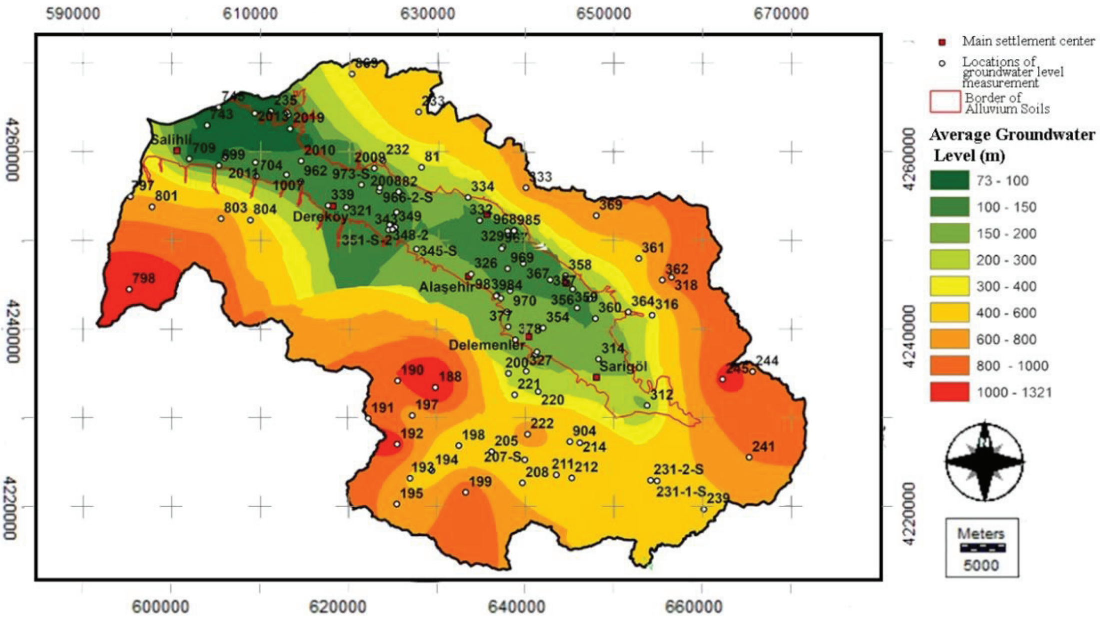

Figure 4.6. Average groundwater level thematic map

Source: TUBITAK project no: 115Y065 (2014).

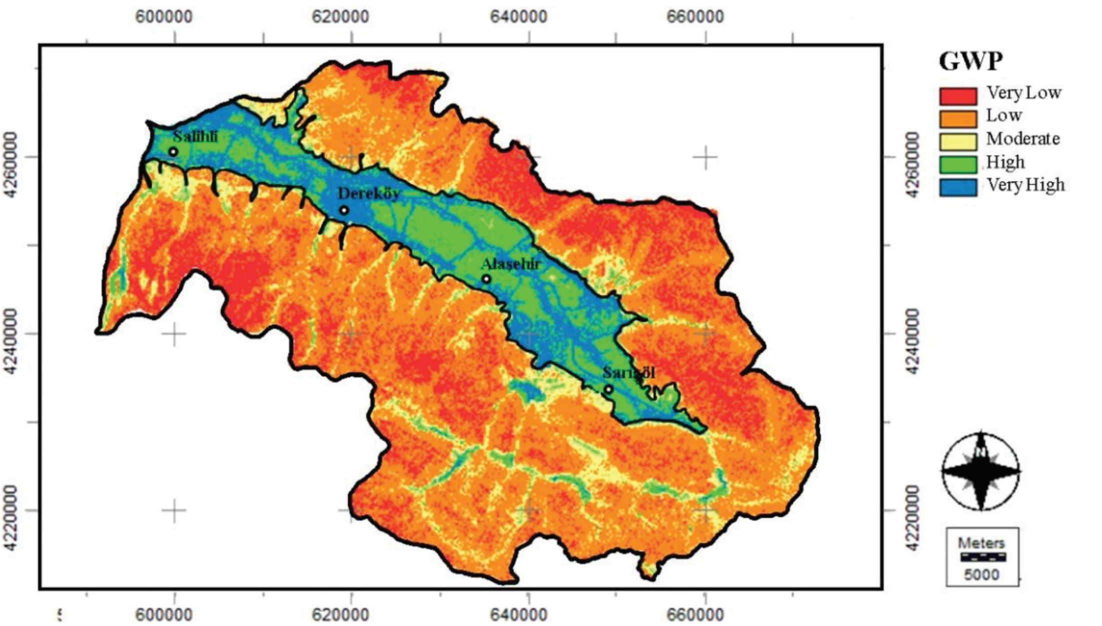

Figure 4.7. Groundwater potential classification map with sub-basin border.

4.3. Recommendations and Future Directions

Based on the results obtained from this study, the 10 proxies were sorted according to the most compatiblity with the groundwater potential:

1. Drainage
2. Hydraulic conductivity
3. Slope
4. Topography (Digital Elevation Model – DEM)
5. Lithology
6. Normalized Difference Vegetation Index (NDVI)
7. Land-use land-cover (LULC)
8. Lineament
9. Soil types
10. Modified Normalized Difference Water Index (MNDWI)

According to this ranking, inclusion of high-order parameters in the calculation with higher weight values will increase the accuracy of the data obtained as a result of the study. The most important proxies, drainage, slope and topography parameters can be obtained from Aster DEM data. On the other hand, although the hydraulic conductivity proxy has a significant effect on the study, since the acquisition of the data is costly. Thus, it may not be an accessible parameter for each work area.

Two remote sensing based indexes were used in this study (NDVI and MNDWI). The NDVI proxy gave consistent results of the study area's groundwater potential while the MNDWI proxy gave less consistent results for groundwater potential. Instead of using both the NDVI and MNDWI proxies together, it is more useful to take into account only the NDVI proxy.

Table 4.1. Summary of proxies and final output

NO	Proxy Variable	Unit	Year	Source	Calculation Method	Weight	Ranges and Trends of Spatiotemporal Change	Class Index Value	Details
1	Normalized Difference Vegetation Index (NDVI)	-1 to 1	21 September 2017	Landsat-8 OLI Data	Idrisi Selva/ Image Calculator tool (with using NDVI formula)	2	<0	4	Water (No vegetation)
							0-0.17	1	Barerock (Inactive vegetation)
							0.18-0.24	2	Crop1
							0.25-0.34	3	Crop2
							0.35-0.44	5	Forest 1 (Active vegetation)
							>0.44	5	Forest 2(Very active vegetation)
2	Modified Normalised Difference Water Index (MNDWI)	-0.69 to 0.29	21 September 2017	Landsat-8 OLI Data	Idrisi Selva/ Image Calculator tool (with using MNDWI formula)	2	<-0.25	1	
							-0.25--0.21	2	
							-0.2--0.11	3	
							-0.1--0.12	4	
							> 0.12	5	Water
3	Land-Use. Land-Cover	Land Use Types	21 September 2017	Landsat-8 OLI Data	Maxlike calculation was performed in Idrisi Selva	2	Settlement	1	Urban and rural settlements
							Barerock	2	
							Crop1	3	
							Crop2	3	
							Forests	4	
							Water	5	Lakes
4	Lineament	Meters	2018	Digital Elevation Model (DEM) of Alaşehir Subbasin /ASTER	Lineaments were determined using Aster Dem and satellite image data	3	>1500	1	Areas furthest to lineaments
							700 to 1500	2	
							300 to 700	3	
							100 to 300	4	
							1 to 100	5	Areas closest to lineaments

5	Topography	Meter	2018	Digital Elevation Model (DEM) of Alaşehir Subbasin /ASTER	Idrisi Selva/ Aspect tool	2	>1000	1	Very high elevated areas in the region.
							500 to 1000	2	High elevated areas in the region.
							200 to 500	3	Moderate elevated areas in the region.
							120 to 200	4	Low elevated areas in the region.
							52 to 120	5	Very low elevated areas in the region.
6	Slope	Degree	2018	Digital Elevation Model (DEM) of Alaşehir Subbasin /ASTER	Idrisi Selva/ Slope tool	4	>29	1	Most sloping areas in the region
							20 to 29	2	
							10 to 19	3	
							5 to 9	4	
							<5	5	Least sloping areas in the region
7	Drainage Hierarchy	Stream Order	2018	Digital Elevation Model (DEM) of Alaşehir Subbasin /ASTER	ARCGIS /Hydrology Analysis tools	3	Other values	1	Sub-tributaries of lower hierarchy
							4th order stream	2	
							3rd order stream	3	
							2nd order stream	4	Alaşehir Creek
							1st order stream	5	Gediz River
8	Lithology	Aquifer Types	2018	İzmir DSI GIS Layers	Available data was used with small edits in ARCGİS.	5	Rock	1	Paleozoic units containing local underground water
							Rock	1	Neogene crushed units containing local groundwater
							Cracked Rock	2	Volcanic rocks containing local underground water
							Karst Rock	3	Paleozoic marbles containing local underground water
							Karst Rock	3	Neogene limestones containing local groundwater
							Granular units	4	Alluvial units with extensive underground water
							Water	5	Lakes
9	Hydraulic Conductivity	0 to 46	2018	115 Y 065 NO/ Tubitak Project	Available data was used with small edits in ARCGİS.	4	No data	1	
							0 to 6	2	Lowest hydraulic conductivity values
							6 to 20	3	
							20 to 35	4	
							35 o 46	5	Highest hydraulic conductivity values

10	Soil Types	Soil Type	2018	İzmir DSI GIS Layers	Available data was used with small edits in ARCGİS.	2	No data	1	
							8th class soil	5	Water collection area
							7th class soil	2	Very sloping, stony, dry, swamp
							6th class soil	3	Woodland, meadow, very sloping, wet or too dry
							5th class soil	5	Stiffness and wetness, flat land
							4th class soil	3	Very sloping, poor drainage
							3rd class soil	4	Medium slope, low water retention capacity
							2nd class soil	4	Low slope, medium thick soil
							1st class soil	5	1% less slope, loamy, good water holding capacity.
11	SUM (Gorundwater Potential Map)	Class Value	2018	Calculation of All Variables	Idrisi Selva/ Image Calculator tool (10 variables were summed)		32-50	1	Very Low vulnerable for underground water
							51-65	2	Low vulnerable for underground water
							66-80	3	Moderate vulnerable for underground water
							81-95	4	High vulnerable for underground water
							>96	5	Very High vulnerable for underground water

CHAPTER 5

CONCLUSION

The issue of groundwater assets is related to many fields of environmental, political and economic issues. This requires accurate detection of the groundwater presence of the areas to be operationalized. The multi-criteria (weighted image overlay) method used in this study was used in the determination of various natural resources in previous studies. This study included several important procedures; selecting the most suitable multi-criteria approach model for the study and determining the appropriate proxies and their significance weights, combining and visualizing the data with using GIS and remote sensing methods, evaluating the proxies according to the selected multi-criteria method and testing the validation of the results as well as comparing the results with comparing the existing information data.

In the study, first of all, the general properties of groundwater were investigated. The existence of multiple factors affecting the presence of the groundwater directed the study to the multi-criteria decision making method focused on GIS and RS systems. A detailed literature review was performed to determine variables and then 10 proxies were identified. A final diagram was created and compared with the previous information data obtained from the TUBITAK project. Although the data do not correspond exactly, there was a great similarity between them. According to this result, it can be said that the results of the study is generally informative and satisfactory.

The preparation of plan-decisions taking into account the presence of the groundwater requires the cooperation of many professional disciplines. It is also useful to benefit not only from technical knowledge and research but also from the experience of the local community. In this sense, it is important to correctly identify the stakeholders of the project team and to ensure their participation.

Units such as residential areas and industrial facilities, located in areas with the high GWP are directly affected by groundwater and also directly affecting the GWP, vise versa. This situation may endangered both the local GWP and the health of the people of the region with an uncontrolled planning approach. In this context, it is important to ensure the construction and land-use restriction in areas with high groundwater potential and to prevent uncontrolled well drilling. The use of areas with high infiltration as garden, recreation or agricultural area will be more useful for the presence of underground water. In addition, it can be possible to increase the production efficiency in the villages and other agricultural settlements, but only if the groundwater and surface water presence are analyzed correctly and shaping the existing and future plan decisions.

The method used in this study is expected to be an alternative to previously used methods, to accelerate research and to be informative and satisfactory. The issue of water is an issue that affects many areas of our lives. The only way to ensure the environmental and economic development of the city and ensure sustainability and benefit from natural resources in the long term is to develop existing methods of getting more geo-information and protection. The groundwater is important and useful to human being. Therefore, it is so important where the GWP is for many purposes in urban planning.

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