Examples of Geological Surveys in Urban Areas using GIS Applications

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ABSTRACT As technology develops and the population rapidly increases, the need for new residential areas is increasing day by day, resulting in several environmental problems such as pollution and natural disasters. In order to meet the needs for energy and adequate food resources, artificial and mostly natural resources are consumed. Thus, the importance of urbanization cannot be ignored, and the planning of urban areas needs to be carried out with the use of Geographical Information System (GIS) to prevent the problems that can arise. GIS applications provide thematic maps and engineering geological maps, which help to interpret the data obtained easily and minimize the rate of observable disasters. This research examines the studies carried out worldwide and, in our country, which involve urban area planning using GIS applications. It also includes comments and criticisms on the methods of applying GIS applications, the beneficial results of these studies, and the applications that are applied worldwide but not commonly in our country.

KEYWORDS Engineering Geology, Geographical Information System, Mapping, Urban Areas

1. INTRODUCTION

The planning of urban areas is one of the most pressing challenges of our time, and it plays a vital role in meeting the needs of the expanding population. In its broadest sense, planning is a process of making spatial arrangements to enhance social welfare and satisfy needs, which involves decision-making for the future. The swift expansion of urban areas in tandem with population growth has given rise to numerous environmental problems. To prevent the degradation of environmental resources, different land use forms must be determined based on the principle of sustainability, taking into account ecological, social, and economic factors. In this regard, the present and future society's expectations are identified, and the land is evaluated to meet these expectations. One of the most challenging environmental studies today is deciding on the most suitable planning of land and resources. The increase in urban population and the growth of cities due to population growth and immigration have made it inevitable to plan new settlements in urban areas. As a result, urban planning is a crucial issue that necessitates the planning of new residential areas.

Urban planning aims to address existing and future problems through the development of short, medium, and long-term goals. This process involves the collection, analysis, and synthesis of data to determine appropriate strategies for achieving these objectives. Geological and physical constraints are among the most fundamental factors that must be considered when selecting suitable locations for urban planning. These factors include topography, geological structure, climatic conditions, seismology, hydrogeological features, building materials, soil quality, mineralogical and geochemical properties. Urban planning plays a crucial role in the mapping and planning of geological environments in cities worldwide and is often synonymous with environmental geology. It encompasses the study of land resources and geological hazards in the development and expansion of urban areas and provides valuable geological information to urban planners and policymakers to facilitate informed decision-making. Accordingly, numerous studies on urban geology have been conducted for various cities worldwide to inform urban planning efforts.

Soil surveys for land planning require determining the variations of parameters describing local soil conditions and understanding the relationships between them by analyzing data layers. Furthermore, it is crucial to correlate all obtained data with geographic coordinates. Statistical or mathematical geographical analyses and visual data presentations are necessary to carry out and implement these processes. One of the most effective tools for this purpose is Geographic Information Systems (GIS). GIS is a technological system that collects and stores data related to objects and events with geographic locations. It enables updating, querying, synthesizing, and analyzing large-volume databases. Geographical Information Systems are essential for efficient and rapid evaluation, viewing, and querying of these databases.

This study aims to evaluate the effectiveness of GIS applications in urban planning. Specifically, it will analyze the methodologies used for urban planning mapping and examine case studies from both Turkey and around the world. Through this analysis, various aspects of these case studies will be compared and evaluated.

2. EVALUATION OF GEOLOGICAL SURVEYS IN URBAN AREAS USING GIS APPLICATIONS EXAMPLES

A Geographic Information System (GIS) is a technological system that manages geometric and non-geometric data through software, hardware, and personnel to store, analyze, query, design, and respond to user requests according to data exchange standards. The main goal of GIS is to expedite the decision-making process by generating alternatives and evaluating different scenarios simultaneously. GIS offers a flexible framework that can be applied to a broad range of fields that utilize geographic data. The application areas of GIS are extensive due to the broad definition of geographic data. This study examines and evaluates numerous GIS studies conducted in Turkey, as well as those conducted globally, to provide examples and inform best practices.

2.1. Study Examples in Turkey

In 2002 [1], the study conducted in Zonguldak aims to demonstrate the benefits and advantages of GIS applications in geology. Therefore, GIS-based Arc View 3.1, 3D Analyst and RockWorks99 programs were used for the selected case study. For the geological map, the 1/10 000 scale map of the area was simplified and digitized, and the drilling sites, faults, contour lines, road and stream information were obtained. Thanks to this information obtained, graphical data layers consisting of geological units, faults, highways and railways, rivers, contour lines and elevation values of the floor of the Westphalian aged Kozlu Formation were created. With the database management system (Access), a tabular database consisting of locations, units, well logs, samples, analysis types, analysis results, and sources used has been created. Thanks to the ArcView program, these two created databases were associated, and a system was established to make inquiries about the needed subjects of the field. Although it is said that geology, aspect and slope maps were created with this system, these maps were not shown in the study. On the other hand, the correlation section between drillings and the base structure map of the Kozlu Formation are presented as an example. This study has created a GIS-based database with various resources to emphasize the importance of GIS-based work in the case context. However, using this database did not bring any comments about the field.

In 2008 [2], the study conducted in Bolu uses remote sensing and GIS technologies to evaluate settlement suitability for disaster mitigation for existing and future settlements. Furthermore, the study specifically focuses on earthquake disaster mitigation while evaluating settlement suitability.

Firstly, the remaining information layers which are terrain slope, land use capability classes, land use derived from satellite image, historical earthquake occurrences within the region, road network derived from satellite image, the main and secondary faults within the study area, distance zones around the main fault, ground acceleration values, basement types were entered into the GIS.

Secondly, existing settlements against distance from main fault, ground acceleration, basement type and terrain slope were evaluated by GIS.

Thirdly, based on these evaluating, a settlement suitability map was created by an empirical weighting scheme. Then, the settlement suitability map was analyzed against land use capability classes, contemporary land use from satellite images, historical earthquake occurrences, road network by GIS in order to refine the results. Finally, suggestions were made for reinforcement of existing settlements and planning new settlement areas for earthquake disaster mitigation.

In 2009 [3], the study conducted in Adana considers the various assessment and decision-making processes in order to create a planning model based on geo environmental criteria using a GIS based AHP analysis method. Data on topography, geology, the type of agricultural land and earthquake susceptibility were compiled and a multicriteria analysis carried out in order to create an urban suitability map, which will assist planners in identifying areas for the development of high- or low-rise buildings, industrial complexes and waste disposal sites. The geo-environmental properties of the site were determined using of geological, hydrogeological, morphological, engineering and environmental data obtained from the studies carried out in the region by governmental organizations. The data were digitalized using Arc-Info. The processing and the evaluation of the data were carried out with remote sensing techniques using the Erdas Imagine

8.7 program to land use map and the multi-criteria analysis was undertaken using AHP (analytical hierarchical process).

In the AHP method used in this study, various geo-environmental criteria such as slope, elevation, surface geology, depth of the groundwater, bearing capacity, agricultural suitability, land use, earthquake susceptibility, and flooding area were evaluated for selecting the most appropriate land uses. These criteria were evaluated based on the categories of high-rise buildings, multi-storey buildings, low-rise buildings, industrial sites, waste disposal sites, and green lands. After the evaluation process, the suitability potential was determined for each category, and maps for the suitability potential of high-rise blocks and industrial sites were presented as examples.

In 2012 [4], the study conducted in Niksar (Tokat) adapts a GIS-based microzonation map to urban planning. The study claims that “Liquefaction, activity, slope, aspect, fault proximity, ground amplification, and lithology are considered during the overlay analysis, using a multicriteria decision-making analysis of the analytical hierarchy process (AHP) and simple additive weighing (SAW) methods.” These methods are the most important key for adapting the GIS-based map to urban planning. AHP, which is one of these methods, is a mathematical method that considers the priorities of the group or individual and evaluates qualitative and quantitative variables together. The areas to be taken into consideration in the evaluations made are divided into 4 different regions as areas suitable for settlement, areas requiring detailed geotechnical investigation, unsuitable areas and temporary settlement areas. The reason why it is prepared with SAW and AHP methods is because it ensures that these fields are compatible with each other. However, only maps prepared with AHP management can control their own consistency, so it is recommended to be used in city planning. 46 cartographic maps with a scale of 1/1 000 were used on the map of this region and these maps were digitized and their geographical references were taken. In addition, the data of 35 old and 7 new drilling wells with depths between 15 and 30 m were used. In addition to these, existing microtremor measurement data at 496 points were used to create the amplification map. It is very important to divide this produced map into the settlement suitability classes recommended by AFAD. Considering this situation, a microzonation map was drawn for city planning. The use of the integrated map used in many articles is not used in this article. This deficiency may cause problems in future studies, so we can say that there are a few shortcomings in this article.

In 2014 [5], the study conducted in Esenler (İstanbul), the soil characteristics of the area located in Istanbul have been investigated with geological, geophysical and geotechnical data the settlement suitability conditions were evaluated by the interrogation capability of the GIS.

In order to evaluate its suitability for settlement, data from a total of 370 drillings and 150 seismic fracture studies, and test results on 908 disturbed and 174 undisturbed soil samples and 39 rock samples were used. With these results, GIS-based the distribution maps of SPT-N30 blow count- shear wave velocity (Vs)- soil classes and the maps of amplification- slope hazard- bearing capacity thematic maps were created. Using these thematic maps and the querying ability of GIS, two types of queries were made, and two different settlement suitability maps were created according to the results of these queries. In the first group of inquiries, inquiries were made using the SPT-N30, Vs velocity and bearing capacity data calculated for the shallow foundations and rock units of the study area. In the second group of inquiries, inquiries were made by using data on soil amplification and slope stability risks that may occur due to earthquakes in the study area. Finally, the maps of these inquiries were evaluated and suggestions for the area were presented. Although the maps created as a result of the inquiries were evaluated as suitability maps, they only show the results of the inquiries, and there is no result map showing the suitability for settlement.

In 2014 [6], the study conducted in Antakya (Hatay), the natural environmental components of area were analyzed in terms of habitability. The ArcMap 10.1 package GIS software was used at the analysis and the mapping stages of the present study. The Analytic Hierarchy Process (AHP), one of the multiple criteria decision-making methods, was employed as the research method.

In the study, primarily using 1/25 000 scale thematic maps, lithology, distance to fault lines, landforms, elevation, slope, aspect, temperature, precipitation, distance to rivers, groundwater level, soil and land use-land cover criteria were determined. Then, considering these criteria, alternatives were determined, and a hierarchical structure was created. Identified criteria and alternatives were rated according to the importance scale between 1 and 9, and then compared with each other in the formation of the comparative decision- making and preference matrix. Percent importance weights were obtained using the AHP Template program. In the last stage of the method, the weight values obtained were processed into maps of alternative factors in vector data format. These vector maps were analyzed according to the determined formula and according to the results of the analysis, a suitability map for settlement was obtained by classifying them according to four levels: very suitable,

suitable, less suitable and inappropriate. As a result of the study, the suitability map for settlement was evaluated and various suggestions were made about the area.

In 2015 [7], the study conducted in Edirne, the researchers claim that earth sciences (engineering geology) maps provide an important layer in making land use decisions and in engineering studies for different purposes, determining the geotechnical characteristics of the region, protection from natural disasters, and balancing in the context of protecting the natural environment. In the study, before starting to work with GIS, 1/25 000 scale maps of Edirne province were combined, and an image file was created, and coordinates were assigned with GIS software. The items on the map that will be the subject of the study are drawn as separate layers in the GIS software (Settlement area, road, energy transmission lines, stream, border line, central district borders). Again, the digital elevation model (DEM) of the study was converted from the image format and transferred to the GIS software as a layer. Areas suitable for settlement were determined and mapped by carrying out studies such as areas to be opened for settlement, power transmission lines, flood areas, geological formations and transport forces. This study and mapping contain many shortcomings in determining suitability for settlement. In the creation of the mapping of the regions suitable for settlement, details were ignored, and surface and subsurface studies were not mentioned.

In 2016 [8], the study conducted in Malatya, a 4-stage method was used to select the location of mass housing areas with the help of GIS. In the first stage, thematic base maps are prepared in ArcGIS program. In the second step, these maps are classified with the help of ArcGIS and the following maps are obtained:

- Topography Suitability Map by weighted overlaying maps of slope, aspect and elevation groups
- Soil Suitability Map by weighted overlaying maps of large soil groups, other soil properties, erosion conditions, land use capability classes, land use capability subclasses
- Geology Suitability Map by weighted overlaying lithology and fault line suitability class maps.
- General Land Use Suitability Map by weighted overlaying base maps such as urban land use map, general land use map (agricultural areas), protected areas, military areas, historical buildings
- Noise Suitability Map by weighted overlapping the maps created depending on the airport and the railway.
- Stream Suitability Map by giving low scores to areas close to the stream and high scores to areas far from the stream.
- Land Types Suitability Map by weighted overlapping water surfaces
- The Other Geographical Features Map by weighted overlapping dam lake, pond, marsh, reed, etc. areas.

In the third stage, the suitability maps obtained in the second stage are overlapped and the suitability final map is obtained. A certain score is given to each suitability area, and these scores are converted into values and suitability final areas are obtained. Accordingly, the areas with the highest scores show the most suitable residential areas, and the areas with the lowest scores show the least suitable areas. In the last part, the locations of the existing residential areas and the proposed residential areas are evaluated with the help of Google Earth program and field studies, and 4 different areas are determined for mass housing construction.

In 2017 [9], the study conducted in Sivas discussed with “Suitability Value Analysis of Natural Potential for Sectoral Use”. In this context, factor weights, sub-units and values of those units are determined. Then, suitability thematic maps are created and reclassified in ArcGIS program in terms of land use capability classes (LUCC), in terms of geology, slope, erosion, aspect and elevation. These thematic maps, which are created by reclassifying the natural factors that are effective in determining the areas suitable for settlement in the study area, were weighted overlapped by evaluating the natural factors together according to factor weights in the ArcGIS program. Regarding the use of residential areas; as a result of weighted overlapping, 5 units of 4 grades (geology-slope-erosion-aspect (a), geology-slope-erosion-aspect-elevation (b), geology-slope-erosion-aspect-LUCC) (c), geology-slope-erosion-aspect-LUCC-elevation (d) suitability maps are created and the distribution of areas suitable for residential use is determined. Finally, suitability maps are evaluated and suggestions for the future are developed.

In 2020 [10], the study conducted in Seydikemer aims to determine suitable settlement areas that are compatible with the natural environment of the area by using MCDA and AHP. Within this context, the socio-cultural, physical and ecological criteria of the region were assessed, and a set of criteria were chosen for analyses.

The study methods contained three stages. In the first stage, the baseline information (such as zoning plans, residential area limits, population, soil maps, green areas, etc.) of the study area were prepared and/or gathered using literature reviews, field studies and materials obtained from public institutions and organizations and a database was created.

In the second stage, the current state maps needed for the determination of areas suitable for settlement were digitized using Geographic Information Systems (GIS).

In this regard, land-use capability classes and maps of drainage areas were digitized using the 1/100 000 scale Muğla province land assessment map. Geological formations and fault lines maps, slope, elevation maps and hydrology maps were created using topographic maps. Land-use status maps with a controlled classification of satellite images and Principal Component Analysis (PCA) with high accuracy were obtained.

In the controlled classification process each land-use class was graded and classified with Random Forest (RF) and Maximum Likelihood Classification (MLC) methods.

In the last stage, at the end of the classification and graduation, the obtained data were evaluated with MCDA. Subsequently, suitability status maps were created for settlement areas.

In 2021 [11], the study conducted in Niğde, the authors claim that the development and planning of urban geological environments is of great importance in many respects, and it is necessary to use a lot of engineering knowledge together to develop these plans. However, doing geological mapping with many images is a useful way of understanding. The authors carried out research in the city of Niğde in order to obtain geological data, conduct research on them and present them in an engineering manner, and visualized the obtained data with the engineering geological mapping method (EGMM). Data from boreholes were used to obtain geological data. According to these data, groundwater table, liquefaction zone, soil classification, plasticity index, bearing capacity and SPT results maps were created. On the other hand, two types of interpolation methods, minimum curvature and Voronoi polygons method, were used for the preparation of these maps. On the other hand, in this study, "ArcGIS", a geographic information system software, was used to observe and compare the properties of geological data, and many mappings were created using this software. This is one of the most useful programs being used in our country and has contributed greatly to the article created. After the mapping, the authors evaluated the obtained data from many aspects and reached a conclusion.

Also, according to the data obtained by the authors, the city of Niğde was divided into 5 different regions from the evaluated aspects. When the SPT values of these regions are examined, it is understood that there is no value that will cause problems in the majority of them. However, looking at the liquefaction values, it is seen that there is a risk of natural disasters in some areas, and this part is stated by the authors.

Furthermore, the produced mappings are highly coherent and comprehensible. Nonetheless, the lack of a mapping delineating the earthquake zone and fault lines is deemed as a drawback. The article encompasses numerous mappings, such as the groundwater table, liquefaction zone, soil classification, plasticity index, bearing capacity, and SPT results table, yet concludes without an integrated map. This integrated map would have been extremely valuable for a prospective residential area analysis, and its absence is conspicuous.

2.2. Study Examples in Worldwide

In 2008 [12], the study conducted in Turin (Italy), rather than optimizing residential district in urban areas, the planning and optimization of underground structures comes to the fore. According to de Rienzo, et al. (2008), this study was conducted in Turin, Italy, and more than 300 drillings were performed to obtain data. These drillings were used in the construction of the metro line, and careful examination of the data obtained from this article during the excavation phase will greatly contribute to this project. In addition, the GIS system has been an indispensable part of this article in order to plan the model well, analyze it and map it to minimize the problems. The biggest advantage of this article is that the created GIS-based mappings are made in 3D format. This will provide great advantage in underground works. The use of 3D mapping instead of the traditionally used 2D mapping system is a finding that is not encountered in many articles.

As shown in Figure 1, the author has tabulated the steps required to construct a 3D geotechnical model. This is very important in terms of evaluating the subsoil of the area on the model. The authors also supported the stages of the 3D modeling system with screenshots.

This article, in which many different modeling such as 3D grip of numerical model, map of cementation classes, fence diagram, explains many data about the ground, but while it is understandable for people who are familiar with these issues, it has not been a general article. On the other hand, the research methods seen in other articles in planning the suitability of the region for underground structures (such as the metro line) are not seen in this article.

In 2009 [13], the study conducted in China measures natural environmental suitability for people in China based on GIS using the Human settlements environment index (HEI) model (Figure 2). According to the results obtained, natural environment suitability decreases from southeast to northwest.

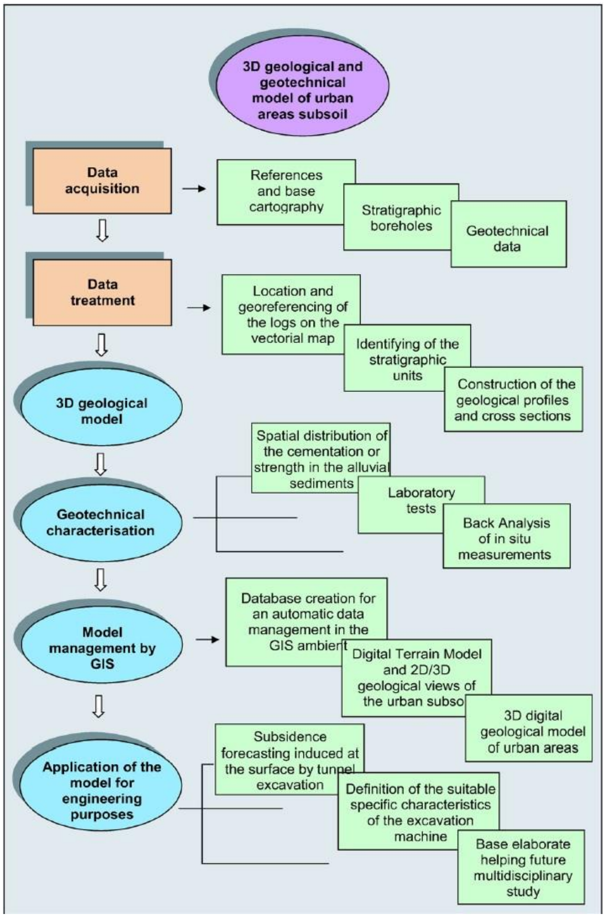

Figure 1. Flow-chart of the proposed procedure in order to analyze the subsoil of urban areas [12].

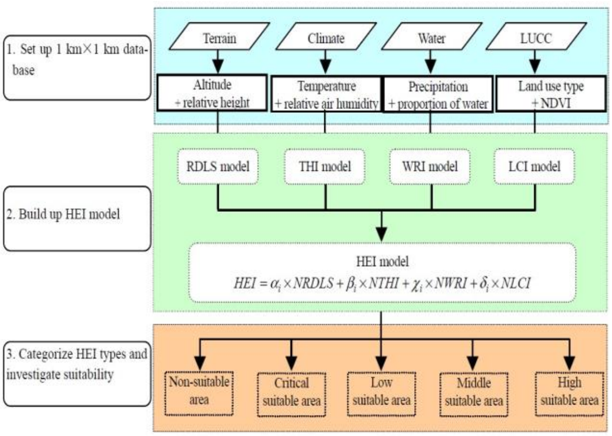

Figure 2. Technical scheme of human environment suitability evaluation of China [13].

Since HEI and population density are related to each other, the coefficient between them is 0.93. This means that the suitability of the natural environment is an important factor for people to be able to settle. Most people in China settle according to this factor. The total area suitable for settlement in China constitutes 45 percent of the total area. The rate of people settled in these areas constitutes 96.56 percent of the general population. There are 18 people per square kilometer. Apart from these, it is known that there are many factors affecting the settlement of people. To evaluate this, a 1km*1km database containing water, terrain, climate and LUCC status data was created. Finally, the residential areas are divided into 5 different titles, and these are unsuitable, critical suitable, low suitable, medium suitable and high suitable.

The reason for using 4 different methods in this article is that there are different factors that come to the fore in human settlements. This table has been created considering all these factors. For example, THI model is a method used by considering climatic conditions and temperature humidity index and the WRI method is used to find the water resource status of the region based on the amount of water resources and precipitation index.

In 2010 [14], the study conducted in Tunisia features such as study area, geotechnical and environmental geology problems, lithology and soil layer, topography, slope layer, seismotectonic, liquefaction susceptibility layer, flooding susceptibility layer, water table depth map, suitable are for construction are examined and mapped. Geological mapping in general involves difficulties. Especially in places with complex geomorphological features. To solve this problem, we must highlight complexity and diversity. This phenomenon causes some difficulty in geological and geotechnical mapping. But their solution can be an urban geological mapping using the data we have. But before we can apply this approach some of the key issues need to be discussed and developed. First, determining the scale is a priority when doing this kind of mapping. Then it should be decided which geology mapping method to use. One of the things that needs to be done after these stages is to observe the drilling data to obtain the geotechnical and liquefaction potential layers as well as the depth of the water table. There are a few important points in determining the scale selection that we mentioned before. The first is to show for what purpose the map was made, and how much detail needs to be shown to show this purpose. The second factor is determining the size of the country we are going to map. The third important criterion is determining the complexity of the area we are going to map. Finally, we should use complementary maps, such as geology, topography, plates, aerial photographs, and soil maps. For example, a map made for the city of Tunisia characterizes a complex geological history and a non-monotonic morphology. Therefore, the scale that should be used for the city of Tunis 1:25 000 should be used. This scale is considered as medium scale within the scale range recommended by UNESCO. First, the topographic maps of the city of Tunisia should be translated into digital format and geographically referenced. It was made based on direct field observations on the Tunisia map and the carrying capacity was evaluated. This is done by compiling all the criteria for geotechnical zoning of the city and adapting them to the geotechnical map. This map is the basis for the development of urbanism and the understanding and evaluation of the engineering aspects of the city.

As seen in Figure 3, at the end of the article, the authors created an integrated geological map that includes all the data as well as the separately evaluated geological maps. This provides great convenience and comprehensibility in the evaluation of the geological data obtained. This map will be very helpful in planning a residential area to be created in this region in the future.

In 2010 [15], the study conducted in Egypt, a GIS-based mapping system method was followed using AHP (analytical hierarchy process). AHP is a mathematical method that considers the priorities of the group or individual and evaluates qualitative and quantitative variables together in decision making. On the other hand, ARC-GIS software was used in the creation of all maps. An area located on the northwest coast of the Gulf of Suez in Egypt was studied and it was aimed to evaluate the environmental, geological and geotechnical conditions of this area. According to Youssef et al. (2010), the study area is a very important touristic, urban and industrial area and it is predicted that many geological problems may arise in the irregular settlement [15]. The authors divided the article into 3 separate parts in order to make this study more

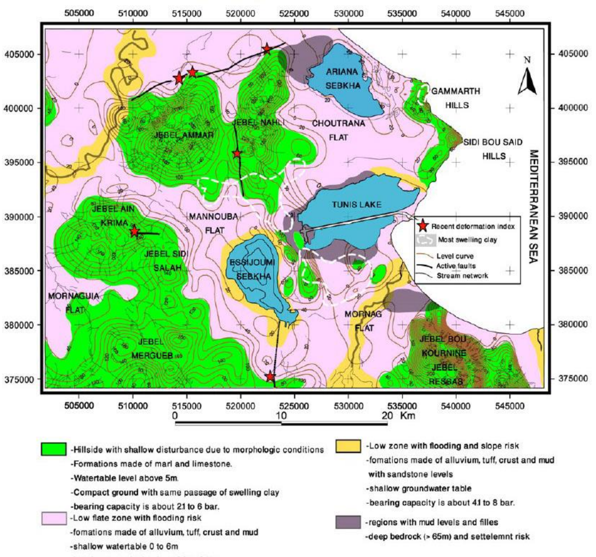

Figure 3. Final geotechnical zoning map of Tunis City [14].

understandable and to evaluate different factors separately. These parts are the surface model, the sub-surface model and the general model. This approach is encountered for the first time in the reviewed articles and its integration with the AHP model is very valuable. In the surface model classified as Group 1 in the article, major faults, distances to major streams, density, slope angles, and types of soil (geology) were considered. While using the AHP system, the intensity of importance values was determined from 1 to 9 and scoring was done for each factor. On the other hand, for the Sub-surface model called Group 2, the stress ratio, material index, and density gradient were considered. Finally, a general suitability map was created, in which Group 1, Group 2 and Group 1 and Group 2 were integrated. These maps contain very valuable research and comments in terms of suitability. The maps are classified region by region and made very understandable as seen in Figure 4. However, I think that suggestions should be made to increase the degrees of the regions with low suitability in the conclusion part.

In 2011 [16], the study conducted in Gyeongju (South Korea), a GTIS based on GIS technology was founded to predict and apply spatial geotechnical information and to specify an accurate evaluation of earthquake ground motion based on subsurface geologic structure.

To build a comprehensive GTIS over the entire study area, two techniques were incorporated: the use of an extended area surrounding the study area and the use of geo- knowledge to obtain additional surface geotechnical data. The research adopted a geo-knowledge technique to obtain sufficient data to ensure reliable prediction of spatial geotechnical information across the entire study area. To acquire-knowledge data for the extended area, landscapes were analyzed based on topographical maps and remote sensing images. Geology was preliminarily analyzed using surface geological maps. Then, site visits to the extended area were conducted to acquire geotechnical data for the ground surface referenced by global positioning system (GPS) spatial coordinates.

Interpolation was expected to yield more reliable results than extrapolation, and therefore the kriging method was applied to the entire extended area containing the study area. Finally, the geotechnical information for the study area was extracted from that of the extended area using GIS tools. This approach allowed for versatile use of the data in the seismic microzonation and geotechnical modeling to evaluate the site effects in the study area. The GIS-based GTIS in this study is composed of five primary functional components: database, spatial analysis, seismic response analysis, geotechnical analysis, and visualization components. The data flow between the database and two additional components (geotechnical analysis and seismic response analysis) out of the general GIS frame used to evaluate the site effects are mutually complementary.

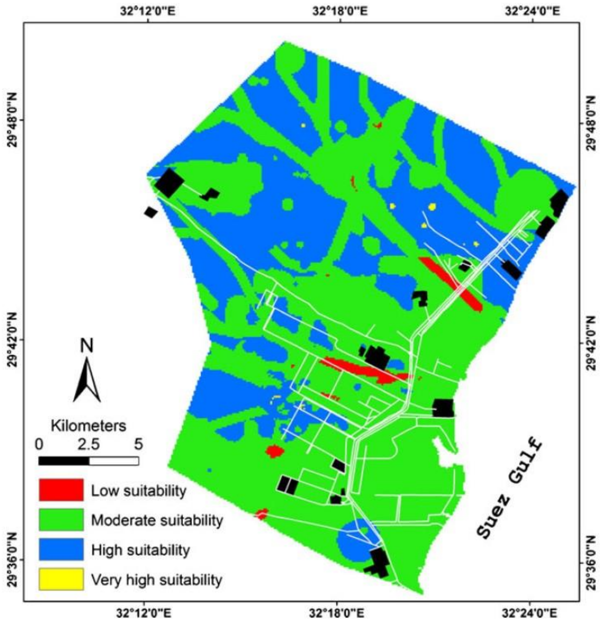

Figure 4. The overall hazard/suitability map for a combination surface and subsurface models [15].

In 2018 [17], the study conducted in Chennai City (India) presents a methodology for creating a digitally formatted and integrated spatial database using geotechnical data and geographic information system (GIS). In this context, firstly, drilling and ground survey reports were collected, and field surveys were carried out. Secondly, data from drilling logs, ground survey reports and field surveys were collected and digitally formatted. After the formatted data has been validated, it is finally organized and standardized for the database. The geotechnical database of the city was created with the standardized data. The database is then integrated with GIS to provide the advantage of spatially visualizing, analyzing and interpreting geotechnical information. The biggest advantage of this developed geodatabase is that it can create underground maps based on various geotechnical data to visualize georeferenced information. Thus, the geotechnical data serves to visualize, query, update and interpret for the future development of the city.

In 2022 [18], the study conducted in Oviedo (Spain), the aim is the creation of a GIS-based geo technical information system designed to provide geological and geotechnical information for a medium-sized Spanish city. This research focuses on addressing some unresolved challenges of the subsurface of Oviedo, which responds to local needs, from the management of ground data stored in a digital database. In this context two types of geological information were compiled: data obtained during this research and data supplied by external sources. With the compiled data, a GIS-based relational database was then designed using ArcGIS Pro v. 2.7 (from ESRI).

The data tabulated in GIS software were grouped into six thematic sections formed by feature classes and non-spatial tables, which contain one or more common key fields to link the data: (i) general information about the compiled documents; (ii) general data about the site investigations indicating the thicknesses of the geological units identified in each prospection; (iii) location of water sources, depth to groundwater, hydraulic testing and water quality (sensory properties, physicochemical parameters, ion concentrations, bacteriological content and chemical corrosiveness according to the Spanish code on structural concrete); (iv) geotechnical properties from field and laboratory tests (e.g. weight–volume relationships, soil grain size distribution, Atterberg limits, chemical testing, soils classifications, corrosivity, mechanical properties, abrasivity, etc.); (v) additional data related to construction works and information about extractive activities. Because of the organized data, data analysis was performed, and the aim of generating a relational database as the core of the geotechnical system was achieved and a significant amount of ground data was obtained.

3. CONCLUSION AND RECOMMENDATION

The study aimed to verify the indispensability of GIS as a tool in evaluating large amounts of data in various processes, particularly in the context of urban areas location. The benefits of GIS in data storage, control, updating, and management were exemplified. The study also examined numerous examples from Turkey and around the world, assessing the outcomes of GIS applications, the methods utilized in implementing the system, and what worked and didn't work in our country. Deficiencies were identified, and recommendations were made on what should be done to address them.

Based on various analyses and research conducted on the matter, it has been determined that data collection in our country has been problematic, particularly when it comes to accessing up-to-date data. It is important to note that certain institutions have been hesitant to share their data, which has hindered the development of GIS applications in our country. Without access to data, it is impossible to carry out GIS-related work. Additionally, several research results have indicated that decision makers in some provinces and regions in Turkey have not fully utilized the benefits of GIS studies. With the implementation of various engineering measures, even unsuitable locations found within a given area can be transformed into viable settlement areas. However, it is not uncommon for financial considerations to overshadow geographical factors in the selection of residential areas. For instance, in some cases, land prices may take precedence over slope factor when deciding on a residential area.

Moreover, it has been noted that a broader range of data has been utilized to determine settlement suitability in global studies, thereby increasing the accuracy of the final conclusions. Furthermore, our research has revealed a scarcity of studies that incorporate Geographic Information System (GIS) applications in 3D format. The third dimension, which holds significant importance in geology, can be readily obtained through various software such as ArcGIS. By utilizing three-dimensional models, it is possible to model both the topography and geological units and structures, allowing for a comprehensive examination from various angles and facilitating various analyses.

Given that GIS originated from a planning need and its primary function is map matching, it is evident that it is the most efficient, precise, and rapid tool available for land use planning studies. To avoid any negative impact on the environment, it is essential to accurately determine the existing working areas of forestry, agriculture, pasture, settlement, industry, and transportation sectors that utilize the land, based on biophysical, social, economic, cultural, and other environmental variables. This requires the development of a comprehensive land use plan and map. With the increase in the change from rural to urban in parallel with the changes in land use; city managers and planners have the opportunity to predict the possible direction of urban sprawl, to take appropriate planning decisions, to ensure that urban development areas are developed in a balanced way to protect fertile agricultural lands, and to inspect risky areas. In addition, with planned management, environmental protection is ensured.

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