Development of a Geotechnical Database using the Geographic Information System Approach

The Case of Djelfa, Algeria

Fayssal Cheriet
Civil Engineering Department, Ziane Achour University of Djelfa, Algeria | Faculty of Civil Engineering, LEEGO, USTHB, Algeria
cheriet.fayssal@yahoo.fr
(corresponding author)

Abderahman Zerguine
Civil Engineering Department, Ziane Achour University of Djelfa, Algeria | Faculty of Electronics and Informatics LTIR, USTHB, Algeria
addresszerguineaer@yahoo.fr

Anfal Rehab Cheriet
Civil Engineering Department, Geomaterials Laboratory, Hassiba Benbouali University, Algeria
cherietrihab@gmail.com

Received: 10 January 2023 | Revised: 20 January 2023 | Accepted: 22 January 2023

ABSTRACT

The present work aimed primarily to carry out a synthesis of the nature of the soil in the town of Djelfa and to develop a database of existing geological and geotechnical data that are available in order to put them at the disposal of all potential users, whether scientific or operational. The carried out work consisted in collecting and organizing the existing geological and geotechnical data on a geographical information system. The criteria were first identified (allowable stresses, allowable depths, etc.) and then maps with the different important factors were developed. Subsequently, these maps were superimposed to arrive, after a succession of generalizations of the geotechnical map, at an official final map with geotechnical terms. The interpretation of the obtained results allows for identifying the contributions and placing limits to the results and then trying to apply this method to other sites presenting similar problems and context. It should be noted that the maps produced are intended to enlighten decision-makers and planners when dealing with areas that are expected to be urbanized. They can also be helpful when conducting a preliminary study before the geotechnical study.

Keywords-geotechnical mapping; GIS; Multi-Criteria Analysis (MCA); Djelfa

I. INTRODUCTION

In geotechnics, the physical and mechanical characteristics of the site are acquired from in situ tests and laboratory tests. The existing historical information can be found in the form of hard, electronic and paper copy, site investigation reports. The traditional data collecting procedure can be a laborious job [1, 2]. Over the past four decades, geotechnical information has been integrated into a computerized database management system called Geographic Information System (GIS), which is a process of mapping and integrating computer founded information [3]. It is an excellent means of geographic access to spatial data acquired from different sources because of its ability to manage large amounts of data. It is a tool for capturing, displaying and, analyzing geographically referenced data [2-6]. GIS played a very important role in geotechnical engineering including preliminary site investigations, better understanding of the scope of possible solutions, the integration of any type of information, interpolation for obtaining data at inaccessible locations and less time may be spent on data analysis and acquisition than on data integration [2, 7].

In the geotechnical engineering field, the traditional procedures for making a soil site investigation require consulting previous conducted geotechnical reports in order to obtain better information of the soil properties. These reports are usually found as the format of electronic and saved paper documents in the archive rooms. However, the data processing can be highly complex and time-consuming due to the reports' condition and abundance.

In order to facilitate the performance of geotechnical engineers as well as to save time and effort, geotechnical data from several years have been collected for building a database and converting them into maps. The resulted maps can be used by geotechnical engineers to obtain a better idea of the site's geotechnical data (the main lithological units, the permissible depths, the allowable bearing capacity, and the aggressiveness rates). The objective behind developing a database for the town of Djelfa is to present and reference all the geotechnical data in GIS. For this, all the data collected were classified in thematic tables in order to be manageable in GIS. Thematic analyses were visualized in the form of maps.

II. STYDY AREA

From a geographical point of view, the Wilaya (Province) of Djelfa is located in the very heart of the high steppe plains (High Plateaus), at an altitude of 1200m. The town of Djelfa is considered a crossroads of transit between the North and the South and between the East and the West within Algeria. This strategic position can itself be a major asset that allows this city to assume the role of a regional hub and capital of the central highlands of Algeria. It must be recognized that this role has been entrusted to it for quite a long time by the regional scheme of the highlands in the central region of the country [8]. The town of Djelfa is bounded by [9]:

- The municipality of Ain Maabed (Daira of Hassi Bahbah) in the North and North-West.
- The municipality of Dar Chioukh in the North-East.
- The municipality of Moudjbara (Daira de Ain El Bel) in the East.
- The municipality of Zaâfrane (Daira de Hassi Bahbah) in the West.
- The municipality of Zaccar (Daira de Ain El Bel) in the South.
- The municipality of Ain El Ibel in the South-West.

The town of Djelfa covers an area of 542.17km^2. It is characterized by a semi-arid and humid continental climate. The winters are cold and harsh and the summers are hot and dry. The temperature amplitude is relatively high. It is widely acknowledged that, from a geotechnical perspective, both dry and wet climatic periods can trigger shrinkage-swelling phenomena of certain clayey geological formations, which subsequently cause soil settlement [8]. Furthermore, the rainfall in the area under study is marked, from one year to another, by great irregularity. The study area is characterized by sudden precipitations and stormy rains, which accentuate the phenomenon of soil erosion. These precipitations often cause flooding.

III. THE GIS-BASED SPATIALIZATION APPROACH - APPLICATION TO THE STUDY AREA

The approach adopted in this work for the preparation of the geotechnical maps is principally based on GIS. This method allows the development of several maps with the geotechnical characteristics of the town of Djelfa. These maps were developed based on the Weighted Sum Model (WSM). It is worth specifying that the exploitation of data GIS in the form of a computerized geotechnical map, makes it possible to carry out a fine and detailed spatial analysis of the underground geological formations. Furthermore, one should know that the database can be organized and structured using GIS. Each element of the database (lithology, categories of sites, etc.) comes from the digitization of its source map which is placed in an information layer. Then, each layer is georeferenced in the map projection system (Universal Transverse Mercator - UTM, zone 31) [10, 11].

A. Data Sources

The data from the geotechnical surveys used in this study were provided by the soil reports established by the National Laboratory for Housing and Construction of the Unit of the Wilaya of Djelfa. These data, which are archived in paper format (Soil study, 2010 - 2017) have been analyzed and organized in a database (Access, 2007) in order to obtain recent surveys and the various geotechnical characteristics such as the allowable stresses, aggressiveness rate, site categories, and the allowable depths. The data used were collected from 47 projects and 115 surveys distributed through different under consideration Land Use Plans (LUPs) of the city (Figure 1) [12]. In addition, in order to carry out the geotechnical characterization, statistical treatment was used to determine the average values of the physical and mechanical parameters of different formations. The extreme values were recorded and made available. Afterwards, all these values were analyzed, interpreted, and discussed.

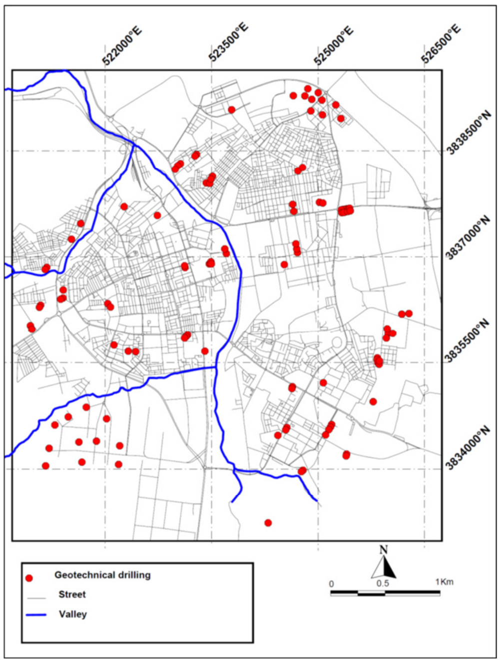

Fig. 1. Geotechnical drilling locations.

B. Layer Maps

It should be emphasized that, in the present article, we tried to develop new working methodologies that are founded on structural analyses and epistemologies (Access, MapInfo, Map Basic) in such a way that the system (application) that was established can be employed to facilitate the transition between the maps used by the MapInfo software and the databases which were already stored in Access. The layer of soil types (lithology), the layer of allowable stresses, the layer of allowable depths, the layer of site categories, and the layer of aggressiveness rates are shown in Figures 2, 3, 4, 5, and 6, respectively.

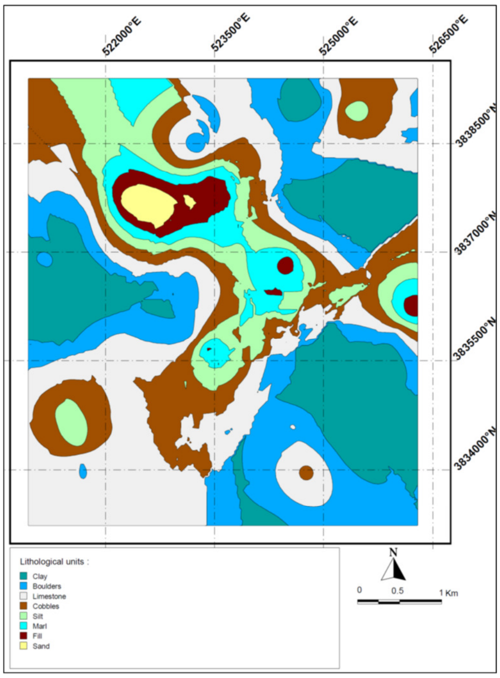

Fig. 2. The main lithological units of the study area.

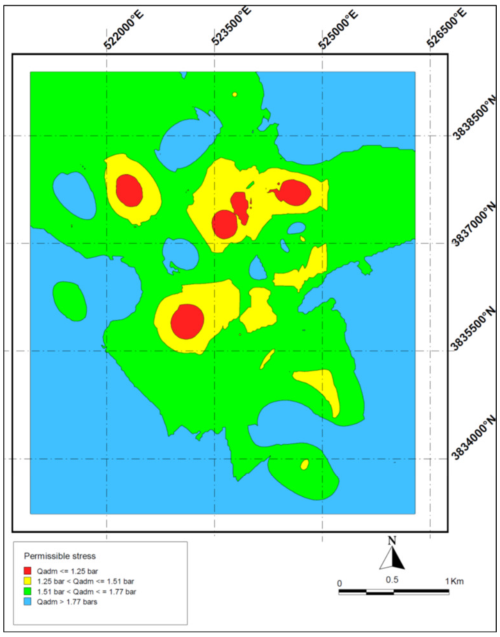

Fig. 3. The allowable bearing capacity map of the study area.

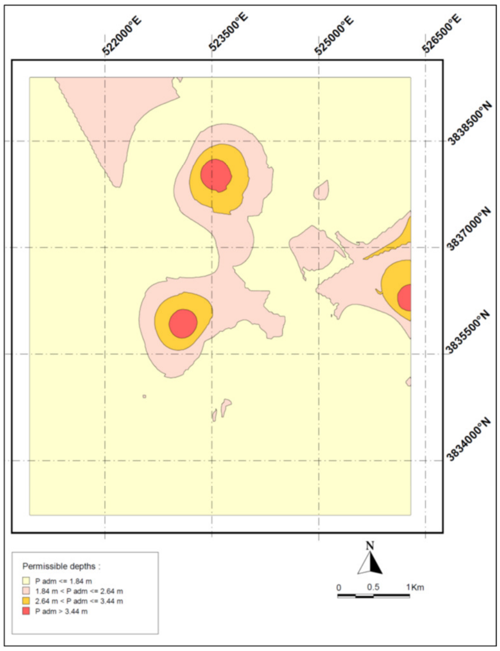

Fig. 4. The permissible depths map of study area.

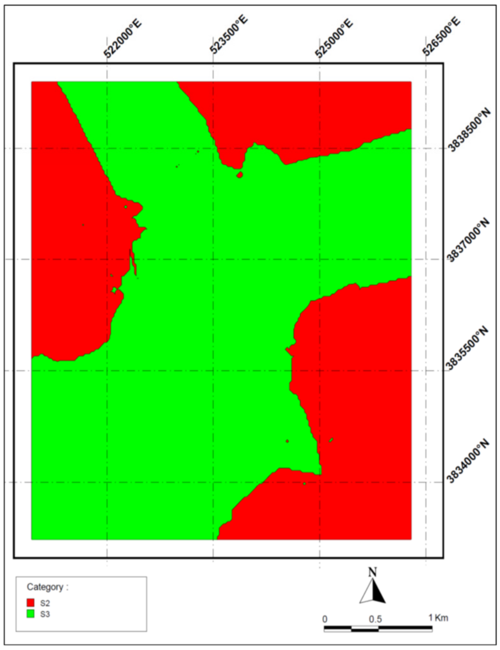

Fig. 5. The site category map of the study area.

It is worth specifying that the original geotechnical data are considered as entirely satisfactory in this study. However, the number of geotechnical reports could be increased to obtain more information and to achieve a better geotechnical characterization of the study area. For the preparation of the data layers, the continuous surfaces were formed by linear interpolation from the first points (drillings or mechanical boring) and the lines that join these different points.

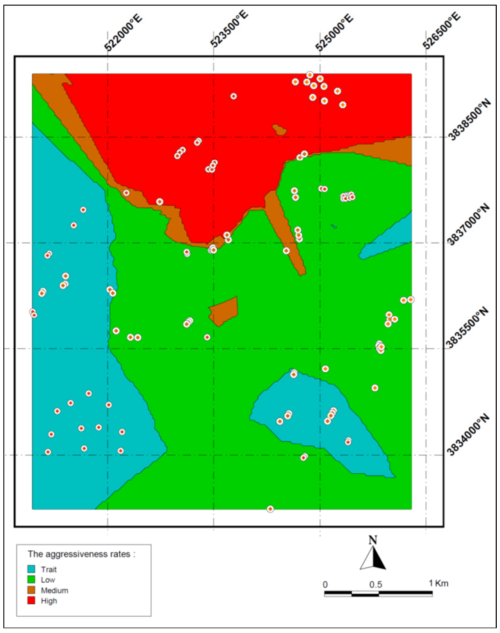

Fig. 6. The aggressiveness rate map of the study area.

IV. CONCLUSION

The approach adopted in this work for the preparation of the spatial distribution map for the purpose of evaluating the lithology, soil bearing capacity, embedment depth, site category, and soil aggressiveness, is based on the Geographic Information System (GIS). The utilized data were taken from previously established geotechnical reports. These data were then incorporated in the GIS program (MapInfo) in order to draw the initial maps. This study made possible to highlight the advantages of using the above mentioned techniques, namely the low cost, the ease of use of data, and their rapid updating process.

It is worth emphasizing that the study area was divided into four different zones, depending on the effectiveness of the foundations: 1) zones with low soil bearing capacity, 2) zones with medium soil bearing capacity, 3) zones with high soil bearing capacity, and 4) zones with very high soil bearing capacity. Moreover, the lithological map shows that there is a certain lithological diversity, in addition to an alternation of limestone facies with clays. In addition, the aggressiveness map allows asserting that the upper part of the study area is strongly aggressive.

The methodology used in the selected study area can be applied to other regions, and other procedures can be adopted for the selection of sites. This approach can also be used to establish the necessary standards in an appropriate manner.

REFERENCES

[1] A. H. Aldefae, J. Mohammed, and H. D. Saleem, "Digital maps of mechanical geotechnical parameters using GIS," *Cogent Engineering*, vol. 7, no. 1, Jan. 2020, Art. no. 1779563, https://doi.org/10.1080/23311916.2020.1779563.

[2] A. Singh, S. Noor, R. Chitra, M. Gupta, and N. K. Vel, "GIS Applications in Geotechnical Engineering - Some Case Studies," *International Journal of Latest Trends in Engineering and Technology*, vol. 5, no. 2, pp. 36–42, 2015.

[3] F. T. Benaissa and B. Khalfallah, "Industrial Activity Land Suitability Assessment Using Delphi and AHP to Control Land Consumption¨: The Case Study of Bordj Bouarreridj, Algeria," *Engineering, Technology & Applied Science Research*, vol. 11, no. 5, pp. 7738–7744, Oct. 2021, https://doi.org/10.48084/etasr.4362.

[4] A. Hallil and A. Redjem, "Assessment of Urban Vulnerability to Flooding Using Multi-Criteria Analysis: The Case Study of El Bayadh City, Algeria," *Engineering, Technology & Applied Science Research*, vol. 12, no. 2, pp. 8467–8472, Apr. 2022, https://doi.org/10.48084/etasr.4828.

[5] W. N. S. Wan-Mohamad and A. N. Abdul-Ghani, "The Use of Geographic Information System (GIS) for Geotechnical Data Processing and Presentation," *Procedia Engineering*, vol. 20, pp. 397–406, Jan. 2011, https://doi.org/10.1016/j.proeng.2011.11.182.

[6] R. Luna *et al.*, "Introduction Of Gis Into Civil Engineering Curricula," presented at the 2008 Annual Conference & Exposition, Pittsburgh, PA, USA, Jun. 2008, pp. 13.808.1-13.808.12, https://doi.org/10.18260/1-2--4433.

[7] K. Loumi and A. Redjem, "Integration of GIS and Hierarchical Multi-Criteria Analysis for Mapping Flood Vulnerability: The Case Study of M'sila, Algeria," *Engineering, Technology & Applied Science Research*, vol. 11, no. 4, pp. 7381–7385, Aug. 2021, https://doi.org/10.48084/etasr.4266.

[8] E. Arour, "Carte de situation géographique de la wilaya de DJELFA," *Découpage administratif de l'Algérie & Monographie*. http://decoupageadministratifalgerie.blogspot.com/2014/10/cartegeographiqueDJELFA.html.

[9] N. Kherfane, "Les outils de gestion de l'espace et la réalité du développement urbain non maitrisé 'approche géomatique' (cas de la Ville de Djelfa).," M.S. thesis, Université de Batna 2, Batna, Algeria, 2014.

[10] A. Guettouche and F. Kaoua, "Using a GIS to Assessment the Load-Carrying Capacity of Soil Case of Berhoum Area, Hodna Basin, (Eastern Algeria)," *Journal of Geographic Information System*, vol. 5, no. 5, pp. 492–497, Oct. 2013, https://doi.org/10.4236/jgis.2013.55046.

[11] A. Guettouche, "Cartographie géotechnique par approche SIG basée sur l'analyse multicritères," Ph.D. dissertation, University of Science And Technology Houari Boumediene, Algiers, Algeria, 2015.

[12] A. R. Cheriet, "Elaboration d'une base de données géotechniques par SIG Application à la commune de Djelfa," M.S. thesis, Ziane Achour University, Djelfa, Algeria, 2018.