Research Article

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Creating digital maps for geotechnical characteristics of soil based on GIS technology and remote sensing

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Abstract: This article investigates creating digital maps for physical and geotechnical characteristics of soil based on Geographical Information Systems (GIS) technology and remote sensing for one of the most important areas in Egypt, namely, Delta Nile region, which is characterized by its agricultural and cultural resources. To create accurate digital maps for the soil characteristics of this area, data are collected mechanically, manually and in the laboratory and loaded up with the help of GIS technology using Modified Inverse Distance Weighted as a spatial interpolation technique throughout using 119 soil samples inside Kafr El-Sheikh Governorate, Egypt. A digital elevation map of the Delta region has been downloaded using remote sensing technology to obtain the reduced levels of the different points for the studied area. Data were analyzed and studied well to produce six digital maps describing the important physical and geotechnical characteristics of soil such as groundwater level, pH water −Log (H^+); the percentage of salts and chlorides (NaCl); Sulfate ratio (SO_4); average appearance of the sand layer and average appearance of the clay layer. The results indicate a significant increase in the percentage of chlorides and sulfates, as the percentage of chlorides increased at a rate ranging between 2,000 and 6,000 mg L^{-1} up to 86.95% of the study area. It was noted that the percentage of sulfates increased at a rate range between 1,000 and more than 2,000 mg L^{-1} up to 91.5% of the study area. The final groundwater level ranges between 1.5 and 3 m under ground level, but the largest percentage is at a level of 1.5 m with a percentage up to 70% of the area of the study area. When conducting tests on water to determine the acidity and alkalinity aspect, we concluded that most of the values are between 6.8 and 7.3, with 44.62% for the first and 52.63 for the latter.

Keywords: GIS, digital soil mapping, prediction, MIDW, digital elevation model

1 Introduction

The properties of soil are characterized by a high degree of variability and uncertainty. Soil may consist of local origin material or be transported by one of the known means of transport such as wind, water, seas, gravity, etc. Errors in the irrigation process of the lands scattered in Egypt led to the deterioration of the soil [1,2], increasing the salt content of the soil to levels detrimental to plant production and the deterioration of some chemical and biological properties of the soil [3,4]. Some lands are transformed into an acid state as a result of excess sodium, which further degrades the natural characteristics. The use of digital maps using geographical information systems (GIS) has now paved the way to optimally store and control soil variation and our ability to chart the exact variation of the landscape around the world is enhanced by the incorporation of GIS with remote sensing. GIS aids in city planning and decision-making, as well as in reading the infrastructure of any position [5]. Digital maps have a special role in GIS, as the process of drawing these maps has become of great importance to many users, such as engineers and developers, whether on the educational or professional side, as it has become easier than any cartographic or manual method as it was in the past [6–8].

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Nutrients, water absorption, soil strength, and soil transport properties are all affected by the surface area of individual particles [9]. Soil contains minerals, organic matter, plants, and animals, as well as air and water [9]. Soil contents change regularly. There are many types of soil, each with distinct properties including color and composition [10]. Particles known as sand, silt, and clay make up most of the mineral content of the soil [10]. Sand and silt are particles of the mineral's quartz and feldspar [11]. Clays consist of illite, kaolin, micrite, vermiculite, and other minerals [11]. Trace amounts of several minerals add nutrients to the soil, including calcium, phosphorous, and potassium [11]. Most soils are called mineral soils because more than 80% of their particles are minerals. Before beginning to build any structure, it is necessary to study the soil characteristics and understand its properties in order to avoid problems that may impede the construction process and damage buildings during and after the construction process is completed. It is important also to know the appropriate foundation depth and date to determine the type of foundations suitable for use and to identify the expected decline according to the loads and nature of the soil, the method of groundwater draining if any, and the extent of its impact on the neighbor's buildings, and determining the types of materials used in the foundations (cement–iron–sand), according to the percentage of salts and sulfates and the extent of their impact on concrete. Therefore, it is significant to study the soil and be familiar with its characteristics and nature [12], especially at present when Egypt is currently witnessing the level of engineering and national projects, which are a great breakthrough and a major unprecedented construction renaissance. There are many methods of spatial interpolation of unidentified points, and each method has its own advantages and disadvantages, which depend first and foremost on the properties of the point data set. It is important to choose the appropriate method of interpolation through criteria for point data with specifying interpolation goals because different goals can produce different criteria for evaluating interpolation. The article's novelty is the use of modified inverse distance weight (MIDW) for predicting soil properties rather than traditional prediction techniques that aid in the creation of digital maps for soil characteristics [13]. Talking about the most important method appropriate to the nature of the study is an inverse distance weight (IDW) method, which relies on giving more weight to the points close to those farther away by distancing each point, which is a very successful method that gives acceptable and good results, but it is critical to the weighting function and can be affected by the uneven distribution of data points [13]. Therefore, we will rely on the MIDW, which considers the Z level, which is the difference in heights between points and some of them, to get the best results, which will be mentioned in detail during the research. Therefore, the main objectives of this research are as follows:

1. Create digital soil mapping for the study area using GIS tools based on the management, processing, and analysis of 119 soil samples (119 soil borings) inside the study area that is obtained from field and laboratory studies, statistical analysis data, and remote sensing related to spatial and non-spatial soil information.
2. Study the possibility of applying MIDW as a spatial interpolation technique for estimating attributes at point locations that are not sampled or at which we don't have the data, by using the attributes at point locations for which we have the data. Spatial interpolation techniques differ from traditional modeling approaches in that they incorporate information about the sample data points' geographic location.

2 Study area

Nile Delta region is a delta formed in northern Egypt where the Nile deviated from its course in the form of two branches to the Mediterranean. The study area is Kafr El-Sheikh Governorate as shown in Figure 1, which is one of the most important governorates of the Delta due to its many ingredients in many agricultural, industrial, tourism, and commercial fields. It is in the far north of Egypt in the Nile Delta, and its capital is Kafr El-Sheikh City. It has a population of 3,919 million, and an area of 3716.68 km^2 representing 28.6% of the total area of the Delta region and about 0.35% of the total area of Egypt [14]. Its entire area is located in the north of the Delta and overlooks the Mediterranean Sea. Administratively, the governorate is divided into 10 centers. Kafr El-Sheikh Governorate is bordered to the north by the Mediterranean Sea with an extension of 100 km, to the south by Gharbia Governorate, and to the east by Daqahlia Governorate. From the west, the Nile River – Rasheed Branch, with an extension of 85 km, where Kafr El-Sheikh Governorate extends between latitudes 31° and 31° 37° N, and longitudes 30° 20° and 31° 20°.

3 Data collection and soil laboratory investigations

Soil boring is a technique for investigating soil properties that involves extracting several shallow cores from the

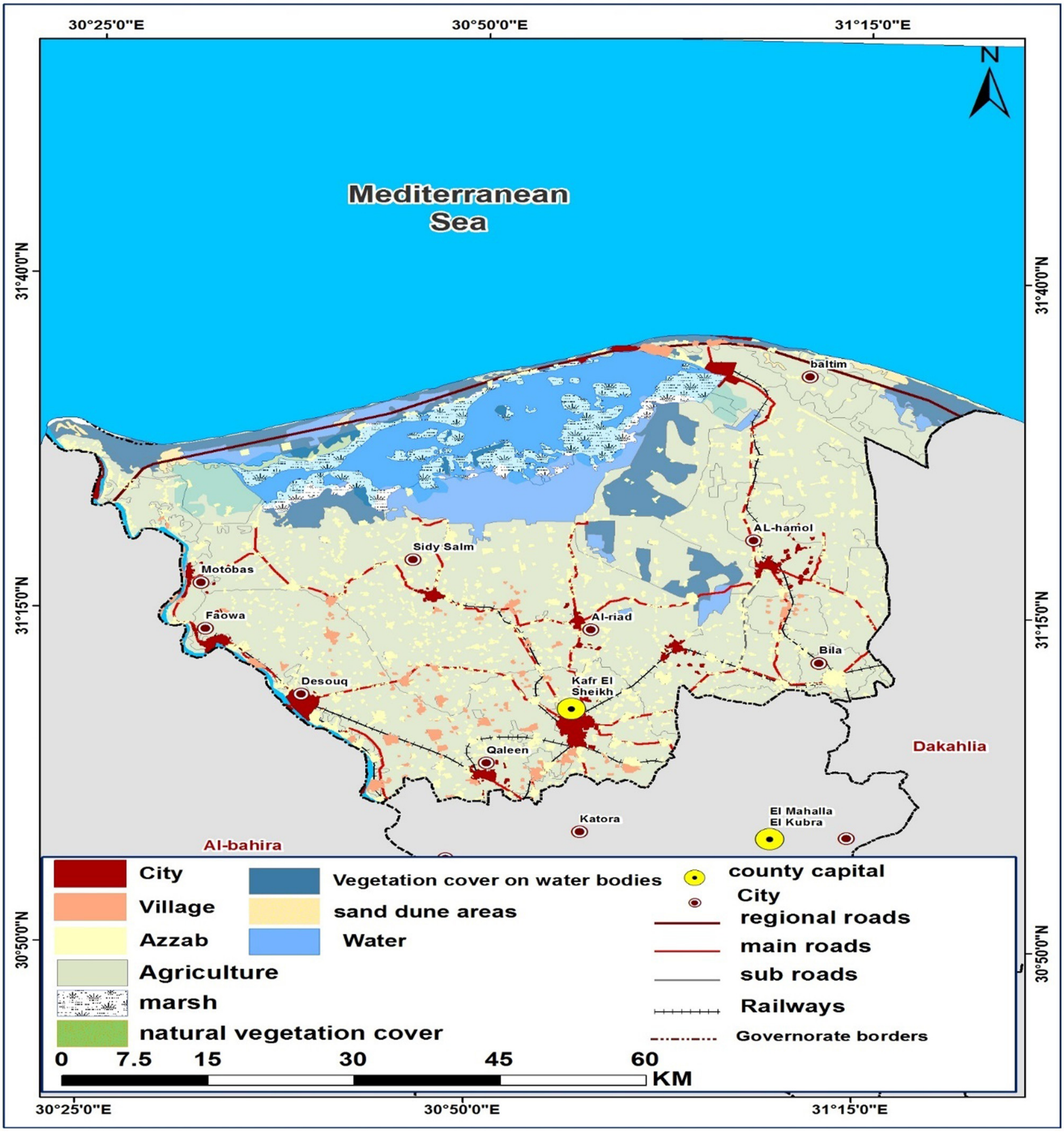

Figure 1: Map of the study area, Kafr El-Skeikh governorate, Egypt.

sediment. It is used when a drilling jacket or jack-up rig is to be supported on the soil. In this article, 119 different samples of soil (119 soil borings) in several different places and positions in Kafr El-Sheikh governorate are collected as shown in Figure 2 (distributed to cover all the study area) using mechanical tensioners with different depths of 20, 25, and 30 m according to the engineering requirements of the Egyptian code. To design and implement the foundations, soil laboratory experiments and investigations were conducted at the Foundations and Soil Mechanics Laboratory, Faculty of Engineering, Kafr El-Sheikh University, Egypt. The level of the natural land at the site of each boring was zero. Altered samples were extracted from the loose soil during the execution of each palpation every 1 meter of the excavation depth,

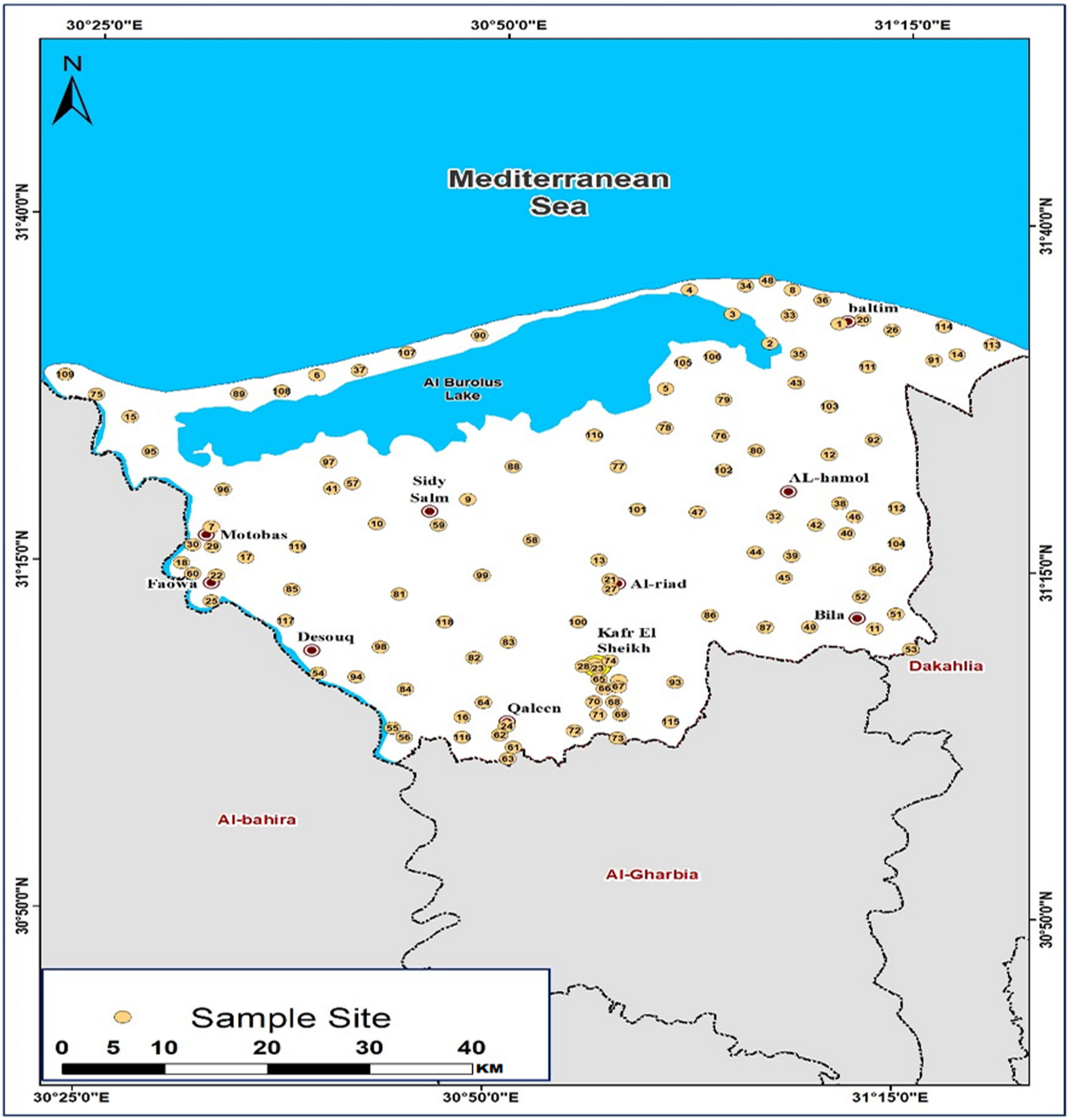

Figure 2: Soil samples locations in the study area map.

as well as when a difference in the soil. Undisturbed samples were extracted from the cohesive clay soil every 1 m. Soil samples were chemically analyzed to determine the percentage of sulfate and chloride salts. The initial and final depth of groundwater was measured in each session to determine the final depth of water stability.

A set of laboratory tests were also carried out as shown in Figure 3a, b, d and e. Some samples that were extracted from one of the study sites that have all the details of the site written on them, sample number, depth, date, and place of extraction, and to preserve them, they are placed in plastic bags to keep them from changing until they are transported to the laboratory; for picture C, it is a sample of sand extracted from a site to verify the visual characterization of the soil samples and to determine some of the physical, mechanical, and chemical properties as follows:

Figure 3: Experimental tests in soil laboratory, Kafr El-Sheikh University, Egypt.

3.1 Moisture content and unit volume weight

Experiments were carried out on cohesive clay soil samples to use them attributed to the limits of fluidity and plasticity to determine the strength index, which is an important indicator of the degree of soil cohesion in its natural state and thus its strength to shear and compressibility.

3.2 Granular gradient test

The Granular Gradient Test was done on a sample of non-cohesive soil at the site to verify the accuracy of the visual characterization and to determine the percentage of fine materials (passing through the No. 200 sieves) because of their effect on the behavior of the non-cohesive soil.

Regarding the physical and chemical analyses of groundwater:

i) natural investigation and analysis;
ii) chemical investigation and analysis.

A chemical analysis test was done on a sample of groundwater at the site to determine the percentages of dissolved salts of sulfates and chlorides and the PH number in this water especially sulfates for their effect on concrete and chlorides for their effect on reinforcing steel, to take precautions when designing and implementing foundations.

The groundwater was monitored during the excavation (the level of the beginning of the emergence of water) as well as after the extraction of the pipes of the probes. These levels are measured from the level of the natural ground surface of the earth. The final level of the stability of the groundwater was monitored below the natural surface of the ground at the site according to the Egyptian code for soil mechanics and foundations. Therefore, the results of all tests for all 119 soil borings are recorded.

4 Interpolation technique using MIDW

To draw an actual and accurate digital map describing the actual soil properties for the studied area, an accurate interpolation technique must be applied to determine the soil properties in places where the real investigations data are missing. In this article, MIDW is applied to predict the soil properties for several thousands of positions inside the study area depending on the resulting soil properties from 119 boring investigations.

IDW is one of the simplest and easiest spatial interpolation methods that exist today [15]. It is a method of estimating the characteristics or features of sites that have not been sampled and one cannot obtain data or information about it. By obtaining information from neighboring sites (soil properties), one can predict data in sites from which information is not available. But this method depends on that the points are all at the same level of level of elevations, which is not commensurate with our study. Therefore, this method was modified and we used (MIDW); we add the attribute variable to the equations, as the points of the study area were not at the same level of elevations, and this led to improving the accuracy of the results that we got it. This method assumes that the variable being assigned decreases in effect with distance from the sample location in addition to the vertical distance, which is the levels of the different points, in other meaning, the height of the land above sea level. An average of values is taken within a space to be determined, and the weights are a decreasing function of distance, and its mathematical form can be controlled by many options for the size of the neighborhood utilizing several points or radius. MIDW uses spatial correlation in mathematics, where the closest values have a greater effect, while the less effective is for the far values, where it cannot deduce values higher than the maximum values and less than the minimum values. As for the power settings and the strength of the impact, a higher energy value is selected, which enables us to focus more on the nearest points. Therefore, the close data will have the greatest impact, and the surface will be more detailed and less smooth. With increasing power, the inferred values begin to approach the value of the nearest sample point. Setting a lower value for energy will increase the impact on distant surrounding points, resulting in a smoother surface. Lo presented the MIDW equation as follows [16–18]:

$$S_x = \frac{\sum_{i=1}^{n}\left(\frac{d_{xi}}{\Delta H_{xi}}\right)^k \cdot S_i}{\sum_{i=1}^{n}\left(\frac{d_{xi}}{\Delta H_{xi}}\right)^k}, k > 0, \tag{1}$$

where S_x is the spot one need to estimate it; $\left(\left(\frac{d_{xi}}{\Delta H_{xi}}\right)\right)^k$ is the weight of each point; d_{xi} is the distance between each-known point and unknown point which one needs to estimate; ΔH_{xi} is the elevation difference between points; K is the power; n is the number of points used.

Equation (2) is the model of Chang et al. which has assumed that the inverse multiply of distances and elevation as a weight in MIDW [17,18].

$$S_x = \frac{\sum_{i=1}^{n} h_{xi^n} * d_{xi^m}}{\sum_{i=1}^{n} h_{xi^n} * d_{xi^m}} * S_i, m > 0, n > 0, \tag{2}$$

where m and n are the powers,

h_{xi} is the elevation difference between points.

This mathematical interpolation technique is applied for soil properties prediction in the study area

5 Contour lines and point elevation for study area from digital elevation model (DEM)

For detecting the levels of all points in the study area, DEM is used and applied. DEM files are free files that can be acquired from several international websites on the Internet and are generated by the United States Survey Authority [19]. These files depict the topography of the Earth's surface and its human usage, as well as the Earth's coverings, which can be used with these files in preliminary and final surveying works [19–21]. The study area, as shown in Figure 4, was downloaded from the Internet via the SRTM 1 (Shuttle Radar Topography Mission) satellitewith a resolution of 30 m as it is a radar through which a complete topographic database is created to obtain digital elevation models, and opened with the ARCMAP program [22]. UTM WGS 1984 zone 36 N was selected for the digital elevation file. The elevations of the study area range between 0 and 15 m above sea level. Contour map, as shown in Figure 5, was created from the raster option with a contour interval of 0.5 m to graphically represent data based on values to model the potential change between the points. Then,

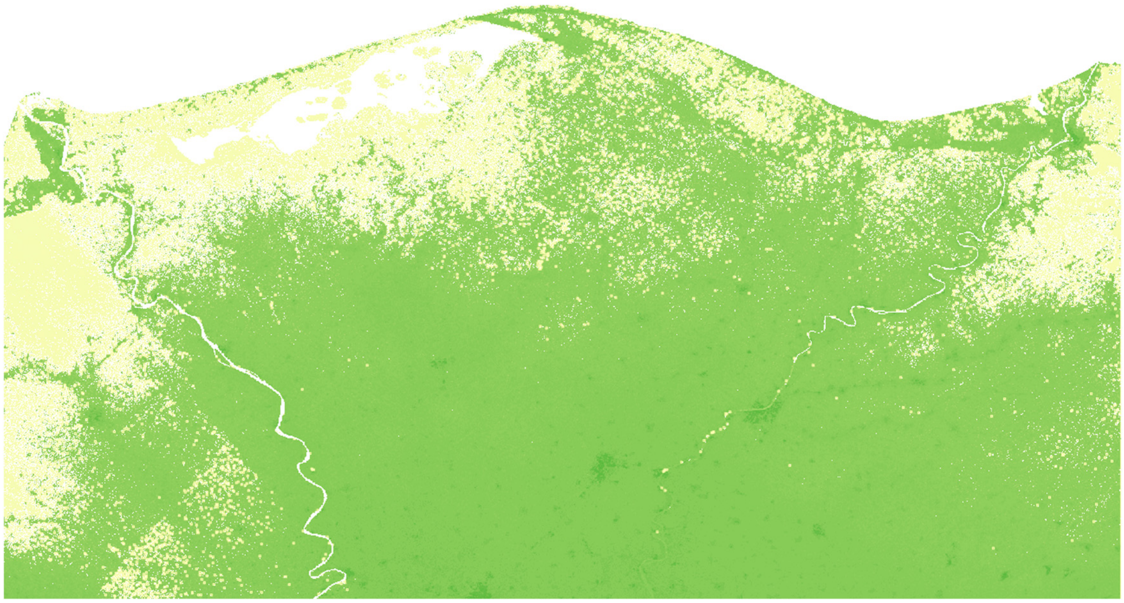

Figure 4: Digital Elevation Model of the study area.

tin layer shown in Figure 6 was done using contour lines. Therefore, the levels of the study area were obtained, and the difference in the levels between the points was obtained (*z* axis).

6 Results and discussion

The map of the study area, which is the map of Kafr El-Sheikh Governorate, was uploaded to the program, a geographical location for the map was made, the WGS 1984 coordinate system was selected, and the location was chosen as Zone 36 N, and thus, the undefined coordinates became metric coordinates. Then, the base map taken by the scanner was added and its coordinates were set to ensure that the error rate was reduced, and the map was saved on the device; we have returned the map geographically. A database has been created for the map by ARCMAP to be used in drawing the map layers by adding the geographically corrected map and choosing the location; in addition, shape files for all the layers were drawn on the map, such as roads and city boundaries. Finally, the layers of the map are drawn, and all layers are made on the map. The available data were collected from the soil borings analysis and data from interpolation techniques using the

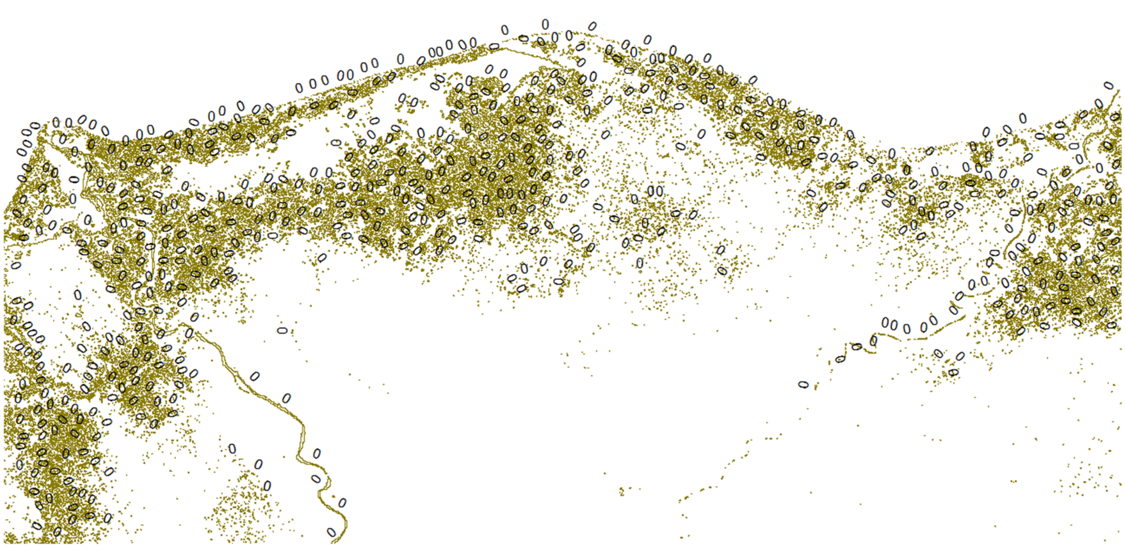

Figure 5: Contour layer of the study area.

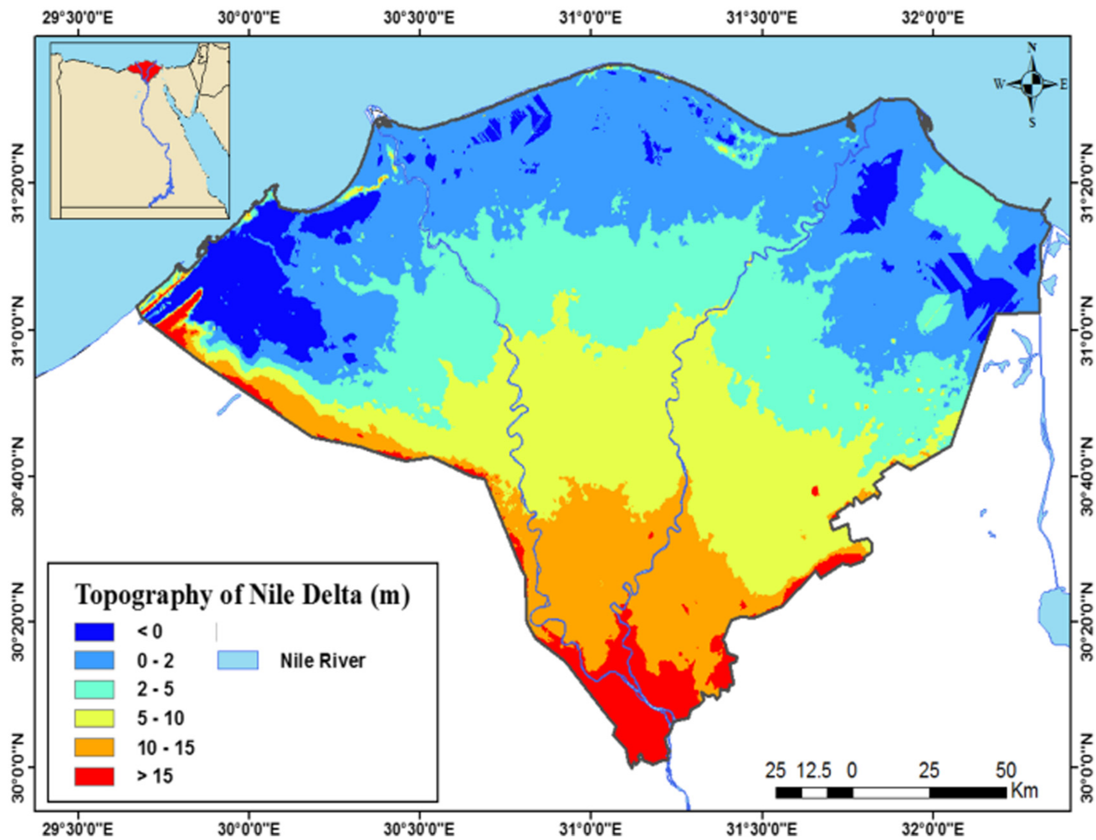

Figure 6: Tin layer and elevations of the study area.

MIDW method and recorded to an Excel sheet for each of the parameters (coordinates, levels, and soil parameters) that were fed into the program to produce digital maps for each parameter separately. The following parameters are studied for soil characteristics.

a) ground water level;
b) pH water −Log (H^+);
c) percentage of salts and chlorides (NaCl);
d) sulfate ratio (SO_4);
e) average appearance of sand layer;
f) average appearance of the clay layer.

Digital maps were produced for each parameter individually using the MIDW method and GIS tools. The results are as follows:

6.1 Groundwater level variation

Groundwater is considered one of the most significant problems that affect the safety of facilities, especially the foundations of buildings. Water penetrates to many centimeters above the surface of the earth, which leads to damage to the elements of construction and building resources, thus reducing the life of the building and making it uninhabitable [23]. This water leads to the growth of fungi and bacteria in the building and the growth of mold inside homes, which greatly affects human health. It also affects cement and leads to a lack of good cohesion, corruption of the used wood, its bending, disintegration, and salting of floors, walls, and foundations. Figure 7 shows a digital map for representing the distribution of the final groundwater level index resulting from GIS using the MIDW method for the study area. The level of water was stable after 24 h of taking samples in each region of Kafr El-Sheikh governorate.

From Figure 7, it is deduced that the final water level in the study area varied between depths 1.5 and 6.50 m from the ground surface. The percentages and areas of each depth are calculated depending on the resulting digital map using GIS tools; the results are illustrated in Figure 8 and Table 1.

Therefore, it is recommended to make wells provided with pumps to transfer and withdraw water outside the site according to the level of the groundwater in the surrounding area. It is also preferable when using the pillars to dig them down to the strong soil and pour them with reinforced concrete according to the design that has been

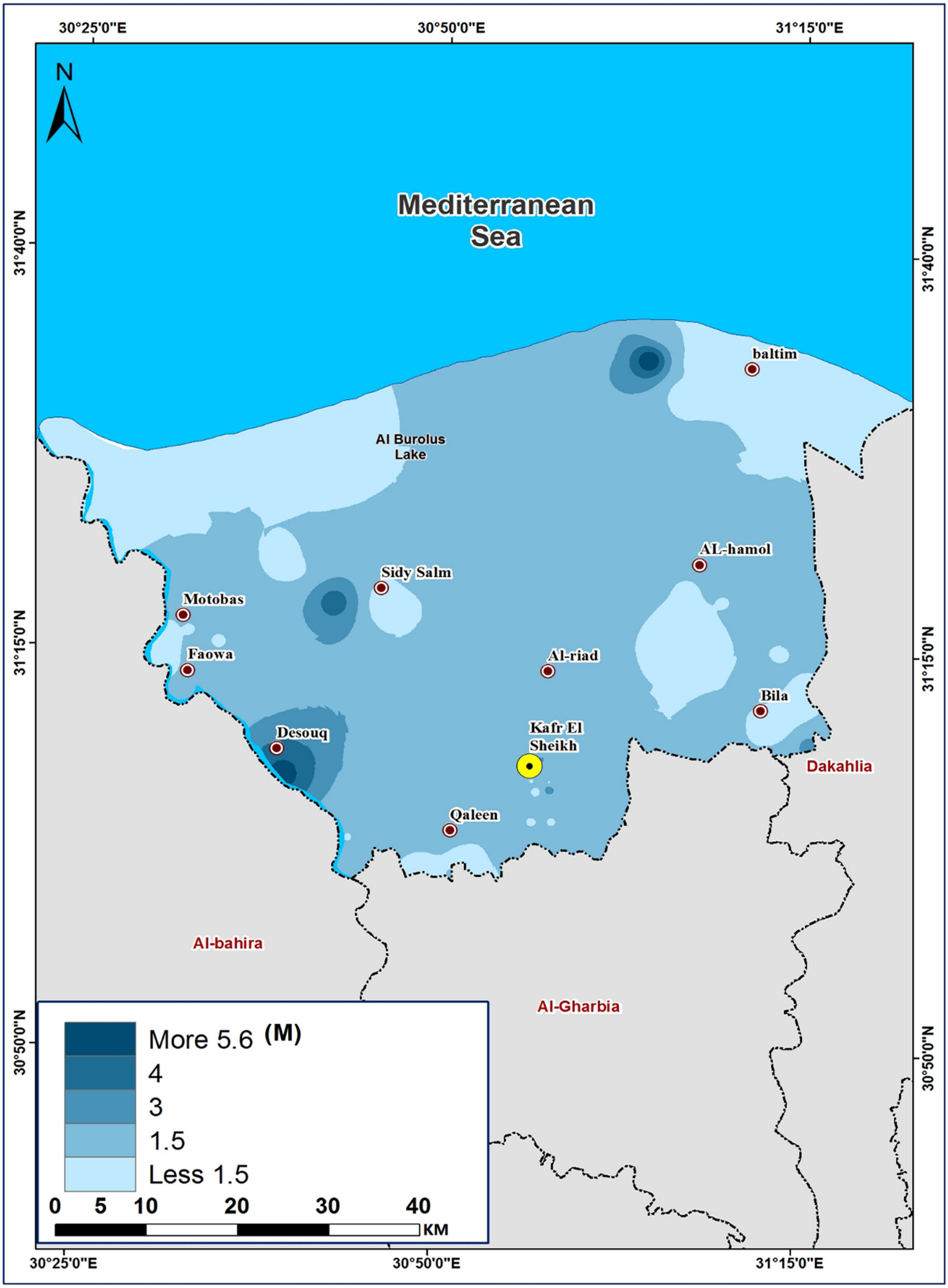

Figure 7: Digital map of final groundwater level index resulting from GIS using MIDW method.

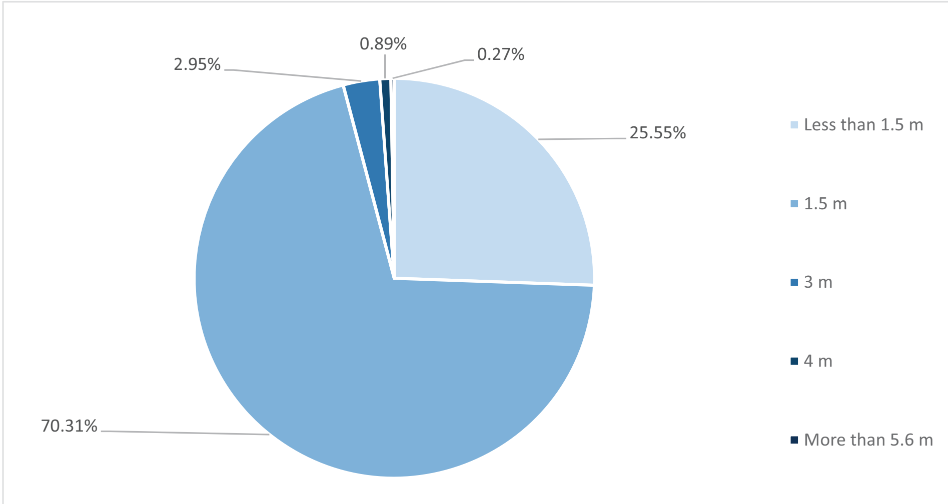

Figure 8: Final groundwater level percentages resulted from the created digital map.

Table 1: Final groundwater level areas and percentages resulted from created digital map

Grid Code	Area (km^2)	Percentage
Less than 1.5 m	979.7891	25.55
1.5 m	2697.007	70.31
3 m	114.1498	2.98
4 m	34.35236	0.89
More than 5.6 m	10.19678	0.27
Total	***3835.461***	***100***

prepared based on the weight of the equipment and the type of soil. In the case of mat foundations, it is preferable to replace the soil with the required depth to obtain the required tolerance, based on soil investigations at the site. It also is recommended to make a moisture-proof layer to prevent the rise of groundwater and the passage of moisture or water between building materials after pouring regular or reinforced concrete for the foundations, which should be continuous on all walls that have foundations below the level of the natural ground and be at a height of 15–20 cm so that its level is above the level of the earth surface to prevent moisture pathways to the floor.

6.2 Investigation of PH water values −Log (H$^+$)

Soil PH is one of the most important ways to determine soil characteristics. Soil PH value is used to measure the degree of acidity and alkalinity of water [24]. The PH value, which represents the danger limit, is limited to a narrow range, which requires extreme accuracy in determining its value. Knowledge of PH aims to assess the value of the elements that are present in water and soil such as free acids, sulfates, chlorides, magnesium, and aluminum [25]. Samples were withdrawn by a pump directly from inside the palpation hole and were immediately placed in clean, dry, prepared bottles in the sampling place with a capacity of 2 L. When conducting a chemical analysis test on samples of groundwater in the sites to determine the PH value as shown in Figure 9. The results of the study indicated that one side of the study area tends to alkalinity (acidity and alkalinity index greater than 7) and another side tends to acidity low salinity (acidity and alkalinity index less than 7). Most of the values were limited between 6.8 and 7.2 as shown in Figure 10. PH less than 6.5 indicates that the surface has a detrimental effect on concrete. Table 2 shows the total area of each indicator for the values extracted from the total area of the study area. The best results were obtained when the indicator was at the number 7, which means that it is the neutral and ideal result of water to reduce the dangers of ground water, whether it is alkaline or acidic, which affects the soil and permeates between its particles, leading to its loosening and increasing its salinity and thus its impact on foundations, buildings with its paints, wood, etc.

From the results, it is recommended to use special concrete mixtures and cement resistant to salts and sulfates. Concrete elements surfaces can also be coated with bitumen to form an insulating layer to isolate the concrete from water, especially the base layer. It is also preferable to use low-alkali cement in the case of alkaline water, which is cement-free of sodium or potassium oxides so that it does not interact with aggregates and active water.

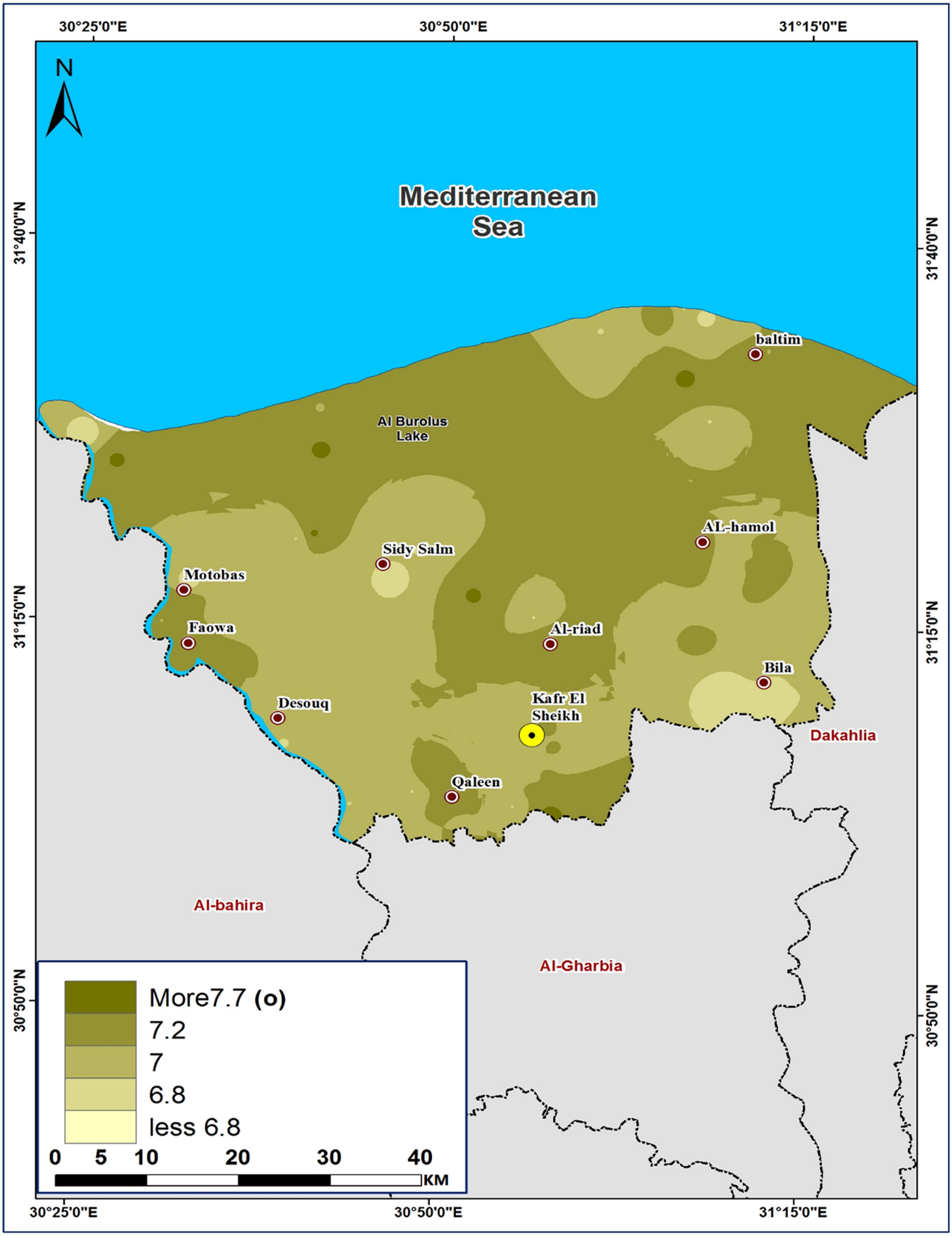

Figure 9: Digital map of Soil PH water index resulted from GIS using MIDW method.

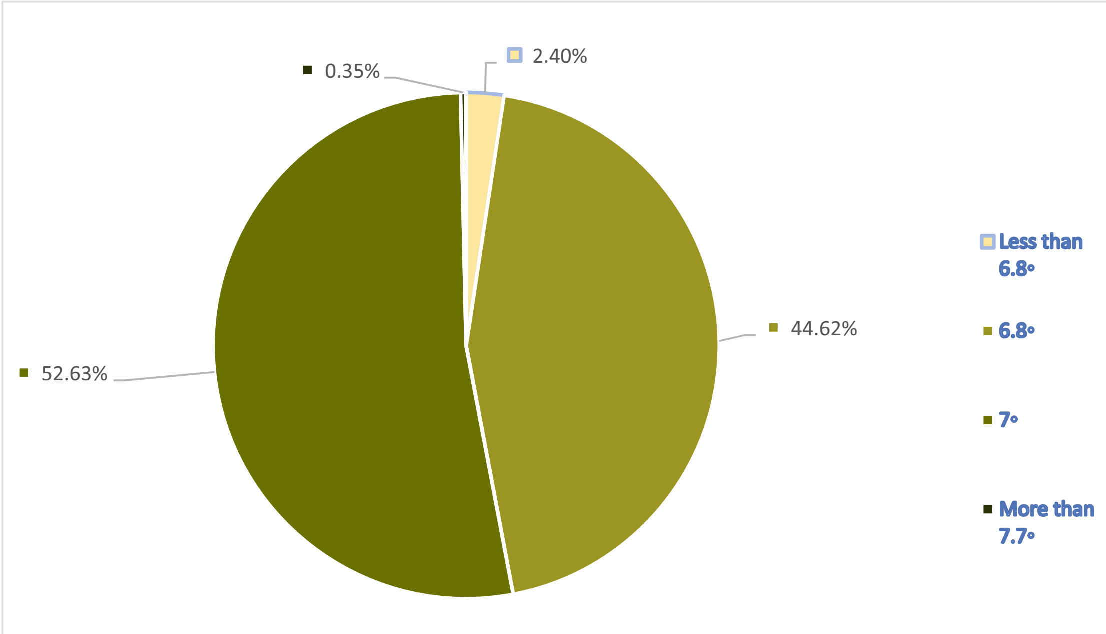

Figure 10: Soil PH water percentages resulted from created digital map.

Table 2: Soil PH water areas and percentages resulted from created digital map

Grid Code	Area (km^2)	Percentage
Less than 6.8°	92.191351	2.40
6.8°	1711.303	44.62
7°	2018.474	52.63
More than 7.7°	13.517224	0.352
Total	***3835.486***	***100***

Portland cement can be used, as it is characterized by high permeability and high density when used in concrete works, it is also resistant to sulfates and is characterized by a low hydration temperature, which qualifies it for use in thick concrete castings. Consider the intensification of concrete as much as possible.

6.3 Determination of the percentage of SALTS AND CHLORIDES (NaCl)

Sodium chloride is one of the most common salts, as it is present in many natural resources such as seawater, sand, rocks, and building materials [26]. Increased salinity of soil and water leads to corrosion of steel reinforcement, which causes cracking of the concrete cover and affects infrastructure such as roads and pipelines [27]. Depending on the laboratory investigations for collected 119 boring for a percentage of Salts and Chlorides and using MIDW interpolation technique, the digital map of the study area was created as shown in Figure 11.

From Figure 11, it becomes clear that the percentage of chlorides increases in the study area, where the largest percentage ranges between 2,000 and 6,000 mg L^{-1}. This is a normal situation for the Delta region, which is famous for its high salt contents as a result of the spread of the irrigation method by immersion and the non-imposition of fees for the use of water, and the lack of settlement which has led to the excessive use of the Nile water, which led to the waterlogging of the soil and the poor condition of the land drainage. NaCl area and percentages are shown in Figure 12 and Table 3.

From the results, it is recommended to use anti-salt cement, as it has an inherent property, which is its union with the chlorides present in concrete and turning it into harmless compounds. The permeability of concrete should also be reduced by adding pozzolanic materials to the concrete mix used below the ground surface to avoid corrosion of concrete and steel reinforcement. It is highly recommended to use good quality drinking water, and the salts in the grit should be disposed of by washing it well. An epoxy-coated iron should be used to delay the arrival of salts to it. Measures must be taken to provide a suitable drainage network, to dispose of wastewater away from the building, and to have good ventilation of the enclosed spaces to avoid condensation of water on the concrete and

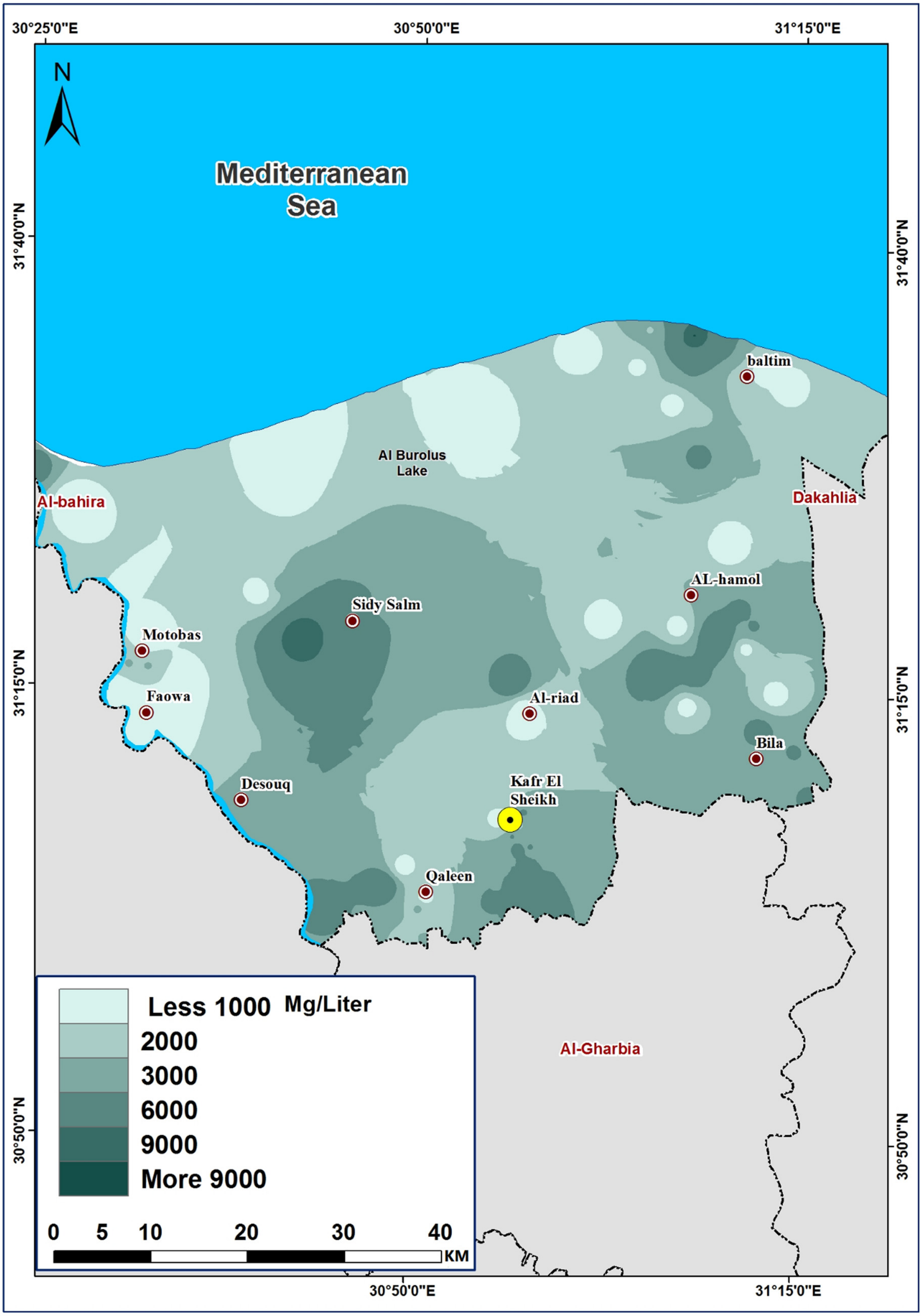

Figure 11: Digital map of NaCl values index resulting from GIS using MIDW method.

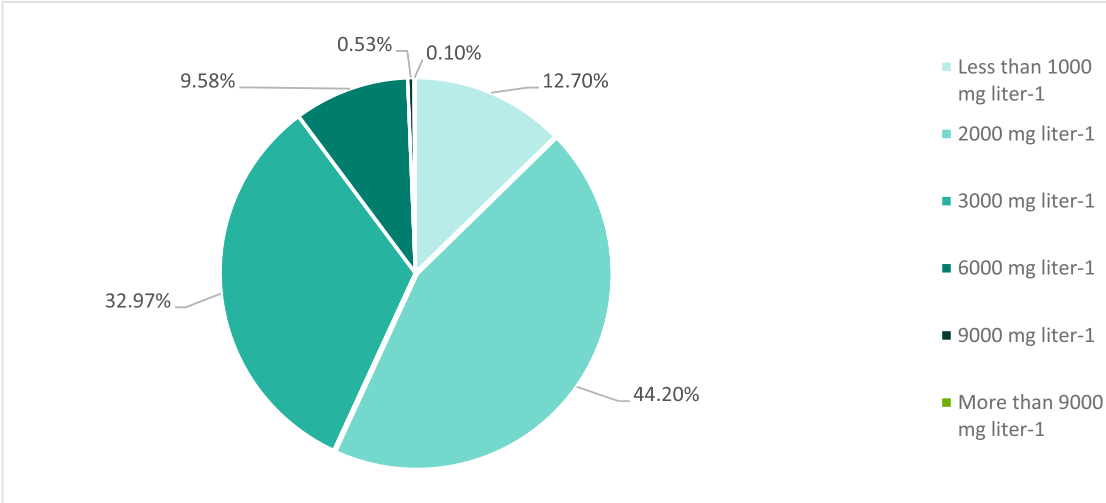

Figure 12: NaCl Percentages resulted from created digital map.

Table 3: NaCl Areas and percentages resulted from created digital map

Grid Code	Area (km^2)	%
Less than 1,000 mg L^{-1}	487.3825	12.70
2,000 mg L^{-1}	1695.628	44.20
3,000 mg L^{-1}	1264.658	32.97
6,000 mg L^{-1}	367.5576	9.58
9,000 mg L^{-1}	20.19719	0.53
More than 9,000 mg L^{-1}	0.045115	0.1
Total	***3835.641***	***100***

walls from the inside and to lay the foundations of the building above the groundwater level as much as possible to avoid the accumulation of dust, water, and moisture on the exposed concrete surfaces. Reinforcement steel must also be cooled by spraying it with water before pouring concrete and after the casting is finished. The concrete must be covered with wet burlap to avoid water evaporation.

6.4 Calculation of sulfate ratio (SO_4)

Studying the sulfate ratio is an important factor for foundation design. The increase in the proportion of sulfates in the soil and water may be a major reason for the destruction of concrete structures. Measuring this percentage is very necessary to maintain and avoid the resulting dangers. Sulfates chemically react with hydrated calcium aluminate or calcium hydroxide components in solid cement to produce sulfur crystalline compounds that cause concrete cracking and destruction, which is technically known as a sulfate attack [28,29]. Therefore, the reinforcement steel begins to be exposed to more erosion factors, and eventually, the concrete begins to crumble and lose its bond with the reinforcing steel, and the life of the concrete decreases significantly, so the concrete elements begin to chip and fall [28]. Hence, determining the amount of sulfate is vital to assess the damages before the reconstruction, restoration, and construction process. Based on the laboratory investigations for collected 119 boring for a percentage of sulfate ratio (SO_4) and using the MIDW interpolation technique, the digital map of the study area was created as shown in Figure 13. Sulfate Ratio areas and percentages are shown in Figure 14 and Table 4.

From the results, it is recommended to use sulfate-resistant Portland cement that conforms to the specifications in regular and reinforced concrete works for foundations at a rate not less than 400 kg per cubic meter of reinforced concrete and not less than 300 kg per meter cube of regular concrete. Concrete intensification is considered as much as possible, clean and graded Suez sand and gravel are highly recommended to be used in concrete and take all the aforementioned measures in the problem of chlorides. Low-porous concrete is used by compacting it well when pouring.

6.5 Average appearance of the sand layer

The appearance of the sand layer in Delta Egypt is vital for the selection of the foundation type and design and consequently the construction cost. Sandy soil is considered one of the good soils in the construction process due to its characteristics. It is characterized by a high percentage of pores in it, which makes it quick to drain and does not

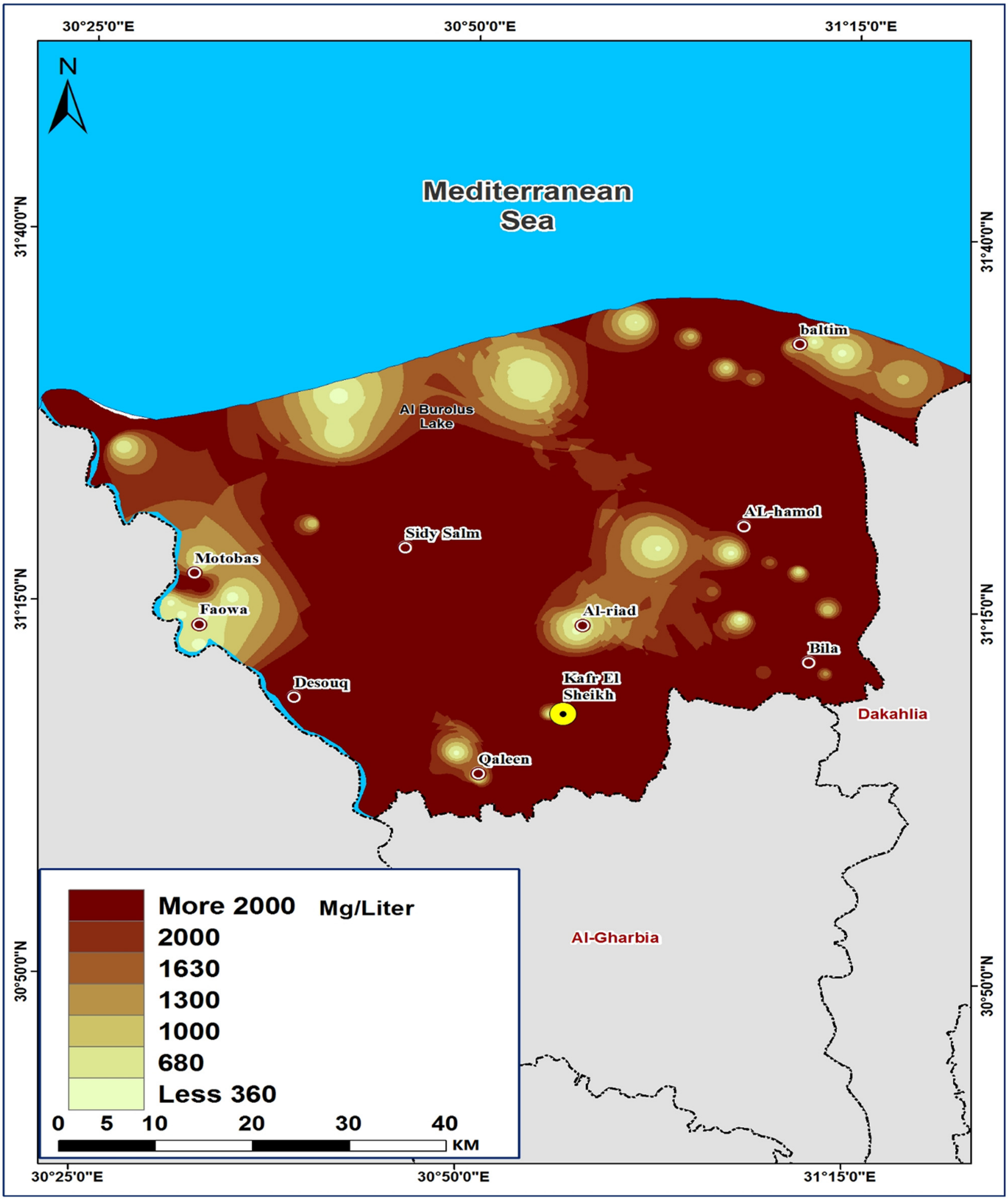

Figure 13: Digital map for SO_4 index resulted from GIS using MIDW method.

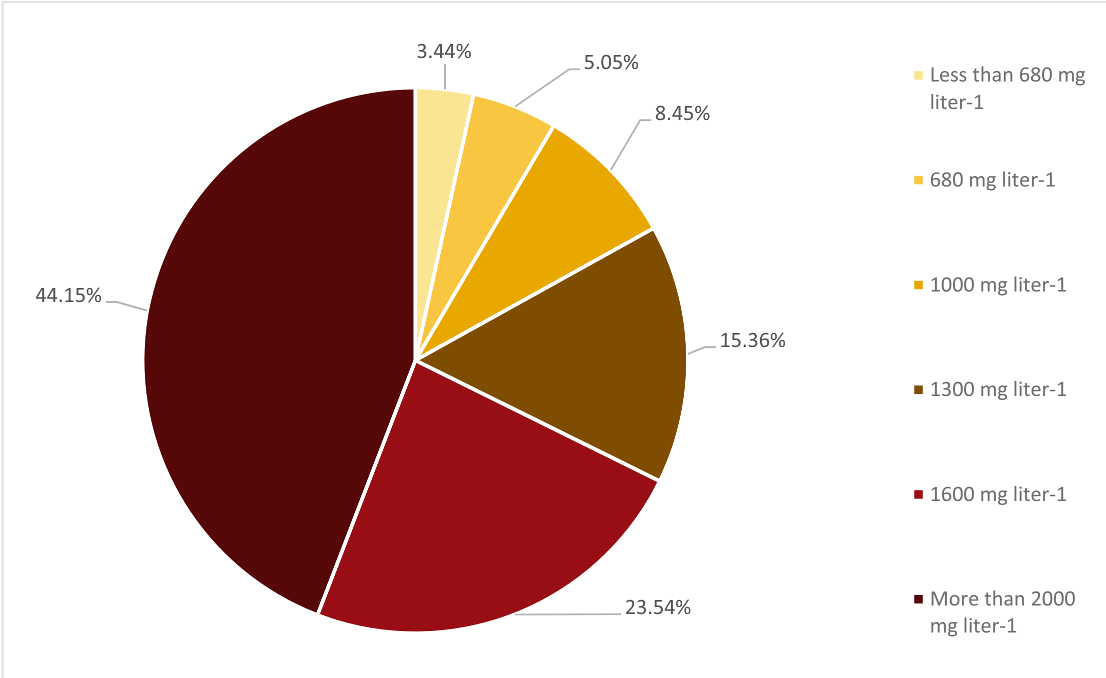

Figure 14: SO_4 Percentages resulted from created digital map.

Table 4: SO_4 Areas and percentages resulted from created digital map

Grid Code	Area (km^2)	Percentage
Less than 680 mg L^{-1}	132.04392	3.44
680 mg L^{-1}	193.8414	5.05
1,000 mg L^{-1}	324.1486	8.45
1,300 mg L^{-1}	588.9907	15.36
1,600 mg L^{-1}	902.9254	23.54
More than 2,000 mg L^{-1}	1693.511	44.15
Total	***3835.4611***	***100***

retain water. Sand has a rough texture that is not elastic or cohesive, and its size varies between the volume of gravel and silt. The size of sand particles ranges from 0.06 to 2 mm, so it is very small. Sand is classified under coarse-grained soils.

Depending on the results of all 119 borings and using MIDW and GIS tools, the digital map for the appearance of the sand layer was created as shown in Figure 15. From GIS tools, the areas for each section of resulting digital map for the sand layer can be calculated as shown in Table 5 and Figure 16.

From Figure 17 and Table 5, it is deduced that the level of appearance of suitable sand layer for construction ranges between a depth of 7 and 15 m in most of the study area, except for Balti city which is characterized by its sandy nature and thus the appearance of the sand layer at a depth of less than 7 m. Sandy gravel soils are considered one of the best sandy soils that support solid foundations, due to the availability of large particles in its components, and it is free from soft rocks. They are highly permeable soils, where the water is expelled in a short time, and thus, subsidence occurs in a short time and ends with the completion of the construction process.

6.6 Average appearance of the clay layer

Clay soil consists of small particles with a diameter of less than 0.002 mm [30,31]. Clay soil is effective because it retains moisture well; therefore, the level of its drainage is bad. When exposed to water, it shrinks and swells. Therefore, the possibility of its exposure to subsidence as a result of loads is very large, which may cause problems in the structure in case of lack of knowledge and a good study of that soil before the start of the foundation stage on it and taking technical and design precautions [31]. In the case of increased moisture of the clay soil, its volume increases

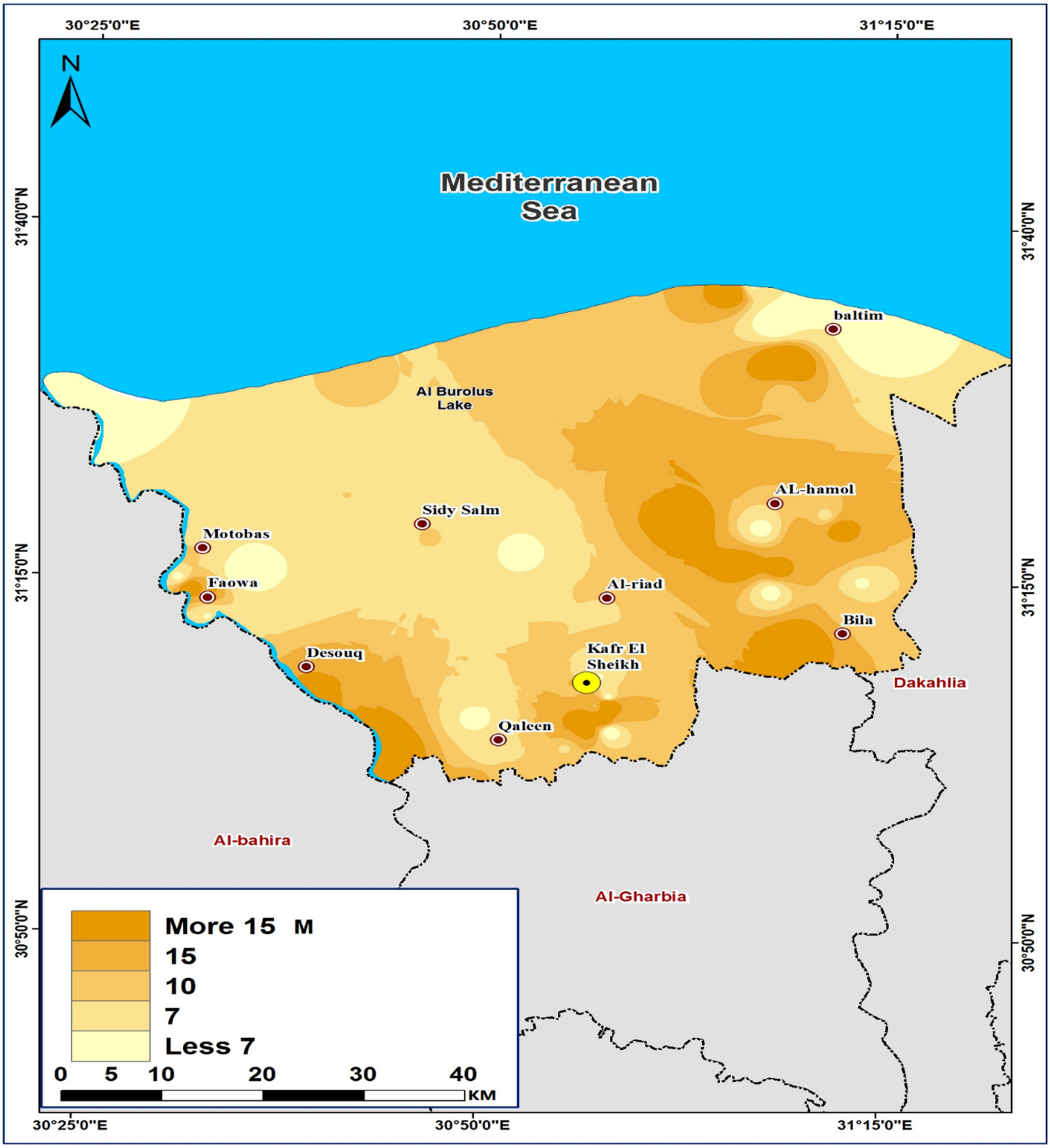

Figure 15: Digital map for the average appearance of sand layer Index resulting from GIS using MIDW method.

and is exposed to an eruption, which leads to cracks in the building. In the event of a lack of moisture and exposure to drought, its volume decreases, and cracks appear. Depending on the results of all 119 borings and using MIDW and GIS tools, the digital map for the appearance of the clay layer was created as shown in Figure 17. From GIS tools, the areas for each section of the resulted digital map for the clay layer can be calculated as shown in Table 6 and Figure 18.

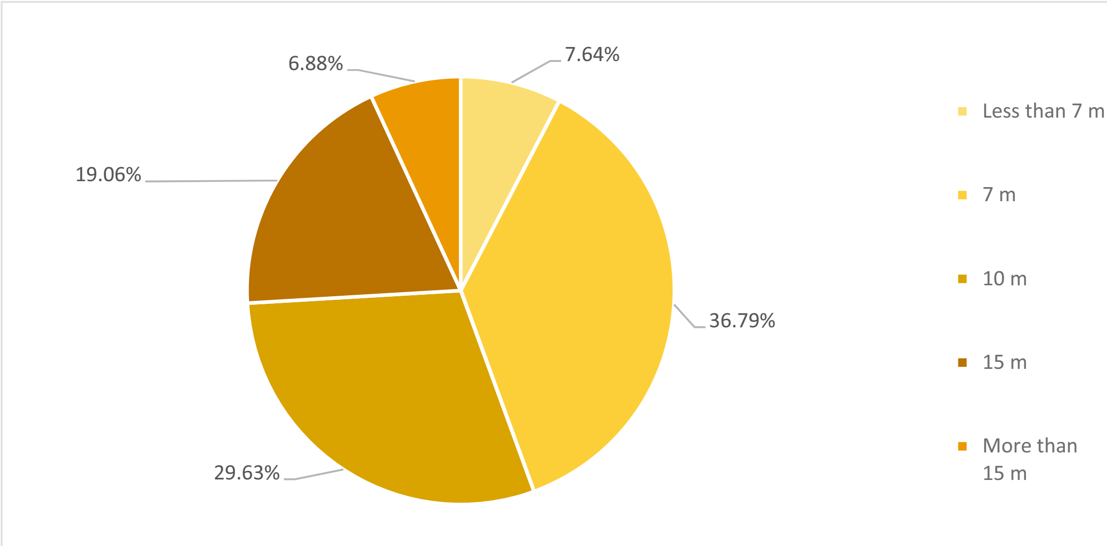

Figure 16: Average appearance of sand layer percentages resulted from created digital map.

Table 5: Average appearance of sand layer areas and percentages resulted from created digital map

Grid Code	Area (km^2)	Percentage
Less than 7 m	292.9969	7.64
7 m	1410.95	36.79
10 m	1136.29	29.63
15 m	731.1287	19.06
More than 15 m	264.1186	6.88
Total	***3835.461***	***100***

From the results, more than half of the study area shows the clay layer at a depth of fewer than 5 m as shown in Figure 18, and the rest of the area ranges between a depth of 8.9 and a depth of 18 as shown in the percentage ratio in Figure 18.

Therefore, when building on clay soil, it is recommended to use a high-quality aggregate filling process, which contributes to alleviating the effects of expanded clay in areas that contain soft clay soil. It is also preferable to increase the area of foundation bases and recycle water sources that affect soil moisture. It is also preferable to replace the soil if possible and use concrete covering the entire surface of the building in the design of the foundations. Loading the soil with loads equal to or more than the pressure of the loads that will be built on it is done by ramming and then removing it after a specified period.

7 Conclusions

This article investigates the possibility of producing digital maps for physical and geotechnical characteristics of soil based on GIS technology and remote sensing for the Kafr El-Sheikh governorate, one of the important governorates in the Delta region, Egypt, with the help of MIDW Spatial Interpolation technique. Depending on the previous experimental and field works, analysis, and numerical results obtained, the following conclusions can be summarized:

1. GIS technique is a good and effective tool to create digital maps and predict the properties of soil, identify its problems, and its ability to display them excellently and professionally, to be a reference for students, researchers, and engineers in various ways and different fields.
2. Creation of digital soil maps is the optimum choice for making the right decisions about building and construction processes on different types of soil accurately and professionally instead of the old traditional methods.
3. The MIDW interpolation method as presented was able to provide predictions about soil properties in places where one could not collect samples, and it is one of the best methods in this particular study.
4. It is preferable to establish on sandy soil because its load is greater as a result of the higher friction angle between the grains, as well as it is faster in pressure and is not affected by the rise and fall of groundwater. Therefore, it is safe to work from clay soil, since the problems of

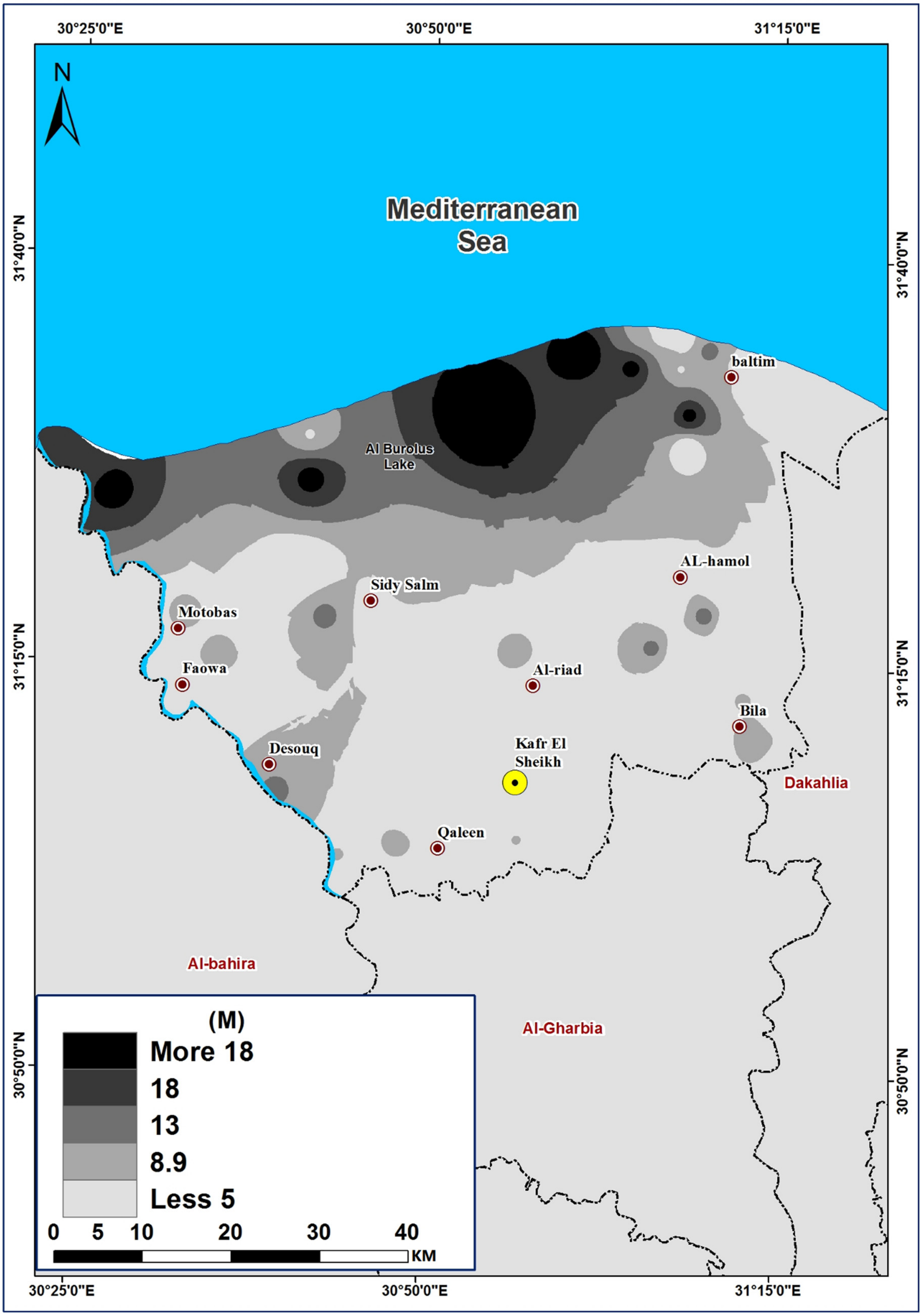

Figure 17: Digital map for the average appearance of clay layer index resulted from GIS using MIDW method.

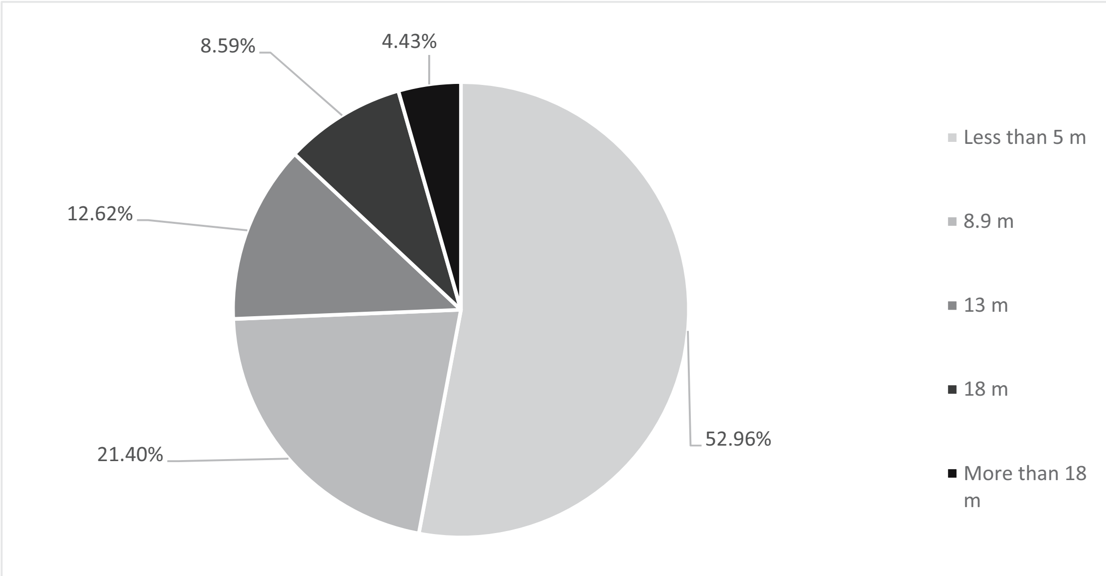

Figure 18: Average appearance of clay layer percentages resulted from created digital map.

Table 6: Average appearance of clay layer areas and percentages resulted from created digital map

Grid Code	Area (km^2)	Percentage
Less than 5 m	2031.136	52.96
8.9 m	820.8198	21.40
13 m	484.4159	12.62
18 m	329.3206	8.59
More than 18 m	169.7894	4.43
Total	***3835.461***	***100***

clay soil are many, as the soil stress is 1.1 kg/cm^2 for clay and 2.2 kg/cm^2 for sand.

5. The Delta region is one of the regions in which the percentage of chlorides, salts, and sulfates increases. Therefore, it is important to take this into account in the design and construction process by using materials that comply with specifications and conditions.
6. Care must always be taken to isolate all concrete, buildings, and basement walls below the level of the decks and all surfaces adjacent to the soil, using moisture-proof materials to avoid the problems that occur to the buildings.

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