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Production of geotechnical maps of the south-west of the city of Kirkuk using geographic information systems

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Abstract
After the Urban Development and urbanization of Kirkuk city in the past two decades, it has become necessary to turn to modern technologies to study the geotechnical properties of soils, and geographic information systems meet this necessity. The main objective of the study was to create geotechnical maps of the southwestern quarter of Kirkuk city, which is bordered by the private river to the East, Al-Badr neighborhood to the west, al-Quds neighborhood to the North, and the University neighborhood to the South, which particularly saves the cost of soil tests, time, and provides a quick source of information necessary for engineering projects. Geotechnical maps are widespread nowadays due to the presence of geographic information systems (GIS) the maps in this depth study were created by the ArcGIS program using the IDW method. In this study, (17) samples were collected to determine the characteristics that were determined for the study and to classify the soil to subsequently assess the permissible bearing capacity. The results of geotechnical examinations of the soil and the resulting maps to a depth of (2m) showed that the study area is dominated by alluvial soils with low plasticity with small areas of gravel soil north of the study area and small areas of clay soil south of it. The moisture content is between (1. 8% -16. 9%), the plasticity limit is between (0% -26%), the liquidity limit is between (0% -48%), the plasticity index is between (0% -26. 6%).

Keywords: Neighborhood, subsequently, determined

Introduction

It is also known that one of the tasks of a geotechnical engineer is to predict the behavior and performance of soil as a structural material or as a bearing material for construction works (Bowles, 1984) [1]. Accordingly, the soil assessment starts from the exploration phase and the collection of available information through the investigation phase, which provides the necessary information for the preliminary studies of the projects (Bowles, 1984) [1]. The documentation of such data was previously done using traditional means of paper tables and reports, and these always need maintenance and preservation, in addition to organizing the data in order to make it easy to refer to them later, and this is difficult to follow up, because the information of the properties of engineering soils varies by location on the Earth, so it is appropriate to (Khattab and Abd, 2013) [2]. The idea of the study is to create digital geotechnical maps of some soil properties for the southwestern quarter of the city of Kirkuk and the possibility of giving an initial idea and presenting it through Geographic Information Systems Technology, which may help the engineer, planner, decision makers and those interested in this topic to identify the soil properties in an initial, easy, fast and economical way for investigation and project construction operations as well as the benefit from the planning of cities and studies for the work of tunnels, laying railways and other other projects (Khattab and Abd, 2013) [2]. The idea of the study is to create digital geotechnical maps of some soil properties for the southwestern quarter of the city of Kirkuk and the possibility of giving an initial idea and displaying it through Geographic Information Systems Technology, which may help the engineer, planner, decision-makers and those interested in this topic to identify the soil properties in an initial, easy, fast and economical way for investigation and project construction, as well as benefit from the planning of cities and studies for tunnels, railway laying and other projects.

In recent years, researchers have turned to the adoption of geographic information systems in multiple engineering fields and dozens of studies have been carried out to analyze the geotechnical properties of soils in many regions of the world through the production of geotechnical maps and analysis of the areas studied, examples of these areas are the southern parts of the Indian province of Chennai and another study in the Saudi city of Riyadh as well as in the Portuguese city of covelha (Cavaleiro, 2006) [4] in addition to the Palestinian city of Nablus, the Algerian city of Saida (Al Gbory, 1988) [5] and the Brazilian city of Sao Paulo (Mendes, 2010) and the Indian city of Bangalore and in Iraq it took place in the Iraqi city of Baghdad / Rusafa.

Study Area

The city of Kirkuk is located in northern Iraq and connects the northern provinces with the central provinces. the urban area of the city is approximately (121,420) km^2, which is 350 meters above sea level. Most of the area of the city is flat land with undulating lands in the northern part of it. the special river passes from inside the city of Kirkuk, which is a seasonal river with a length of (190) km and passes (16) km of it from the city center. the river contains several small dams. The study area is located between the coordinates (X 444000-Y 3924000) northeast, (X 438000_Y 3924000) northwest, (X 444000_Y 3914000) Southeast and (X 438000_Y 3914000) Southwest, and (X 438000_Y 3914000) the area of the study area is approximately (34662) square kilometers. As shown in below Figure 1.

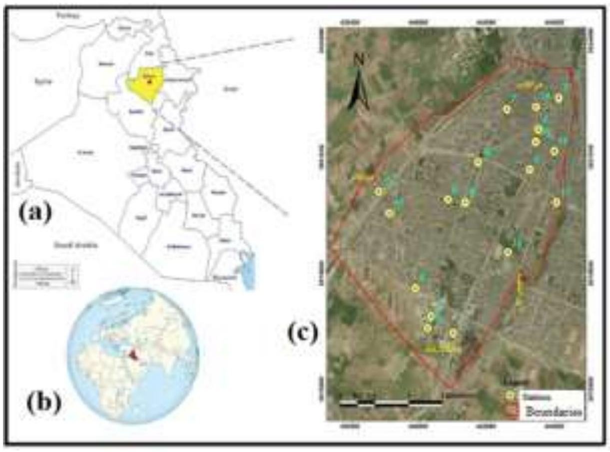

Fig 1: Map of the study area: (a) Map of Iraq. (b)World map. (c)Visual image of study area.

The Soil Geotechnical Tests

1. The Moisture Content

Moisture content is defined as the percentage by weight of water present between the voids of the model to the percentage by weight of the solid material of the model, the moisture content is closely related to the durability of the soil and its resistance to various processes (thawing, freezing, modulus of elasticity, tensile and compressive resistance) where the soil resistance to previous processes decreases as the moisture content increases. The process of measuring the moisture content was carried out using the method approved by the American Society for the examination of materials known.

2. Grain Size Test

This examination is used at a global level in soil classification, through which the suitability of the soil for engineering works, such as dams, roads and other institutions, is determined. The method approved by the American Society for material inspection (ASTM D422, 2014) was used to obtain the results of granular gradation, where the examination was carried out in the examination at the National Center for structural laboratories and research in Kirkuk. The volumetric distribution of the grains that make up the soil is expressed as a percentage of the weights of varieties of different granular sizes (Wilun & Starzewski, 1975). Granular size is also considered one of the most important geotechnical properties of soils, as it is a function of soil (Index Properties) (Das, 2014). To extract the values of the weight percentage of soil contents, two methods can be used, namely, the method of mechanical examination (sieved) as well as the method of wet analysis (hydrometric). The method of mechanical analysis (sieved) is used to isolate coarse grains such as gravel and sand in the soil by moving the sieves manually or mechanically, as the sieves have standard openings designed according to American International specifications (ASTM D421, 2014).

3. Atterberg Limits

It is the percentage of moisture content (water) in the soil at the limits where its state changes, as all types of soils have a clear effect and different behavior when the percentage of moisture content changes, especially clay soils are clearly affected. The Swedish scientist Atterberge was the first to address the establishment of limits on the strength of soils in (1911). And classify the transition boundaries or boundaries separating cases based on the percentage of water, known as Atterberg Limits or Consistency limits:

- Liquid limit.
- Plastic limit.
- Shrinkage limit.

Results and discussion

Table 1: Shows the values obtained as a result of geotechnical examinations

Stations	M.C%	L.L%	P.L%	P.I%	Clay%	Silt%	Sand%	Gravel%
1	15.8	39	15	24	32	56	12	0
2	2.5	----	----	----	6	11	53	30
3	1.8	----	----	----	3	8	36	53
4	15.9	48	26	22	55	41	4	0
5	14.1	37	13	24	34	49	13	4
6	11.2	38	16	22	48	44	4	4
7	----	35	15	20	27	59	12	2
8	12.4	41	25	16	43	56	1	0
9	1.9	----	----	----	4	5	29	62
10	17	28	10	18	40	51	9	0
11	15.8	34.94	17.31	17.63	25	65	10	0
12	12.8	43.76	17.13	26.63	40	55	4	1
13	11.2	32.59	16.23	16.36	28	60	12	0
14	8.5	----	----	----	18	60	22	0
15	13.8	33.76	16.43	17.33	----	----	----	----
16	11.6	35.9	22.8	13.1	----	----	----	----
17	11.3	35.1	21.2	13.9	----	----	----	----

The following are the results of the tests and the maps produced for the studied parameters of the geotechnical properties of the soil depth (2m), which help engineers and decision makers to make initial decisions with a short period of time and the lowest possible cost. The maps in this letter were prepared by the IDW method and using the ArcGIS program for the depth studied. The results showed that the maps that were produced could be used for the preliminary study of projects, after indicating the error rate based on the data of the two sites (6, 12) that were used to indicate the possible error rate. The discussion of the results obtained also includes Table 1.

Moisture Content

The obtained moisture content values were used for (17) sites where an Interpolation Map was created to find out the water content to a depth of (2m) and indicate its change from one place to another in the study area, when determining the moisture content by percentage (%), varying percentages were obtained, as the lowest moisture content appeared in the areas (Jerusalem neighborhood and parts of the teachers ' neighborhood) by (1. 8% - 4. 8%) located in the north - eastern part of the study area and surrounding areas, the moisture content ranged between (4. 8% -7. 8) as for the northern part of the study area to its center, the moisture content ranged from (7. 8% - 10. 8%), as for the largest part of the study area, which was represented by parts of the Northeast and even the West and south of the region, the moisture content in it was (10. 8% - 13. 9%), the moisture content peaked in the south of the study area represented by (University District) and parts of the areas adjacent to the special River were (13. 9% - 16. 9%), Table 1 and figure 1, it was noted that the prevailing value of moisture content in the study area is (10. 8% - 13. 9%). The moisture content of the site number (6,12) that was extracted from the laboratory examination is (12. 8%, 11. 2%), but when deleting the output from the mentioned sites and drawing the map, the value of the moisture content predicted by the program becomes (10. 95%, 12. 1%) for the site, that is, the error rate is estimated (15%) approximately. Moisture content is closely related to the granular sizes, the mineral composition of the granules, porosity, permeability and precipitation, soft-grained soils (clay and silt) have a high moisture content due to the capillary property that raises groundwater to higher levels, while coarse-grained (sand and gravel) have a lower moisture content due to the large voids between their grains, and the moisture content is inversely proportional to the values of shear coefficients of the soil.

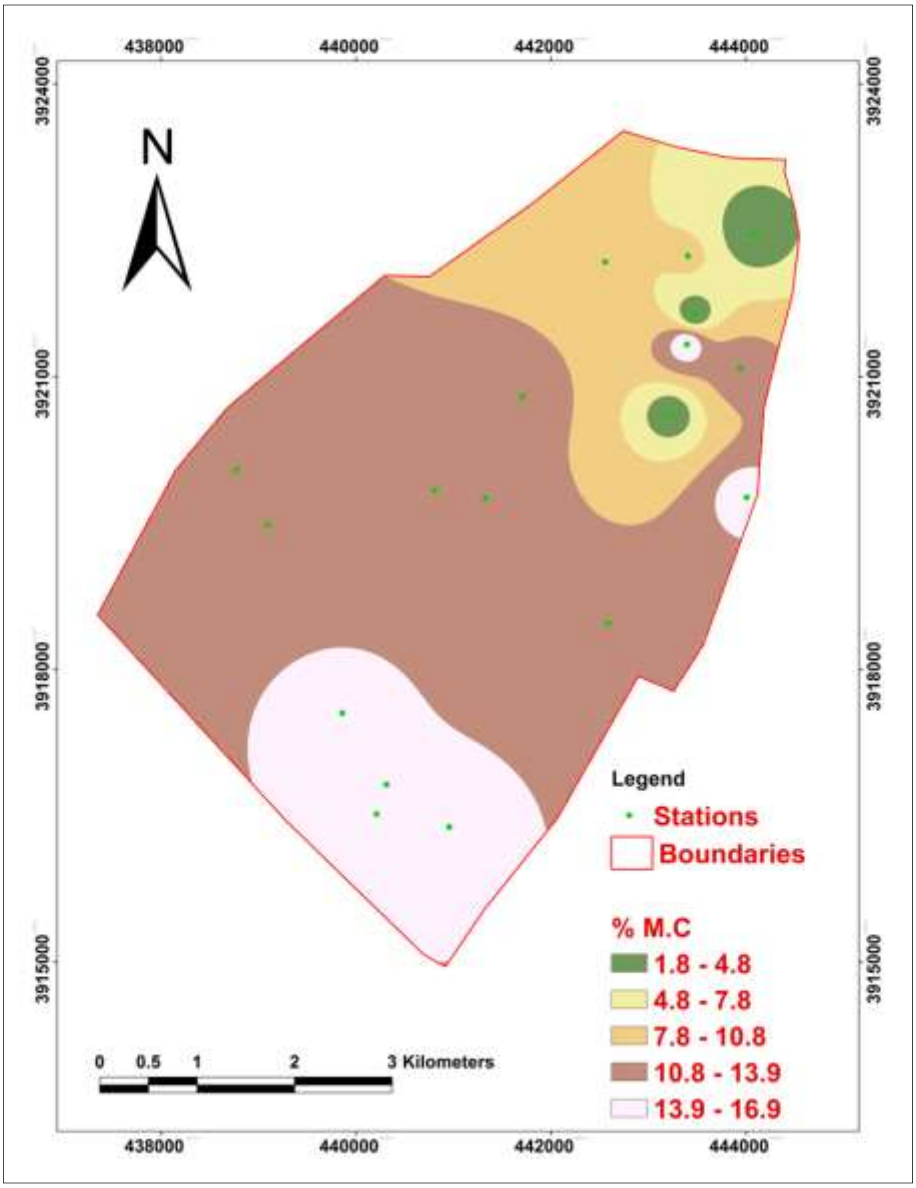

Fig 2: The spatial interpolation map of moisture content is spatially equipped with UTM units

Grain Size

The weight ratios of the obtained granular sizes were used for (14) sites where a spatial interpolation map was created to find out the weight ratios of granular sizes to a depth of (2m) and indicate its change from one place to another in the study area, when expressing the weight ratios of granular sizes by percentage (%) varying weight ratios were obtained, and in general the soil of the study area at the studied depth is soft soil because soft soil (clay, Silt) more than (50%) except for the two sites (2,3,9) the percentage of coarse grains is more than (50%), where showed that soils with coarse-grained sizes (sand and gravel) are more stable than soils with soft-grained (clay and silt), the following are the laboratory results and maps resulting from the study and the possible error rates:

Sand

The weight ratios of sand in the study area vary from one region to another, but the prevailing percentage was between (1% - 21%), which occupied more than (80%) of the study area at the depth indicated in the study, while the peak weight ratio of sand was (42% - 52%), which was represented in part of the Granada region in the north-eastern part of the study area. Table 1 and figure (1-2), where the percentage of possible error in the resulting map is about (20%) based on the data of the two stations (6,12), the laboratory results for them were (4%), but after deleting the data of the two stations and drawing the map, the values of each became (5%, 14%).

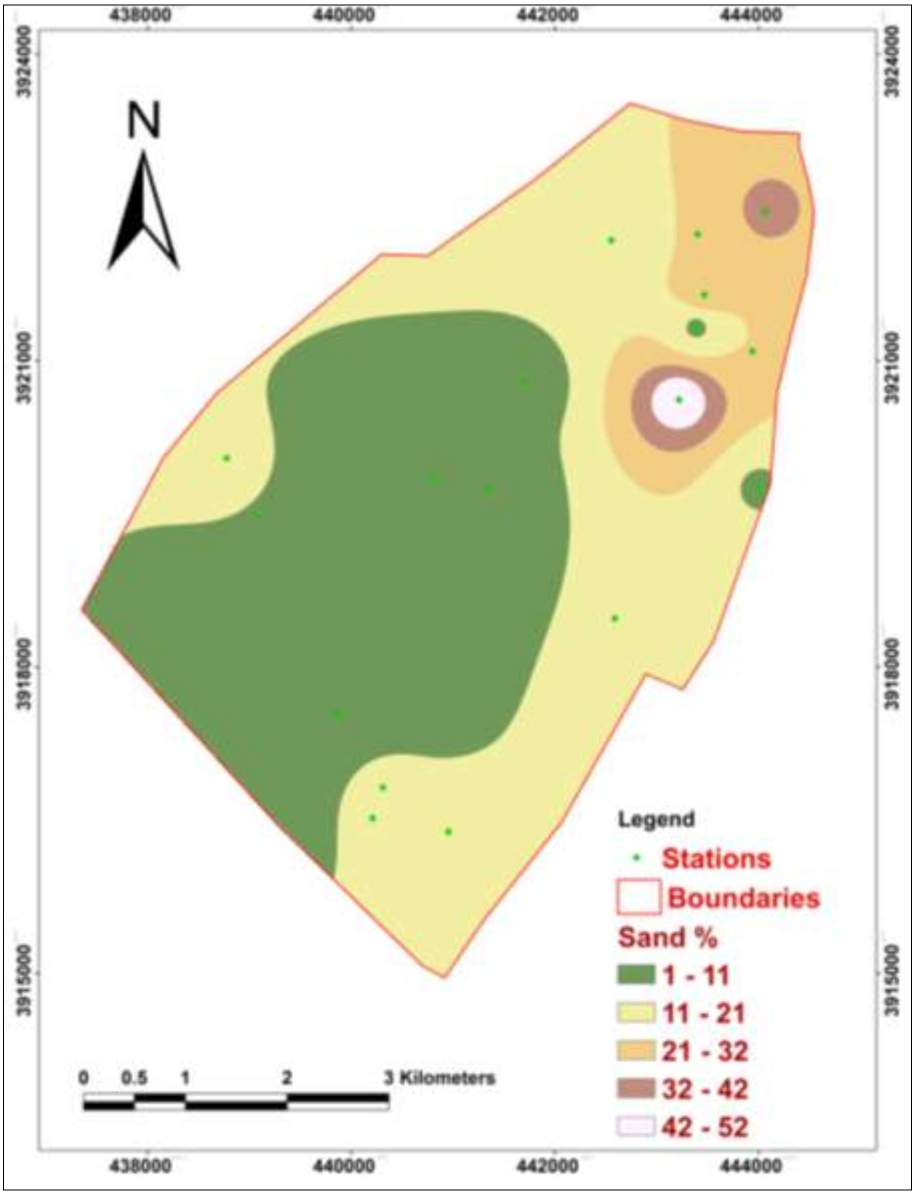

Fig 3: The spatial interpolation map of the sand ratio is spatially equipped with UTM units

Silt

The weight ratios of silt in the study area are different from one region to another, but the prevailing percentage was between (40%-52%), which occupied about (80%) of the study area at the depth indicated in the study, while the peak weight ratio of sand was (42%-52%), which represented most of the study area except some northern parts and small scattered parts of the study area, Table 1 and Figure 1, as the percentage of possible error in the map is less than (20%) based on the data of the two sites (6,12), as the results of the laboratory examination of the two sites (44%, 55%), but after deleting the data of the two sites and drawing the map, the program predicted that the percentage of green weight in the two sites is (52%, 44%).

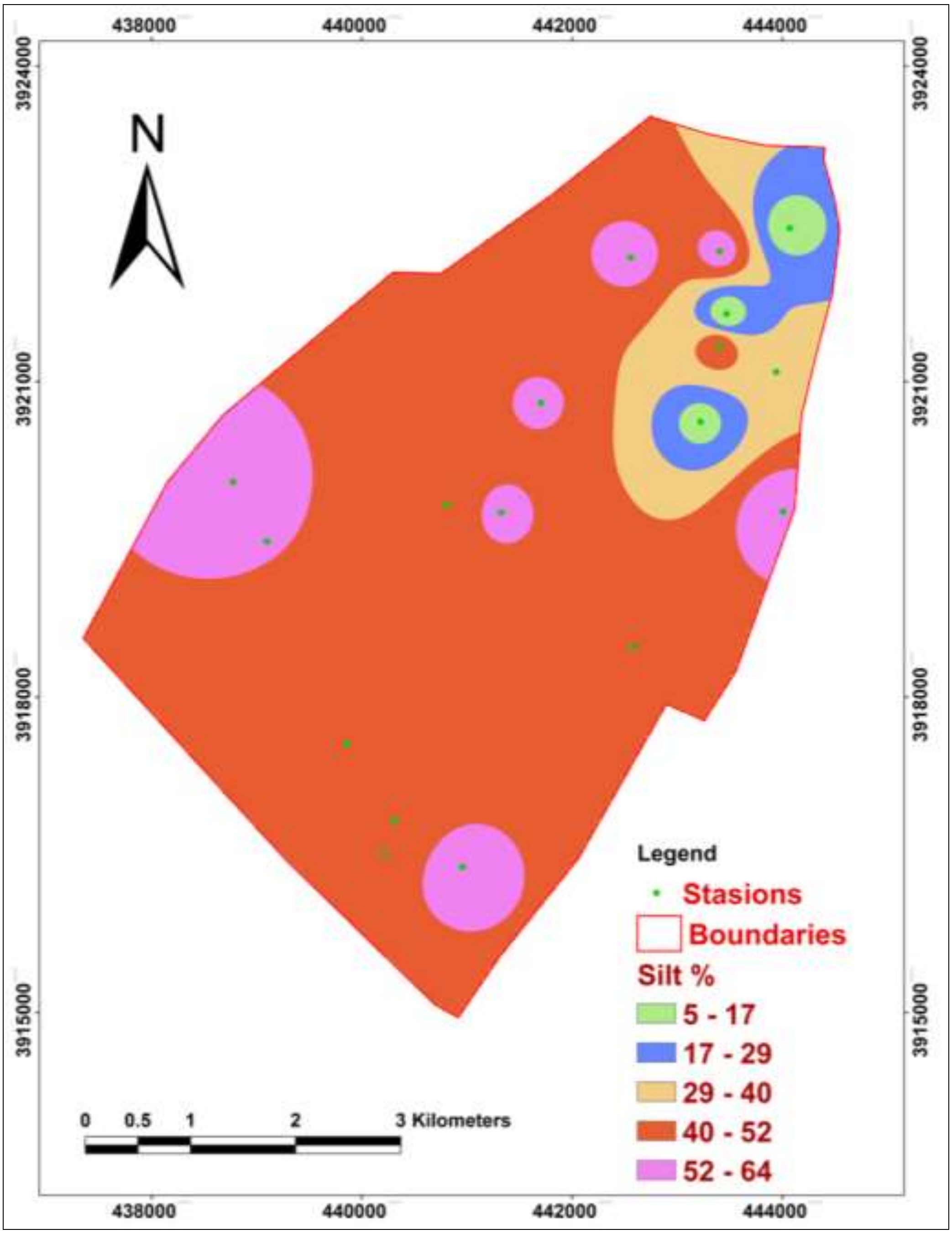

Fig 4: The spatial interpolation map of the grain ratio is spatially equipped with UTM units

Clay

The weight ratios of clay in the study area are different from one region to another, but in general, the study area is divided into three predominant areas, the first ranged between (13% -23%), which occupied the northern part of the study area, the second range ranged between (23% - 34%), which occupied the center and some sides of the study area, the third range ranged between (34% -44%), which occupied the south to the middle of the study area at the depth indicated in the study, the peak weight ratio of Clay was (44% - 54%), which was represented by two sites in the southern part of the study area (university district and one March), and the lowest percentage of clay weight was in the northern part of the study area, ranging between (3% - 13%), Table1 and Figure 1. The percentage of possible error in the spatial interpolation map of the weight ratios of clay is (22%) based on the data of the two sites (6, 12), whose values resulting from the laboratory examination were (48%, 40%), while the values predicted by the program are (38%, 31%).

Gravel

The study area is characterized by the fact that the weight ratio of gravel in the overwhelming majority of the area at a depth of (2m) is less than (12. 4), the weight ratio of gravel increases towards the north of the study area, where it reached its peak in two locations far north of the study area, reaching (49. 6 – 62) represented in the area (Jerusalem neighborhood) Table 1 and Figure 1. The error rate in the map was determined based on the data of the two sites (6, 12), where it appeared that the error rate is approximately (20%), as the weight ratio of gravel in the laboratory examination of the two sites (4, 1) while its percentage in the map predicted by the program after deleting its data is (3, 10).

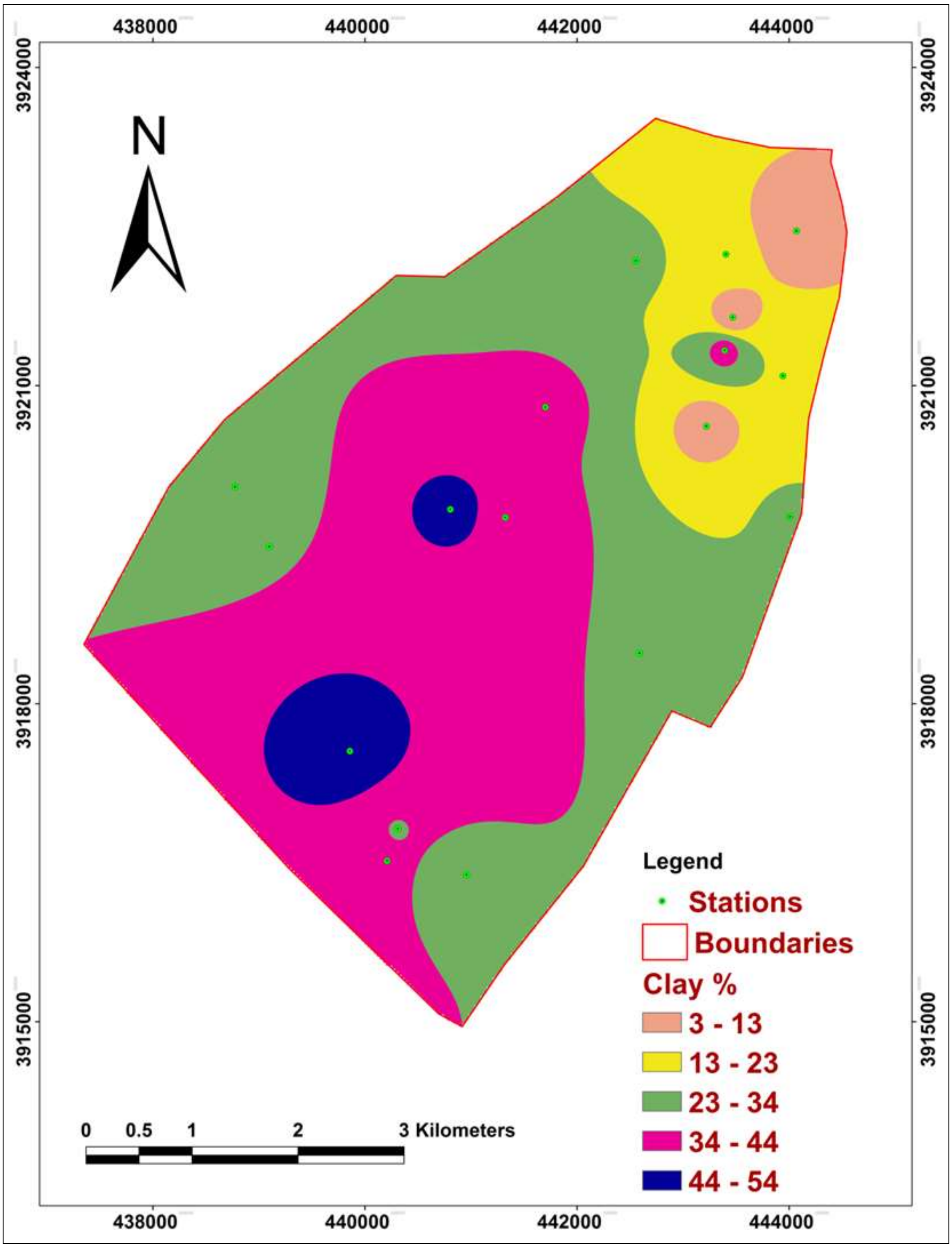

Fig 5: The spatial interpolation map of the clay ratio is spatially equipped with UTM units

Atterberg Limits

It is the percentage of moisture content (water) in the soil at the limits where its condition changes, since all types of soils have a clear effect and different behavior when the percentage of moisture content changes, especially clay soils are clearly affected. The study showed that the plasticity limit values are directly proportional to the percentage of fine grains (clay), and that gypsum helps to increase the plasticity limit and the liquidity limit, and also leads to a decrease in the values of the plasticity guide, If the classification of (Kerbs & Walker, 1971) is taken as the basis for describing the liquidity limit values obtained in the study area, we find that the sites where the soil consisting of clay with a high percentage and silt have an average liquidity limit, while the soil consisting of silt with a high percentage and sand have a high liquidity limit. Based on (Mitchell, 1993), who expressed through the Casagrande scheme that soils with a liquidity limit of less than (30%) are non-cohesive soils, therefore, one site of the study area with non-cohesive soils, site Number (10), which represented a small area north of the study area in the resulting map. The plasticity index can also be classified based on the classification sites (7-17) can be described as medium-plasticity soils, while sites (1, 4, 5, 6, 12) as high plasticity. The following are the results (Table 1) and maps of the Waterberg coefficients:

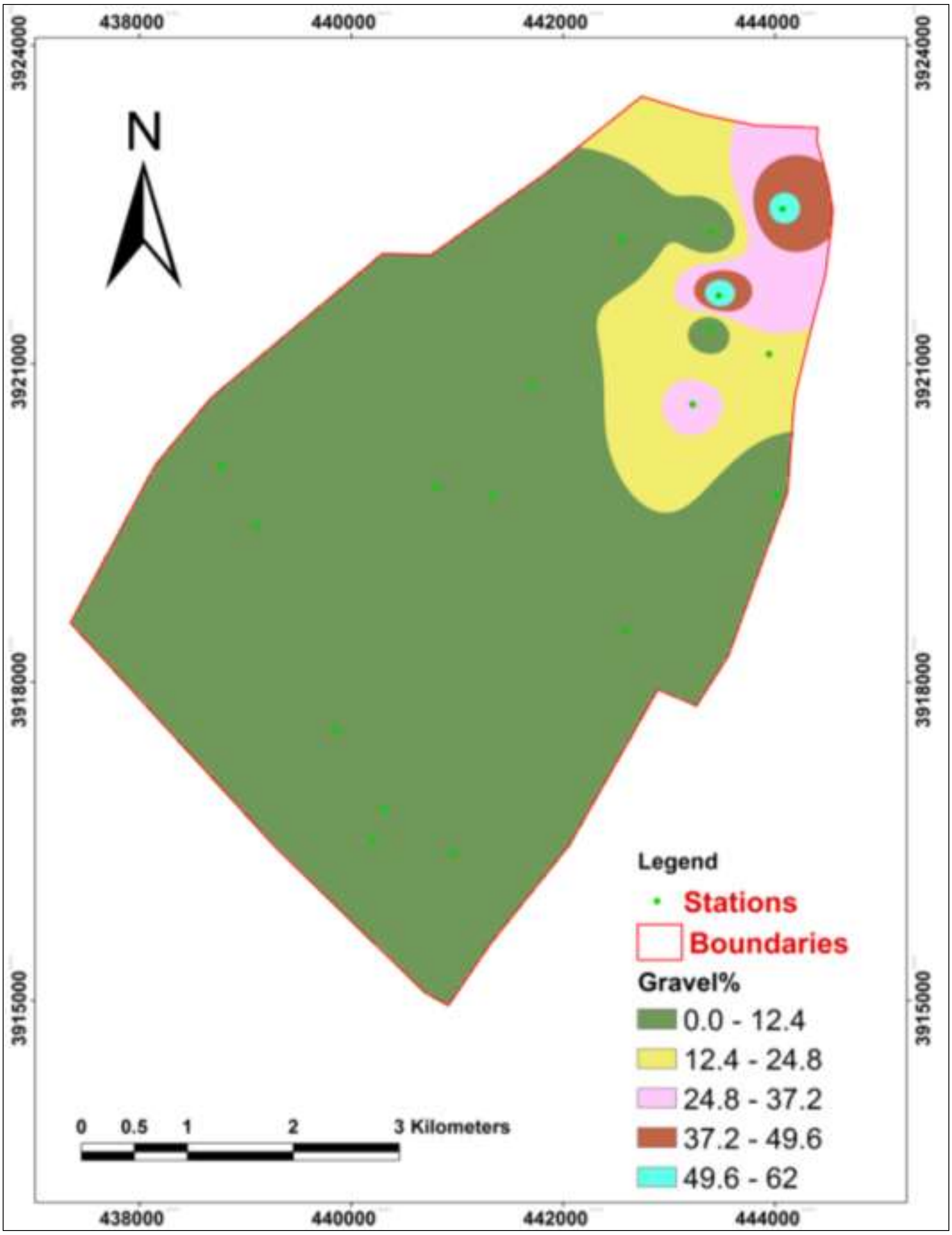

Fig 6: The spatial interpolation map of the gravel ratio is spatially equipped with UTM units

Plastic Limit%

The plasticity limit values were calculated based on the results of an examination of(17) sites, where the map resulting from the results of the examinations showed that the study area is generally divided into three areas, the northern part of it and part of the south of the study area represented by(Koods and part of the University District) the plasticity limit ranged (13. 2%-16. 4%), the second range was represented by (Wahed Aathar, Hozayran and sayada) the plasticity limit ranged between (19. 6%-22. 8%), as for the third range, which was represented by parts of the central and southern study area where the plasticity limit is uniform (16. 4 – 19. 6), Table1 and Figure1. The percentage of possible error in the resulting map based on the data of the two sites (6,12) is about (25%), where the value of the plasticity limit resulting from laboratory tests is (16, 17. 13) while the value predicted by the program is (22. 4, 18. 6). The study showed that the plasticity limit values are directly proportional to the percentage of fine grains (clay), Gypsum helps to increase the plasticity limit and the liquidity limit, and also leads to a decrease in the values of the plasticity guide.

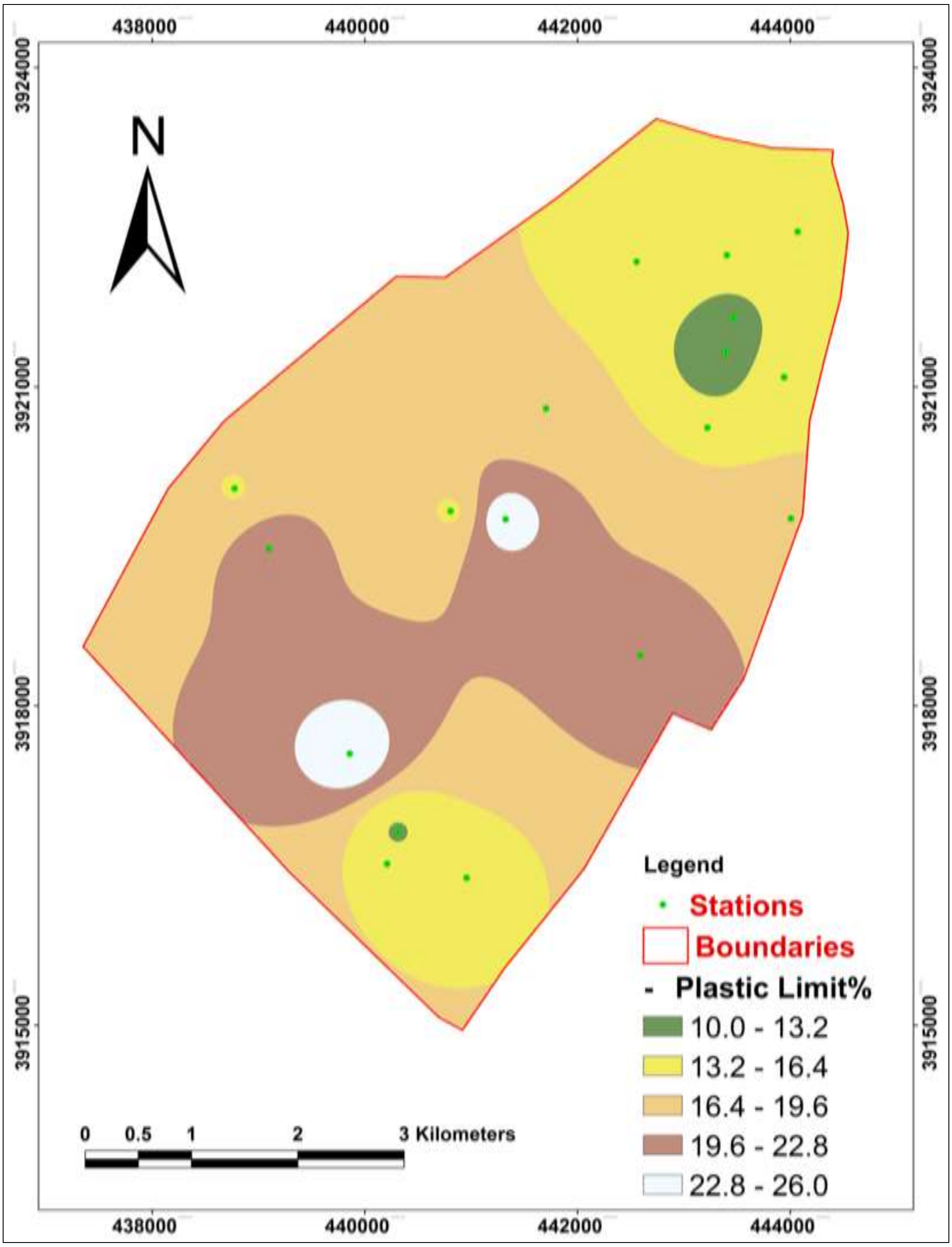

Fig 7: The spatial interpolation map of the Plastic Limit is spatially equipped with UTM units

Liquid Limit%

A geotechnical liquidity limit map was produced based on the results of tests for(17) sites from the study area, the resulting map showed that the lowest value of the liquidity limit is in the north of the study area, represented by part of the koods neighborhood area, where it ranged (28% -32%) and the liquidity limit reached its peak in the south of the study area, specifically in the area of Madinaty complex, where it ranged (44% -48%) and in general, the liquidity limit increases in the south of the study area, table (1-1)and Figure(1 -7), and that the percentage of possible error in the resulting map is less than (20%) based on the data of the signatories (6,12), whose data was before deletion (38%, 43. 76%), but after deleting its data, the program predicts that its values are (39. 6%, 36. 7%).

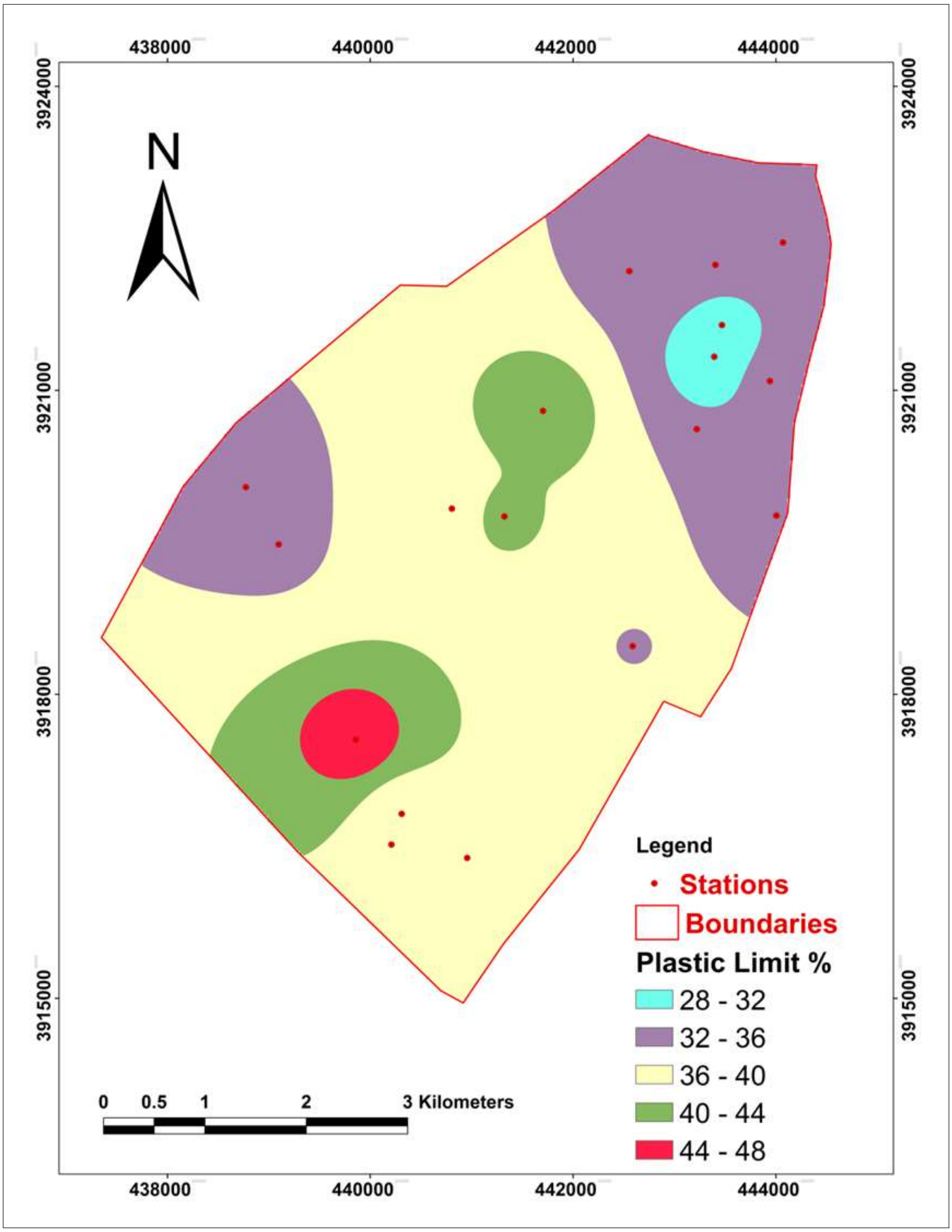

Fig 8: The spatial interpolation map of the Plastic Limit is spatially equipped with UTM units

Plastic Index

A geotechnical map of the plasticity evidence was produced based on the results of examinations of (18) sites from the study area, the resulting map showed that the study area is distributed in general, the three main areas are distributed in the study area, and it also showed that the most range that occupies the study area ranges from (18. 5% -21. 2%) that extended from North to south of the study area, the second range that occupied a large part of the study area ranged from (15. 8% -18. 5%), the the third, which also occupied a large area of the study area, ranged in plasticity evidence (21. 2% – 23. 9%), table (1–1) and Figure (1-8), and the percentage of possible error in the resulting map is less than (20%) based on the data of the signatories (6,12), whose data were before deletion (22%, 26. 63%), but after deleting their data, the program predicted that their values are (17. 7%, 18. 2%).

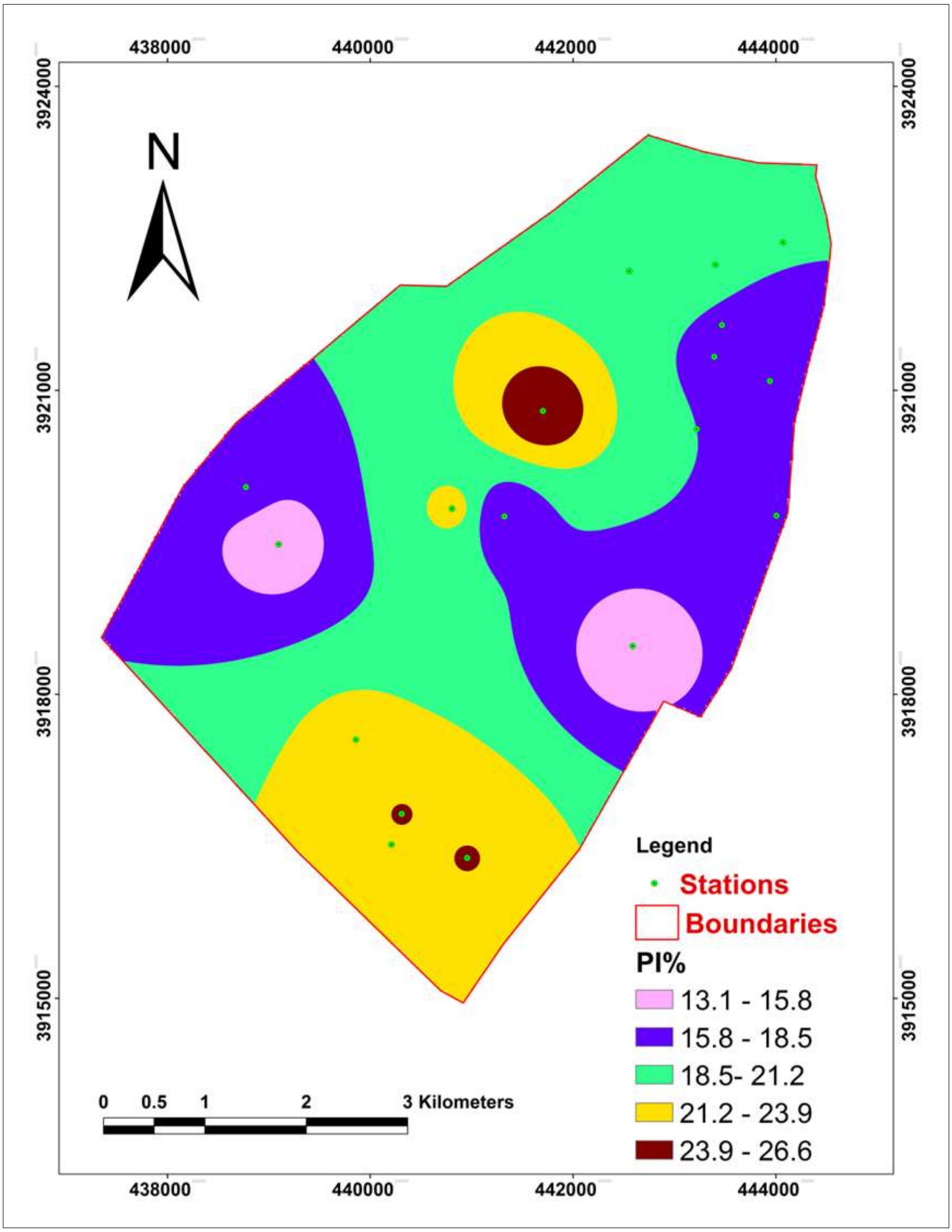

Fig 9: The spatial interpolation map of the Plastic Index is spatially equipped with UTM units

Conclusions

In this study, a database was created by taking advantage of the values obtained from the results of field and laboratory tests of the study area, using geotechnical data in the database geotechnical coefficients of the studied depths (2 m) in the city of Kirkuk were also determined, and geotechnical maps of the study area were drawn using the ArcGIS program based on geographic information systems, these maps.

1. The percentage of moisture content (Water Content) was calculated for the selected sites and a map of spatial interpolation (Interpolation Map) of the data resulting from the examination in the study area, where it was found that the moisture content ranges between (1. 8% – 16. 9%), as the small percentage of it is associated with groundwater levels that have suffered a decline in recent years, low rainfall, as well as high evaporation due to high temperatures, and that the moisture content is inversely proportional to the stability of the soil in engineering terms, as the presence of water reduces soil cohesion and also reduces the sternal resistance.
2. The weight ratios of the granular sizes of the selected sites in the study area were calculated and the spatial interpolation map of the weight ratios of the granular sizes in the study area was drawn, it turned out that the study area at the depths studied has soils of different granular sizes and soft soils predominate on it (alluvial and silty clay), where the percentage of sand ranged between (1% - 52%), the percentage of silt (5% - 64%),

the percentage of Clay (3% - 54%), the percentage of gravel (49. 6 – 62). It was also found that the soil in the study area is quaternary age deposits, and the soil of the study area in general is a cohesive soil.

3. The plasticity limit values were calculated and it turned out that the sites (7,8,10,11,13,15,16,17) are medium-plasticity soils, while the sites (1,4,5,6,12) are highly plasticity, and a geotechnical map of the plasticity limit coefficient of the study area was drawn using data obtained from laboratory tests.
4. The liquidity limit values were calculated and a geotechnical map of the liquidity limit coefficient for the study area was drawn, as the results showed that the prevailing soil in the study area is very low-liquid soil to low-liquid soil.
5. The plasticity index values were calculated and a geotechnical map of the study area was drawn based on the resulting data, as it turned out that the plasticity index of the study area ranges between (13.1% - 26.6%).

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