Production Thematic Map for Predicated CBR and M_R Values for Subgrade Soil of Baghdad City Using GIS Tools

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Abstract:

The aim of this research is to produce thematic maps for California Bearing Ratio (CBR) and Resilient Modulus (M_R), for Baghdad city depending on traditional soil properties obtained from soil investigation reports of the case study taking advantage of the ability of GIS tools , these maps are used in varies pavement design layers.

In this research the available data are collected from soil investigation reports such as Atterberg limits or parameters and sieve analysis these values are used in correlation equations to predict CBR and M_R values, then thematic maps are drawn for several municipalities used in design and evaluate the pavement.

Due to the thematic maps that produced depending on the collected data of the study area this research conclude that subgrade for Baghdad soil is classified as fair to poor according to AASHTO Classification. Some regions in study area shows high percentages of sulphate content (SO_3) therefore these areas should be either treated or avoided to reduce the effect of erosion of subgrade or lower layer of pavement system.

The pH value of subgrade soil explains alkaline action (greater than ٧) and T.S.S (Total Soluble Salts) value is rather low so it can be used as a filling material or embankment for roads.

Key Word: *Thematic Map, CBR, M_R, Subgrade, Baghdad Soil, GIS*.

انتاج خارطة موضوعية لقيم نسبة التحميل الكليفورني و معامل الرجوعية المتوقعة لتربة ماتحت الاساس لمدينة بغداد باستخدام تقنيات نظم المعلومات الجغرافية

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المستخلص:

يهدف هذا البحث الى انتاج خارطة موضوعية لقيم نسبة التحميل الكليفورني و معامل الرجوعية او الارتداد لتربة مدينة بغداد بالاعتماد على قيم معاملات او خصائص التربة التقليدية والتي يمكن الحصول عليها من تقارير تحريات التربة لمنطقة الدراسة و بمساعدة قابليات و امكانيات برنامج نظم المعلومات الجغرافية للاستفادة من هذا الخارطة في تصميم طبقات التبليط المختلفة

في هذا البحث تم تجميع البيانات المتوفرة في تقارير تحريات التربة لمنطقة الدراسة (حدود اتربرغ , معاملات اتربرغ, التحليل المنخلي للتربة المنطقة) حيث تم ربط هذة المعاملات بعلاقات رياضية لتوقع قيم نسبة التحميل الكليفورني و معامل الرجوعية ومن ثم رسم خرائط موضوعية لمختلف قطاعات المدينة يمكن استخدامها لتصميم او تقييم التبليط.

من خلال الخرائط الموضوعية المنتجة في هذا البحث اعتمادا على البيانات الحقلية المتوفرة بينت ان تربة ماتحت الاساس لمدينة بغداد هي متوسطة الى ضعيفة وحسب التصنيف التابع لهيئة مهندسي الطرق والنقل الأمريكية (AASHTO) ومعامل الإنضغاطية لتربة ما تحت الاساس قليل، ولهذا نحتاج الى تحسين قابلية هذه التربة لتحمل الاحمال الخارجية. بعض الاماكن لمنطقة الدراسة تبين وجود نسبة عالية من الكبريتات ولهذا يتطلب معالجة الوضع او تجنب هذه الاماكن وذلك لتقليل تأثير التآكل الحاصل لتربة ماتحت الاساس او الطبقات السفلية للتبليط. مقياس الدالة الحامضية للتربة pH تبين ان تربة بغداد هي تربة قاعدية حيث القيمة كانت اكبر من ٧ وكمية الاملاح الذائبة كانت قليلة نسبيا ولهذا يمكن استخدام هذه التربة كإملائات ترابية او سداد ترابية للطرق.

Introduction

Geotechnical maps are widespread nowadays due to the existence of Geographical Information Systems (GIS) and Global Position Systems (GPS). These maps provide a powerful database and strong visual presentation of data. The use of such maps will save effort, time. *(Derman, ١٩٩١)*

The design and evaluation of pavement structures requires a significant amount of supporting data such as subgrade material properties. However, the thematic maps that are considered here in order to represent the properties. In addition, this map will help in preliminary studies, feasibility studies and land use policy. *(Gandhimathi et al, ٢٠١٠).*

Study Area Location

The study region located in the center of Iraq and extends to include both sides of the Tigris River for area about (٦٦٠ km²) as a specific, bounded by the coordinates (from ٤٣٠٢٧٢ to ٤٥٧٤٢٧) easting and (from ٣٦٧٣٩٠٧ to ٣٦٩٩٢٨٤) northing in zone (٣٨ N) according to UTM Projection system. The study area has a length of approximately (٢٤٫٤) km and its width is about (٢٥٫٧) km with an area of about (٦٦٠) km². *(Al.Nedawi, ٢٠١١)*

Methodology

Data are collected from various agencies (ANDREA Engineering Testing Laboratory (AETL), The reports included soil investigations for various types of structures (overpass Bridges, interchanges, water treatment stations, colleges, commercial buildings, police station, health centers, etc.). The total numbers of bore holes in the study area are (٢٠٣). The main data was taken from these reports such as the name, objective of the job, location, depth of borehole, etc.
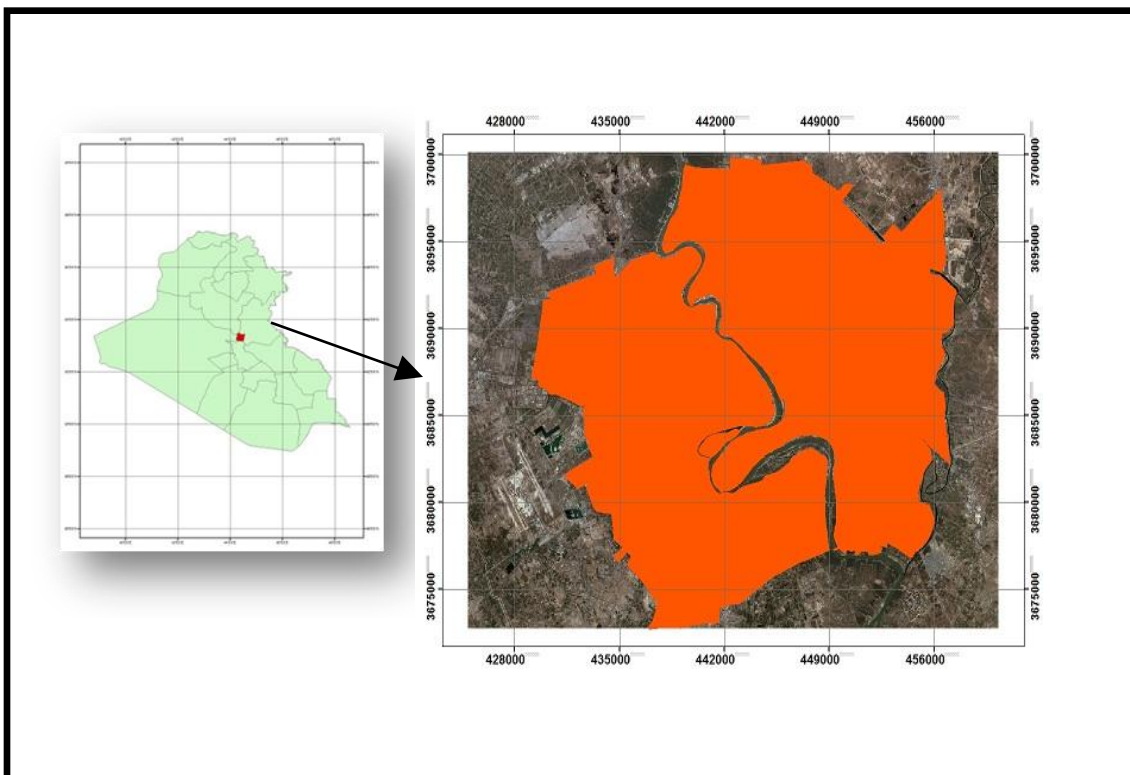

Figure (١) The Study Area of Baghdad City

Figure (٢)Borehole Location in the Study Area.

Empirical Equations to Calculate the Values of CBR and M$_R$

The database was prepared in Microsoft Office Excel, soil investigations reports contain physical, chemical and mechanical soil properties examined and the expected establishment of the road and these information are not adequate for use in the structural design layers tiling construction different because they do not reflect the amount of structural strength of the soil or the materials used in the layers of the pavement, many attempts have been made by international organizations to link the mathematical relations of these variables used to predict the amount of structural strength for materials used in the layers of pavement. Therefore California Bearing Ratio (CBR) is obtained by using *(NCHRP, ٢٠٠٤)* equations:

$$wPI = Passing \ \#٢٠٠٠ \ Plasticity \ Index = P٢٠٠٠ PI \qquad\qquad \text{--١}$$

$$CBR = ٢٨,٠٩ (D٦٠)^{٠,٣٥٨} \qquad\qquad \text{--٢}$$

$$CBR = \frac{75}{1+0.728(wPI)} \qquad\qquad \text{--٣}$$

Where: *PI* =Plasticity Index.

wPI = a weighted Plasticity Index.

D٦٠ = Diameter at ٦٠٪ passing from the Grain Size Distribution - mm.

Resilient Modulus M_R is obtained by using *(Heukelom and Klomp, ١٩٦٢)* which is suggested by AASHTO design guide.

$$M_R{}_{(psi)} = ١٥٠٠\ CBR \qquad\qquad --٤$$

These values of the CBR and M_R were classified in to two layers (٠-٢) meter and (٢-٤) meter.

Zoning of Baghdad City

A digital map of Baghdad of scale (١:٤٠٠٠٠) was used to define the boundaries of the Municipalities (Baladiyah) in the area as show in Figure (٣), which was produced in ٢٠٠٣ by National Imagery and Mapping Agency ,USA), the boundaries were drawn on the satellite image by using GIS tool , fourteen Municipalities were produced with their names:

a- ٩ Nissan Section,   b- Adhamiyah Section ,   c- Al-Doura Section,   d-Al-Mansour Section,
e- Al-Sha'ab Section, f- Al-Shula Section,   g- Kadamiyah Section,   h-Karada Section,
i-Karkh Section,   j- New Baghdad Section, k-Rasheed Section,   l- Rusafa Section,
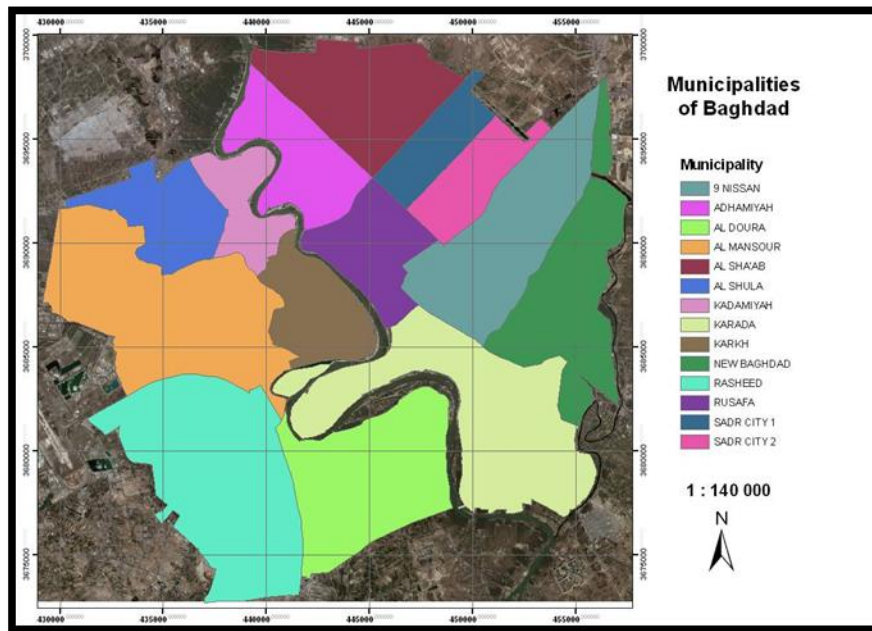m- Sadr City ١ ,   n- Sadr City ٢ .

Figure (٣) Zoning of Baghdad City as Municipalities.

## Applying GIS Techniques to Analyze and Represent The Results

Many of the benefits of GIS system just from the fact that map data are made available in electronic form, therefore they are more easily stored, managed, edited, and transmitted. However, GIS also provides the ability to quickly analyze that information in a variety of ways, often in way that are not feasible with paper maps. The analytical functions of GIS are at least as important as the map storage and distribution functions *(George & Korte, ٢٠٠١)*.

Data were interpolated to introduce a continuous surface as visual display by using spatial interpolation which is the process of using points with known values to estimate values at other unknown points. In GIS, spatial interpolation of these points can be applied to create a raster surface with estimates made for all raster cells; Inverse distance weighting (IDW) interpolation method was used to create a continuous surface for the subgrade properties.

Thematic Maps

١. California Bearing Ratio (CBR Value)

The values of CBR were obtained numerically by using the NCHRP predicated equations, then these values were integrated to GIS tools, Figure (٤) illustrates the variation of predicated CBR on the study area at depth (٠-٢) m the ranges of these CBR values between (٣-١٦), the most of the region has CBR values range (٣-٦) while the highest CBR values between (١١-١٦) are concentrated in southern side of (Kadamiya sector) and in the eastern side of (Al mansour sector), Figure (٥) illustrate the variation of CBR on the study area at depth (٢- ٤) m the ranges of these CBR values between (٣-١٣) there is no great difference of CBR values with the upper layer at depth (٠-٢) m.
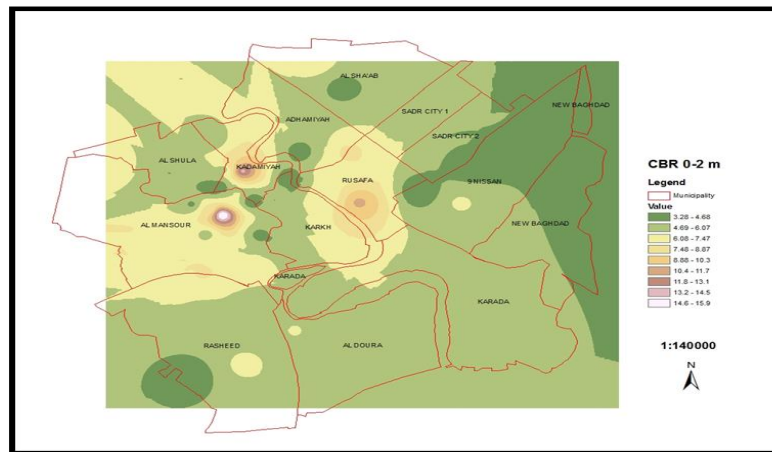
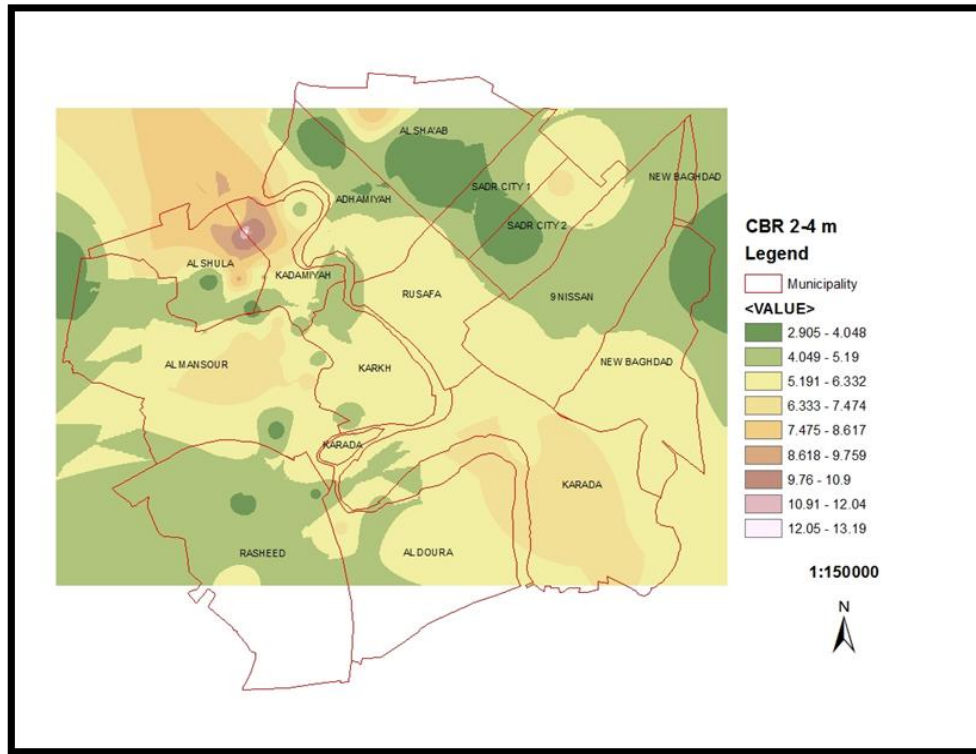**Figure(٤): Distribution of California Bearing Ratio at Depth ٠– ٢ m across Study Area**

Figure (٥): Distribution of California Bearing Ratio at Depth ٢– ٤ m across Study Area

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٢.   Resilient Modulus (M$_R$ Value)

The M$_R$ values are determined by using AASHTO correlation equations, Figures (٦) and (٧) show M$_R$ at depth (٠ - ٢) m and (٢ - ٤) m. M$_R$ at depth (٠-٢ m) has a maximum value of (٢٣٧٧٢,٤ psi) and a minimum value of (٤٩١٥,١٥ psi), the eastern side of the study area has the minimum range of M$_R$, the maximum value of the range concentrated in simple spot in (Kadamiya, Al mansour, Rusafa), in the other hand M$_R$ at depth (٢-٤) m has approximately the same value range but it is differ in distribution.

٣.   Soil Chemical Distributions

The values of sulphate content (SO٣) encountered in the study area vary between (٠,٠٢٦٩) and (٢,١) for the two layer. The distributions of the values of sulphate content (SO٣) across the study area for depth intervals (٠-٢, ٢-٤) m are shown in Figures (٨) and (٩) respectively.
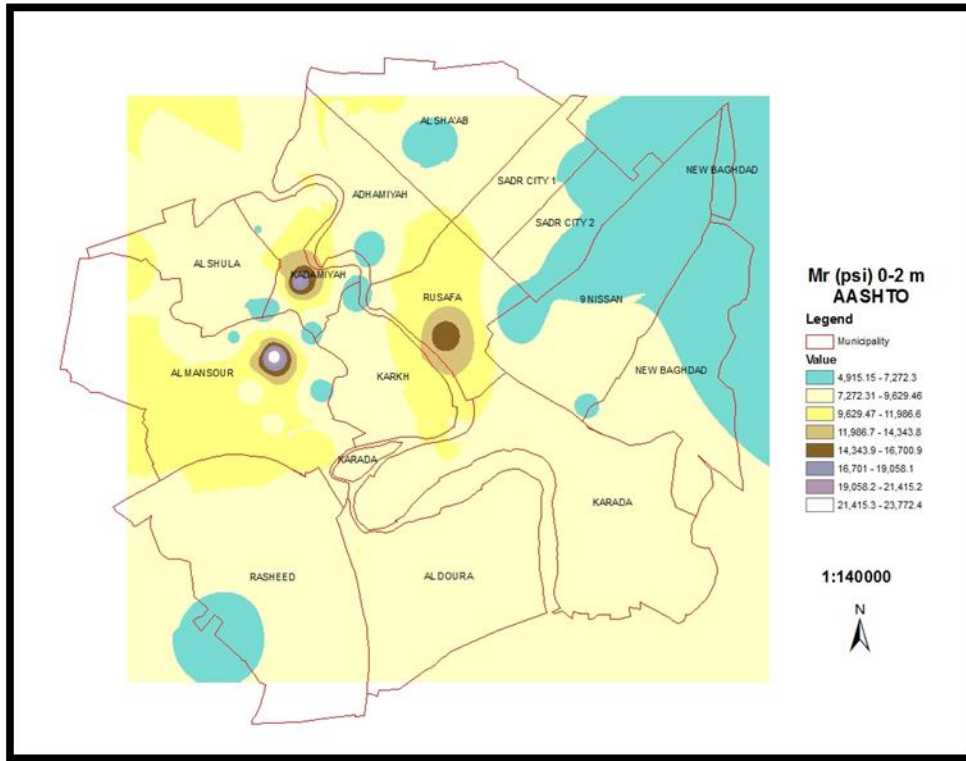
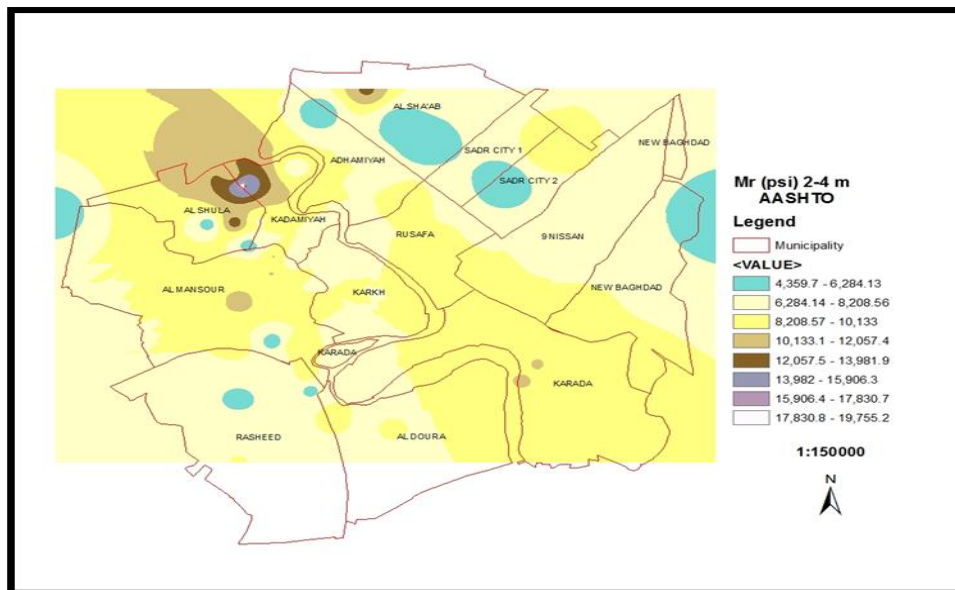**Figure (٦): Distribution of Resilient Modulus at depth ٠– ٢ m Across Study Area**.

Figure (٧): Distribution of Resilient Modulus at depth ٢– ٤ m Across Study Area.
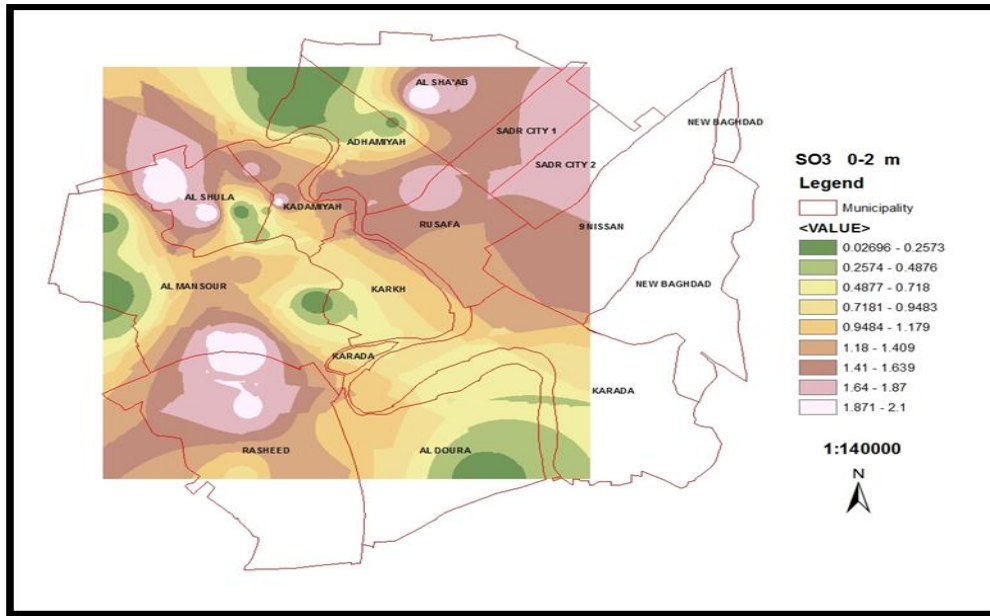
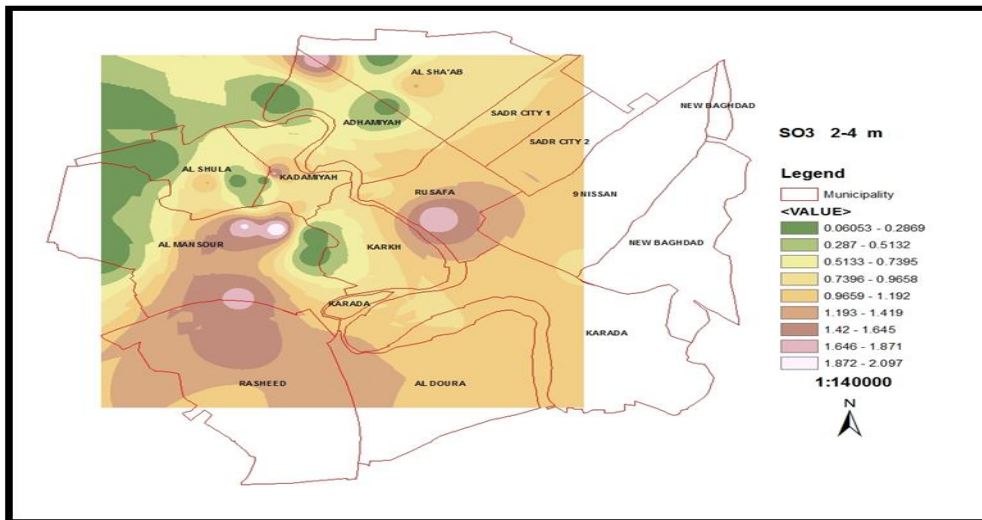**figure (٨): Variation of Sulphate Content at Depth ٠-٢ m across Study Area.**

Figure (٩): Variation of Sulphate Content at Depth ٢-٤ m across Study Area.

Figures (١٠) and (١١) present the distribution of total soluble salts (TSS) of soil in the depth intervals (٠-٢, ٢-٤ m) respectively, the values of (TSS) in the area vary between (٠,١٣٥٩ - ٦,٧٩٨). The (PH) value range between (٧-٨,٧) at depth (٠-٢, ٢-٤ m) as shown in Figures (١٢) and (١٣).
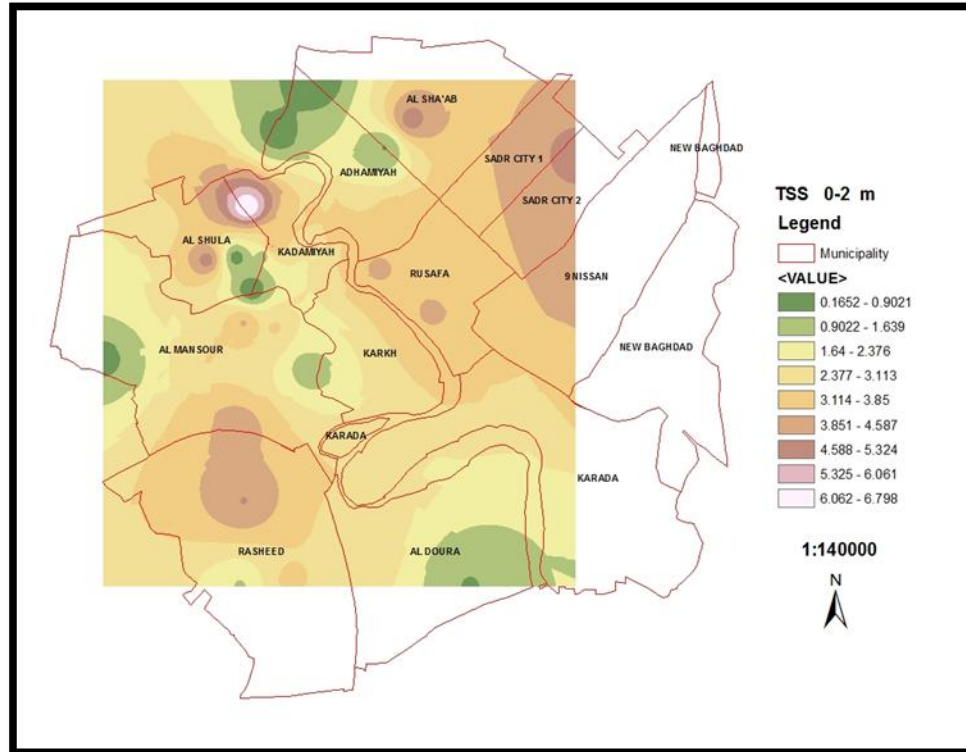

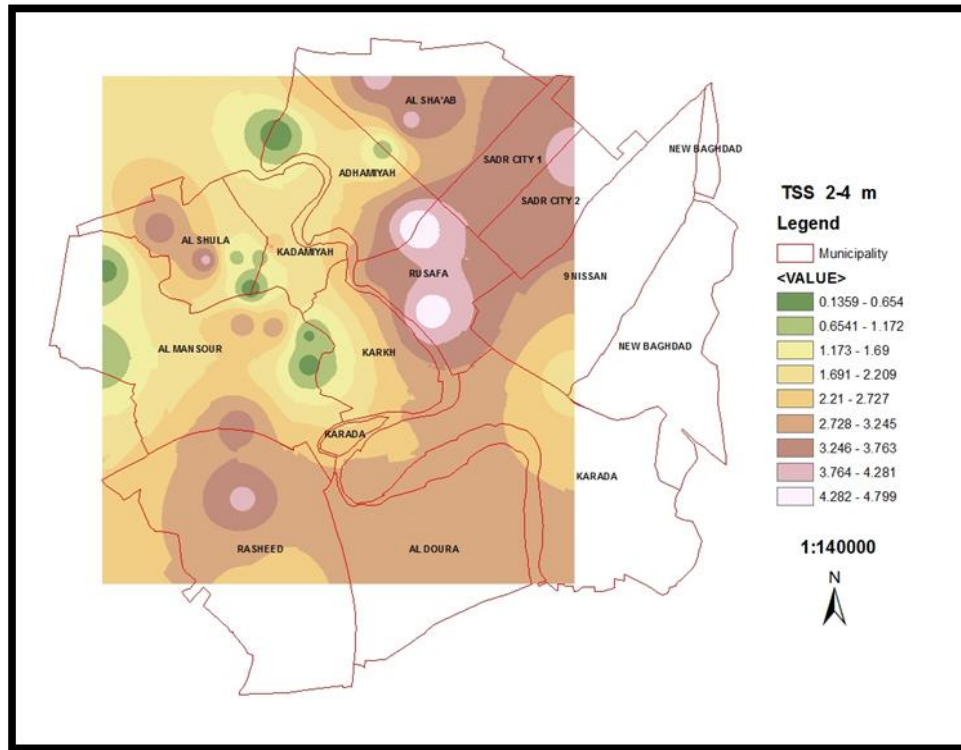**Figure (١٠): Variation of Total Soluble Salts at depth ٠-٢ m across Study Area.**

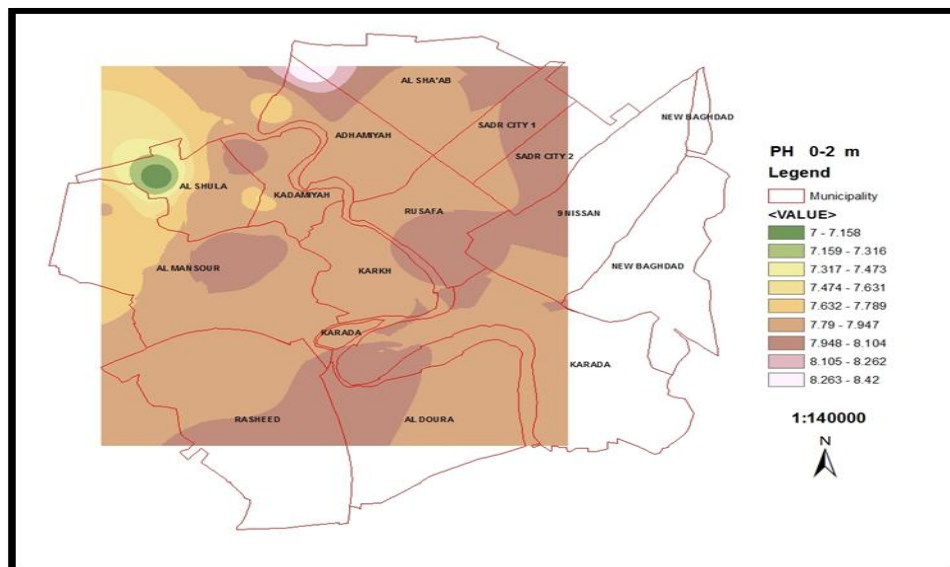**Figure (١١): Variation of Total Soluble Salts at depth ٢-٤ m across Study Area.**

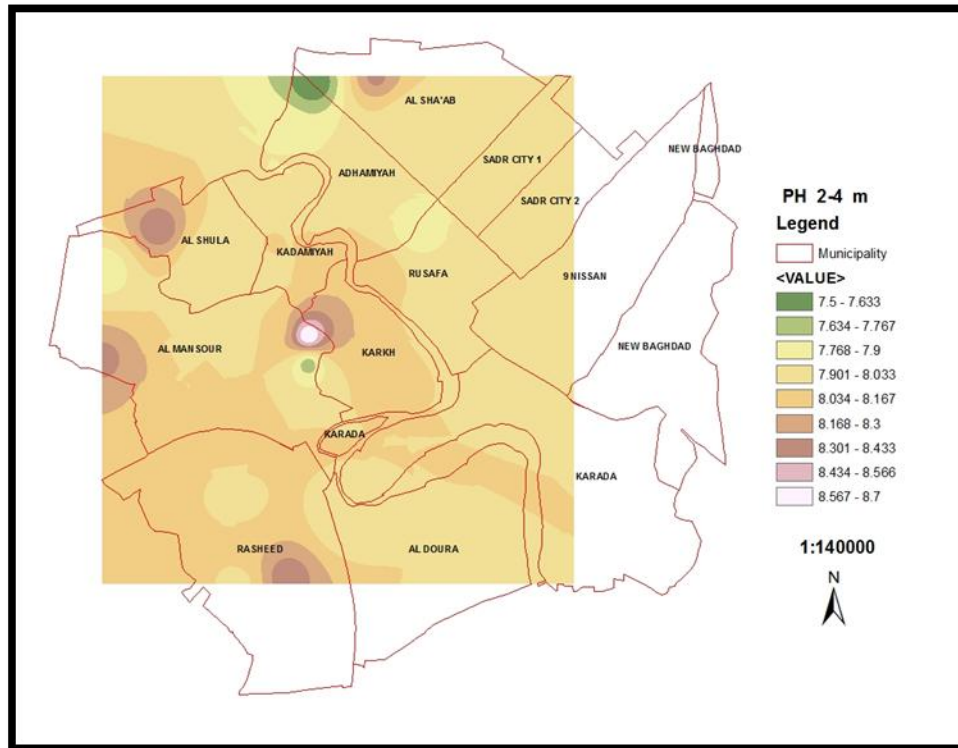**figure (١٢): Variation of (pH) at Depth ٠-٢ m across Study Area**

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Figure (١٣): Variation of (pH) at Depth ٢-٤ m across Study Area.

Conclusion

١- Some regions in study area shows high percentages of sulphate content (SO٣) therefore these areas should be either treated or avoided to reduce the effect of erosion of subgrade or the lower layer of pavement system.

٢- The pH value of Baghdad subgrade soil explains alkaline action (greater than ٧) and the T.S.S (Total Soluble Salts) value is rather low so it can be used as a filling material or embankment for roads.

٣- The distribution of some of the geotechnical properties studied showed a wide scatter in the results due to the geotechnical nature of the soil where the composition and stratification are non-homogenous because of several geological, hydrological, and human reasons.

٤- Using the abilities of GIS to produce a thematic map consist of CBR and M_R values for Baghdad soil which help the highway engineers to predict the
pavement's layers depth.

٥- This research should not be taken as a standard of a code, because it only represents an indicative trend of Baghdad soil that should benefit engineers in having a general sense of the soil properties, help in preliminary studies, feasibility studies and land use policy, but in implementation's stages, site investigation cannot be dispensed.

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