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Cartographic Modeling of Soil Properties and Their Suitability for Commercial Investment Projects in Ramadi City Using Geographic Information Systems

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النمذجة الخرائطية لخصائص التربة وملاءمتها للمشاريع الاستثمارية التجارية في مدينة الرمادي باستخدام نظم المعلومات الجغرافية

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الملخص :

تضمن هذا البحث (النمذجة الخرائطية لخصائص التربة وملاءمتها للمشاريع الاستثمارية التجارية في مدينة الرمادي باستخدام نظم المعلومات الجغرافية) ؛ وتم اعتماد الية عمل متقدمة هدفها بناء نماذج خرائطية للملاءمة المكانية للتربة واثرها على توقيع المشاريع التجارية الاستثمارية ؛ ومن ثم معرفة ابرز الخصائص الفيزيائية المؤثرة في توقيع تلك المشاريع لما لها من اهمية كبيرة في سلامة وامن تلك المنشئات التجارية ، اذ تم جمع وتحليل(٣٢) عينة تربة من منطقة الدراسة وتحليلها في مختبر الجزيرة واهم الخصائص الفيزيائية للتربة التي تم تحليلها هي (نسجة التربة ، ومحتوى رطوبة التربة ، وحد سيولة التربة ، ودليل لدونة التربة ، والتصنيف العالمي الموحد للتربة) لما من اهمية كبيرة على استقرار التربة تحت اسس المباني وسلامتها من التشقق والانهيال والهبوط ،اذ توصلت الدراسة هنالك تباين في خريطة نسجة التربة في مدينة الرمادي مابين نسجة (طينية رملية ، ومزيجية طينية ، مزيجية رملية ، مزيجية طينية غرينية) ويعد افضل الانواع للتوقيع المنشئات العمرانية الاستثمارية هي تربة ذات نسجه (طينية رملية) لانها تجمع بين خصائص التربة الطينية القوية والرملية المتماسكة مما يوفر اساسا مستقرا للمباني وقدرتها على توزيع الاحمال بشكل جيد؛ اما عند تحليل خريطة محتوى رطوبة التربة فقد تراوحت مابين (٣.٧-١٢ % - ٣٨،٤٥٪) ويعد افضل انواع الترب لتوقيع تلك المشاريع التي فيها نسبة رطوبة منخفضة وشكلت نسبته (٣.٧-١٢٪) لان الارتفاع في نسبة الرطوبة يؤدي الى تشقق وتحطم اسس ومباني تلك المشاريع ؛ وعند تحليل خريطة حد سيولة التربة فقد تراوح حد السيولة مابين (٩.١-٤.٢٪ -٤٥-٥٨٪) ويعد افضل انواع التربة لتوقيع تلك المشاريع التربة التي فيها نسبة حد سيولة منخفض وشكلت نسبتة (٩.١-٤.٢٪) لانها تكون اكثر صلابة مما يمنحها استقرار اكثر في الاساسات ؛ وعند تحليل خريطة دليل لدونة التربة فقد تراوحت نسبتها ما بين (٨.٢-٢.٩٪-٧-٤٨٪) ويعد افضل انواع التربة لتوقيع تلك المشاريع التربة التي فيها دليل لدونة منخفض وشكلت نسبته (٩.١-٤.٢٪) مما يساعد ذلك على استقراريه وصلابة التربة وتماسكها ؛ اما عند تحليل تحليل خريطة التصنيف العالمي الموحد للتربة فقد تكون من عدة انواع (طين رملي ، طين ضعيف اللدونة رمل سئ التدرج طمى ضعيف اللدونة ، طمى عالي اللدونة، طين عالي اللدونة) وتكون التربة ذات التصنيف (طين رملي) من افضل انواع الترب للبناء وتتمتع بتصريف جيد للمياه وتدعم الاساسات بشكل مستقر لقابليتها لتحمل احمال تلك المنشئات وقابليته للحدل كبيرة ؛ وتوصل البحث الى اعداد نموذج خرائطي للعامل التربة بعد جمع العناصر الفيزيائية اعلاه واعطاء كل عامل وزن ترجيحي ؛ الصنف الأول (عالية الصلاحية): بلغت مساحته (١٠.٢) هكتار وبنسبة(٠.١٪) وتكون هذه الترب عالية الصلاحية عند توقيع المنشئات العمرانية التجارية وعلى الرغم من المميزات الموقعية للخصائص الفيزيائية للتربة لهذه المساحات لم يوقع اي مشروع تجاري استثماري فيها ؛ الصنف الثاني (متوسطة الصلاحية بلغت مساحته (٤٧٢.٠) هكتار ، وبنسبة

(٣.١٪) ووقعت (٣) مشروع تجاري استثمارية ضمن هذه المساحات الصنف الثالث (حدي الصلاحية): بلغت مساحتها(٧٤٧١.٦) هكتار وبنسبة (٤٩.١٪) وقع (٩) مشروع تجاري استثماري ضمن هذه المساحات ؛ الصنف الرابع (غير صالح حاليا): بلغت مساحته (٧٢٦٣.٢) هكتار وبنسبة (٤٧.٧٪) ، وقع (٢٠) مشروع تجاري استثماري ضمن هذه المساحات؛ وفي ضوء النتائج توصي الدراسة المتابعة الدورية من قبل الدوائر المعنية بذلك الامر (هيئة استثمار محافظة الانبار و، دائرة بلدية الرمادي) للمشاريع التجارية التي نفذت في المساحات الغير صالحة حاليا من السلامة العامة ويجب الاعتناء بشكل مفصل وبأمانة تامة لدراسة (تحريات التربة) قبل الشروع بتنفيذ المشروع الاستثماري، وتكون دراسة تحريات التربة في مختبرات خاصة وبأشراف الدوائر المعنية بذلك وبعيدا عن التلاعب بنتائج الفحص المختبري

الكلمات المفتاحية :النمذجة الكارتوكرافية ، الخصائص الفيزيائية للتربة ، المشاريع التجارية الاستثمارية ، نظم المعلومات الجغرافية .

Abstract:

This research included (cartographic modeling of soil properties and their suitability for commercial investment projects in Ramadi city using geographic information systems); an advanced work mechanism was adopted with the aim of building cartographic models of the spatial suitability of soil and its impact on signing commercial investment projects; And then knowing the most prominent physical properties that affect the signature of these projects because of their great importance in the safety and security of these commercial facilities, as (32) soil samples were collected and analyzed from the study area and analyzed in the Al-Jazeera laboratory. The most important physical properties of the soil that were analyzed are (soil texture, soil moisture content, soil liquidity limit, soil plasticity index, and the unified global soil classification) because of the great importance of the stability of the soil under the foundations of buildings and its safety from cracking, collapse and subsidence, as the study concluded that there is a difference in the soil texture map in the city of Ramadi between textures (sandy clay, clay mixture, sand mixture, silty clay mixture), and the best types for signing investment urban facilities are soils with a texture (sandy clay), because it combines the characteristics of strong clay soil and cohesive sand, which provides a stable foundation for buildings and its ability to distribute loads well; When analyzing the soil moisture content map, it ranged between (3.7-12% - 38.45%). The best soil types for these projects are those with a low moisture content, which constituted (3.7-12%), because the high moisture content leads to cracking and destruction of the foundations and buildings of these projects. When analyzing the soil liquidity limit map, the liquidity limit ranged between (9.1-4.2% - 45-58%). The best soil types for these projects are those with a low liquidity limit, which constituted (9.1-4.2%), because it is more solid, which gives it more stability in the foundations. When analyzing the soil plasticity index map, its percentage ranged between (8.2-2.9% - 7-48%). The best soil types for these projects are those with a low plasticity index, which constituted (9.1-4.2%), which helps in the stability, solidity and cohesion of the soil. When analyzing the global unified soil classification map, it may be of several types (sandy clay, weak plastic clay, poorly graded sand, weak plastic silt, high plastic silt, high plastic clay), and the soil with the classification (sandy clay) is one of the best types of soil for construction and has good water drainage and supports the foundations in a stable manner due to its ability to bear the loads of those structures and its ability to be reduced greatly; The research led to the preparation of a map model for the soil factor after collecting the above physical elements and giving each factor a weight; the first category (high suitability): its area reached (10.2) hectares and a percentage of (0.1%) and these soils are highly suitable when signing commercial urban structures, and despite the locational advantages of the physical properties of the soil for these areas, no commercial investment project has been signed in them; The second category (medium viability): Its area reached (472.0) hectares, at a rate of (3.1%), and (3) commercial investment projects were located within these areas. The third category (limited viability): Its area reached (7471.6) hectares, at a rate of (49.1%), and (9) commercial investment projects were located within these areas. The fourth category (currently unsuitable): Its area reached (7263.2) hectares, at a rate of (47.7%), and (20) commercial investment projects were located within these areas. In light of the results, the study recommends periodic follow-up by the departments concerned with this matter (Anbar Governorate Investment Commission and Ramadi Municipality Department) for commercial projects that were implemented in areas currently unsuitable for public safety. Care must be taken in detail and with complete honesty to study (soil investigations) before starting to implement the investment project. The soil investigations must be studied in special laboratories and under the supervision of the departments concerned with this and away from tampering with the results of laboratory testing.**Keywords**: Cartographic modeling, physical soil properties, commercial investment projects, geographic information systems

Introduction:

Commercial investment services constitute one of the pillars of the sustainability and development of cities due to their great importance and impact on various aspects of residents' lives. Without them, a city cannot develop. Therefore, the success of these projects requires careful planning and effective management when starting to implement them. One of the first basic steps is conducting soil investigations. As a result, the importance of the research emerged as it is the first study at the level of the study area that addressed (cartographic modeling of soil properties and their suitability for commercial investment projects in the city of Ramadi using geographic information systems). Modern geographic technologies are an effective means of storing, processing, analyzing, managing and linking them into descriptive information and developing cartographic models and scenarios for decision makers. Therefore, the research the materials for preparing the research were prepared as special maps for the city of Ramadi such as topographic maps, thematic maps, and basic design maps for what they contain of natural and human landmarks (**1**), and satellite data through the preparation of a modern satellite image of the study area with high spatial accuracy (**2**). The study that was conducted dealt with the cartographic modeling of the investment map in Baghdad Governorate using geographic information systems (GIS), as it addressed investment and the factors affecting it and its cartographic representation, and the most prominent geographical factors affecting investment in Baghdad Governorate, which were divided into (natural and human) factors (**3**); The study dealt with cartographic modeling of soil properties in Habbaniyah district using geomatics techniques. The study also addressed the geographical factors affecting soil properties using remote sensing data (**4**); the study also addressed the spatial analysis of the geographical components and economic potentials available in Anbar Governorate, then building a geographical database and the geographical distribution of approved investment projects, then analyzing them on maps and determining the spatial suitability of those projects (**5**); the study was conducted in Al-Karmah district and addressed the cartographic modeling of agricultural land uses (**6**); the current study came to address the cartographic modeling of soil properties and their suitability for commercial investment projects in Ramadi city using geographic information systems in order to identify the most prominent physical properties of the soil that directly affect the signing of commercial investment projects and provide cartographic models of spatial suitability for each element separately and give each element a weight and come up with a final model that explains the soil factor in general and explains the mechanism for signing commercial investment projects in the study area.

Research Problem:

The lack of accurate laboratory test results for soil investigations during the planning stages of commercial projects in the city of Ramadi prompted a field visit to assess the current situation of these commercial investment projects through spatial analysis. Accordingly, this research addresses the following questions:

A. What are the most prominent physical elements of soil investigations that should be considered when planning commercial investment projects in the city of Ramadi?

B. Did these projects meet the required standards and site selection controls?

C. Were the soil investigations conducted with professionalism and accuracy, without any shortcomings in credibility or effort?

D. Can Geographic Information Systems (GIS) be used to develop cartographic models of soil suitability to support optimal site selection for commercial investments?

Research Hypotheses:

The hypotheses were formulated as initial answers to the research questions, as follows:

A. The spatial siting of commercial investment projects was done inaccurately, based on the results of laboratory soil investigations.

B. The spatial siting of commercial investment projects was done accurately, based on the results of laboratory soil investigations.

Research objective:

This study aims to examine the cartographic modeling of soil in the city of Ramadi and its influence on the siting of commercial investment projects using GIS tools. It specifically explores the spatial distribution of key physical soil elements and how they affect location decisions. The research also identifies the most critical factors to consider before project implementation and presents mapping models that reflect soil suitability for commercial development**.**

Concepts and Terminology:

The research used several core concepts and terms, including:

1. **The Model:** Defined as the ability to mathematically simulate reality through technical and statistical methods that simplify and synthesize relationships within a studied phenomenon. A model is essentially based on a testable and observable assumption, aimed at approximating reality through the relationships and interactions it represents(**7**).

2. **Cartographic Modeling:** It is an applied methodology that specializes in processing geographical information to extract cartographic documents that may differ from each other in the purpose of their creation and the time period for their production, but they share in covering one geographical region and using more than one sub-application topic (**8**) Cartographic modeling involves processes such as comparison, spatial analysis, and cartographic composition(**9**).

3. **Soil investigations:** It is a comprehensive examination process of soil layers to determine their physical and chemical properties and assess their suitability for various construction foundations. It aims to collect accurate information about the nature of the soil and its ability to bear the loads of urban structures for the safety of those structures(**10**).

4. **Geographic Information Systems:** A group of files containing information coded according to specific coordinates, stored automatically or manually. Information for investment projects can be deleted or added from them and used in a systematic manner in the process of building a geographic database(**11**).

5. **Spatial data:** This is data that is in the form of shapes (point, line, and area). This type of data is often obtained directly when it is drawn on computers using specific programs. In general, this data is obtained using numbering, which represents the process of tracking a specific model that is present within an image that appears on the computer screen and drawing it(**12**).

6. **Metadata:** These are the attributes, descriptions, or characteristics associated with a spatial location, which are usually stored in separate tables and are in the form of images, lists, reports, tables, and graphs. The degree of success of the process of building a database for investment projects depends on the connection(**13**).

7. **The Musataha system:** It is a real investment that entitles its owner to build facilities or erect a building on the land of others by virtue of an agreement between him and the owner of the Musataha. This right must be registered in the Real Estate Registration Department. The term of the Musataha right must not exceed fifty years. If the term is not specified, either party may terminate the contract after three years of notifying the other(**14**).

8. **Soil texture:** Soil texture refers to the nature of the arrangement of soil particles, which differs from one place to another depending on the size and shape of the particles, which consist of sand, silt or clay, gravel, and coarse and fine rock fragments. That is, the soil is a mixture of these components in varying proportions, and for this reason, the soil takes on different names according to the proportions of these formations or components(**15**).

9. **Soil liquidity limit:** It is the moisture content at which the soil moves from a liquid state with a higher moisture content and without measurable shear resistance to a plastic state. The liquidity limit can be measured using the Casagrande device. The values of the liquidity limit differ in the horizontal and vertical directions from one place to another depending on the different types of soil(**16**).

10. **Soil Plasticity Index:** The plasticity index represents the difference between the flowability of soil and the plasticity limit and holds great importance, especially in signing commercial investment projects. If its value is small, any slight increase in moisture makes the soil liquid, and any small decrease makes it semi-solid. On the other hand, a high plasticity index indicates that the soil is softer and more susceptible to volumetric changes, such as compression and swelling. The soil's ability to undergo such changes is described based on the plasticity index(**17**).

11. **The Unified Global Soil Classification:** It is a system used to classify soil based on its physical properties. This classification is widely adopted in engineering and geology. The system aims to identify the soil type and characteristics in order to assess its suitability for constructing urban structures(**18**).

1.1 Analysis of the Physical and Chemical Properties Map of the Soil in the City of Ramadi

Understanding the important physical and chemical properties that directly influence the design of commercial urban facilities is a fundamental assumption, given their impact on the safety of these facilities. Among the most prominent physical and chemical elements that must be considered before embarking on commercial projects are:

1.1.1 Analysis of the Physical Properties Map of the Soil

Upon analyzing Table (1), it becomes clear that the most important basic physical elements to consider for the implementation of commercial investment projects are as follows:

Table (1) : *Physical Properties of Soil in the City of Ramadi for the Year 2025*

No.	Neighborhood	Soil Texture	Moisture Content	Liquidity Limit	Plastic Limit	Unified World Classification
1	Al-Mua'lemeen	Mixture	23	0	0	Poorly graded sand
2	Al-Shuhadaa	Granular Mixture	24	0	0	Poorly graded sand
3	Al-Salam	Mixture	23	0	0	Poorly plastic silt
4	Al-Jumhuriyya	Sandy Mixture	24	0	0	Highly plastic silt
5	Al- Amjad	Clay Mixture	24	0	0	Highly plastic silt
6	Al-Warrar	Sandy Mixture	23	43	20	Poorly plastic clay
7	Al-Riyadh	Clay Mixture	25	0	0	Sandy silt
8	Al-Ijtimaa'i	Sandy Clay Mixture	26	30	16	Sandy silt
9	Al-Ikhaa	Sandy Clay Mixture	29	22	22	Sandy silt to sandy silt
10	Al-Shafi'i	Sandy Clay Mixture	36	20	23	Sandy clay to sandy silt
11	Hussein	Clay Mixture	32	0	0	Sandy silt to sandy silt
12	Al-Tahrir	Sandy Clay Mixture	23	12	22	Sandy silt to sandy silt
13	Al-Nour	Clay Mixture	30	24	18	Poorly plastic silt
14	Al-Zohour	Sandy Clay Mixture	30	22.19	5.69	Sandy silt to sandy silt
15	Al-Azizia	Clay Mixture	28	28	38	Poorly plastic silt
16	Al-Qatana	Sandy Clay Mixture	20	35	13	Sandy silt
17	Al-Adl	Clay Mixture	10	29	11	Poorly plastic clay
18	Al-Quds	Sandy Clay Mixture	10	0	0	Poorly plastic clay
19	Al-Taqadum	Clay Mixture	18.67	0	0	Poorly plastic clay
20	Al-Sufiya1	Sandy Clay Mixture	18.67	43	17	Poorly graded sand
21	Al-Sahaba	Clay Mixture	45.3	0	0	Poorly graded sand
22	Al-Waha	Mixture	18	0	0	Poorly plastic silt
23	Al-Amin	Granular Mixture	36	0	0	Sandy silt
24	Al-Nasr	Mixture	36	0	0	Highly plastic clay

25	Al- Firdaws	Sandy Mixture	36	0	0	Highly plastic clay
26	Al-Mustaqbal	Clay Mixture	32	0	0	Poorly graded sand
27	Al-Ula	Sandy Mixture	32	0	0	Poorly graded sand to sandy silt
28	Al-Budhiyab	Clay Mixture	43	40	28	Poorly plastic silt
29	Al-Bu Faraj	Sandy Clay Mixture	27	28		Poorly plastic clay
30	Al-Sufiya2	Sandy Clay Mixture	27	43	17	Poorly plastic clay
31	Al- Wahda	Sandy Clay Mixture	30	0	0	Highly plastic clay
32	Al- Nakhil	Clay Mixture	30	20	18	Poorly graded sand to sandy silt

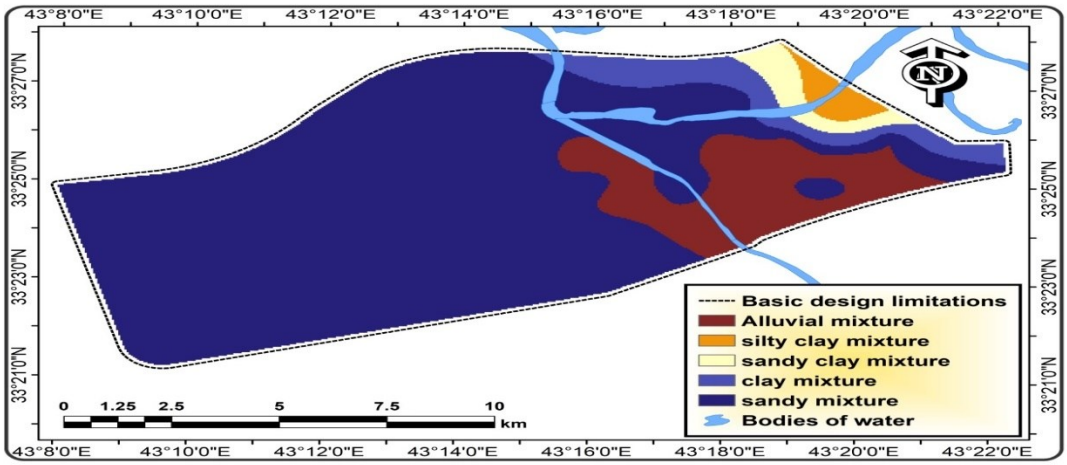
Source: (**19**).

١,١,١,١ Soil Texture Map Analysis.

Upon analyzing Map (1) and Table (2) it was found that the spatial distribution of soil texture types in the city of Ramadi is as follows:

1. **Silty Mixture**: This soil texture covers an estimated area of 348.2 hectares in the city of Ramadi, representing 2.3% of the total area.
2. **Sandy Mixture**: This soil texture occupies approximately 842.1 hectares, representing 5.5% of Ramadi's total soil area.
3. **Clay Mixture**: This soil texture is distributed across most of Ramadi, covering about 11,812.9 hectares, which accounts for 77.7% of the total soil area.
4. **Sandy Clay Mixture**: This soil type occupies 248.1 hectares, representing 1.6% of Ramadi's total soil area.
5. **Silty Clay Mixture**: This texture covers 1,965.7 hectares, making up 12% of the city's total soil area.

Map (1): *Spatial Distribution of Soil Texture Varieties in Ramadi City for the Year 2025*



Source:

1.Data derived from Table.(١)

2. Analysis conducted using ArcGIS version 10.8.1.

3-Satellite imagery of Ramadi city from WorldView-3 satellite, with a resolution of 30 cm, JPEG format, United States, year 2025.

4. Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033.

Table (2) *Soil texture types in Ramadi city for the year 2025*

No.	Soil Texture Class	Area (Hectares)	Percentage%

1	Silty Mixture	1965.7	**12.9**
2	Sandy Mixture	11812.9	**77.7**
3	Clay Mixture	842.1	**5.5**
4	Sandy Clay Mixture	348.2	**2.3**
5	Silty Clay Mixture	248.1	**1.6**
Total		15217	**100**

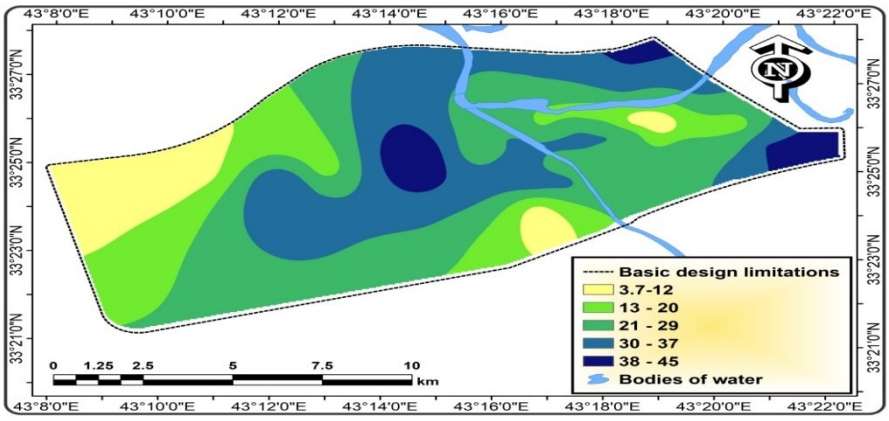
Source: Based on Map (1) and analysis using ArcGIS version 10.8.1.

1.1.1.2 Analysis of the Soil Moisture Content Map

Upon analyzing Map (2) and Table (3), the soil moisture content distribution in Ramadi was found as follows:

1. These are soils that accounted for a soil moisture level of (3.7-12)%, occupying an area of (833.5) hectares of the total soil area in Ramadi city, and a percentage of (5.5%). This represents a low moisture percentage due to the fact that these areas are located far from the Euphrates River basin and the Al-Wara Canal, and are at high elevations compared to the elevation of the residential neighborhoods in Ramadi city.
2. The soil moisture content level was 13-20%, and it occupied an area of 1630.8 hectares of the total soil area of Ramadi city, representing 10.7% of the total soil area. This is an average moisture content, as most of the residential neighborhoods within this category are served by a rainwater drainage and sewage network.
3. The soil moisture content level was (21-29)%, and covered an area of (3304.4) hectares of the total soil area of Ramadi city, representing (12.7%). These areas have marginal moisture content in terms of commercial investment, due to their proximity to the Euphrates River, and most of the areas are not served by a rainwater drainage and sewage network.
4. The soil moisture content level was (30-37)%, and covered an area of (5770.1) hectares of the total soil area of Ramadi city, representing (37.9%). These areas are located near the Euphrates River and the Suez Canal. Al-Warrar
5. The soil moisture content level reached (38-45)%, and its area constituted (3678.2) hectares of the total area of Ramadi city, representing (24.2%), due to the proximity of these areas to the Euphrates River basin and drains, and the presence of large water-filled excavations called (Sarat).

Map (2): *Relative Distribution of Soil Liquidity Limit in Ramadi City for the Year 2025*



Source: 1.Based on data from Table.(١) .

2.Analysis performed using ArcGIS version 10.8.1.

3.Satellite imagery of Ramadi city from the WorldView-3 satellite, with 30 cm resolution, JPEG format, United States, year 2025.

4.Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033.

Table (3): *Soil Liquid Limit Ratios in Ramadi City for the Year 2025*

No.	Soil Moisture Content	Area (Hectares)	Percentage%
1	3.7 – 12	833.5	**5.5**
2	13 – 20	1630.8	**10.7**
3	20 – 29	3304.4	**21.7**

4	30 – 37	5770.1	**37.9**
5	38 – 45	3678.2	**24.2**
Total		15217	**100**

Source: Based on Map (2) and analysis conducted using ArcGIS version 10.8.1.

1.1.1.3 Analysis of the Soil Liquid Limit Map

Upon analyzing Map (3) and Table (4), it was found that the soil liquid limit in the city of Ramadi is distributed as follows:

1.This category includes a soil liquid limit ranging from 4.2 to 9.1 degrees, covering an area of 11,981.8 hectares, representing 78.8% of the total area of Ramadi.

2.This category includes a liquid limit between 4.3 and 18 degrees, covering 765.0 hectares, which represents 5.0% of the total soil area.

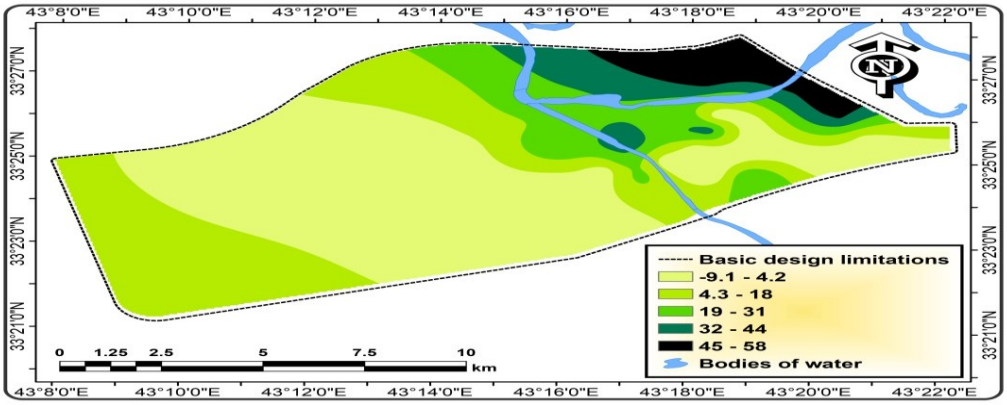
3.This category has a liquid limit ranging from 19 to 31 degrees, covering 658.1 hectares, or 4.3% of the total soil area.

4.This category includes a liquid limit between 32 and 44 degrees, covering 1,319.4 hectares, representing 8.7% of the total soil area.

5.This category includes a liquid limit between 45 and 58 degrees, covering 492.7 hectares, or 3.2% of the total soil area.

The high level of soil liquidity in the city of Ramadi directly affects the signing of commercial projects, through the subsidence of the soil under the foundations of buildings of the urban facility over time, leading to a rise in the level of groundwater at the site of those projects, in addition to a rise in the percentage of salts and sulphates.

Map (3): *Relative Distribution of Soil Liquid Limit in Ramadi City for the Year 2025.*



Source

: 1.Based on data from Table.(١) .

2.Analysis performed using ArcGIS version 10.8.1.

3.Satellite imagery of Ramadi city from the WorldView-3 satellite, with 30 cm resolution, JPEG format, United States, year 2025.

4.Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033**.**

Table (4): *Soil Liquid Limit Ratios in Ramadi City for the Year 2025*

No.	Liquid Limit Ratios	Area (Hectares)	Percentage%
1	9.1 - 4.2	11981.8	78.8
2	4.3 – 18	765.0	5.0
3	19 – 31	658.1	4.3
4	32 – 44	1319.4	8.7
5	45 – 58	492.7	3.2
Total		15217	100

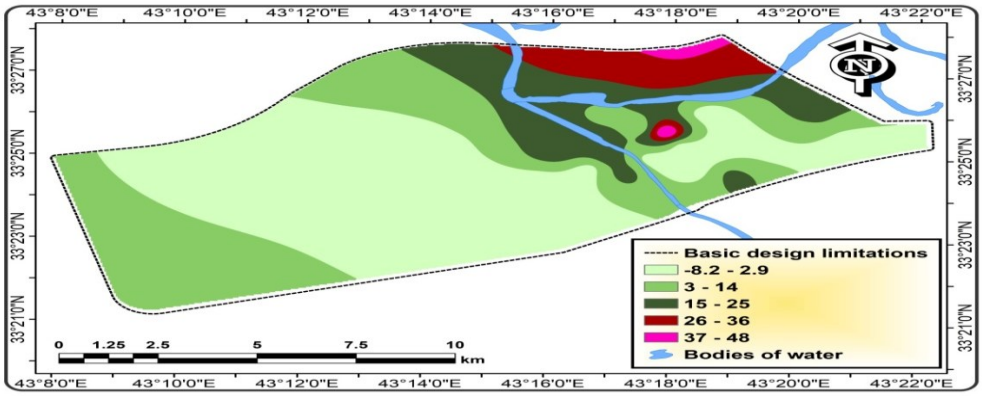
Source: Based on Map (3) and analysis conducted using ArcGIS version 10.8.1

1.1.1.4 Analysis of the Soil Plastic Index Map

Upon analyzing the soil plastic index map (4) and Table (5), it became clear that the soil plastic index in the city of Ramadi is distributed as follows:

1.The plastic index ranged from -8.0 to 2.9%, covering an area of 3,492.9 hectares, representing 23.0% of the total soil area in Ramadi.
2.An index range of 3.0 to 14.9% covered 5,394.0 hectares, accounting for 35.6% of the total soil area.
3.The range of 15.0 to 25.9% represented 2,259.8 hectares, or 14.9% of the soil area.
4.A plastic index between 26.0 and 36.9% covered 1,116.8 hectares, representing 7.3% of the total.
5.The highest category, with an index range of 37.0 to 48.0%, covered 2,953.5 hectares, amounting to 19.4% of the total soil area.

Since the soil plasticity index is higher than the accepted limit, it is a negative factor for the signing of commercial investment projects through the occurrence of cracks in the foundations and walls of buildings and the corrosion of reinforcing steel.***Map (4):*** *Relative Distribution of Soil Plastic Index in Ramadi City for the Year 2025*



Source:

1. Based on data from Table.(١)
2. Analysis conducted using ArcGIS version 10.8.1.
3. Satellite imagery of Ramadi city obtained from the WorldView-3 satellite (30 cm resolution, JPEG format), United States, 2025.
4. Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033.

Table (5): *Soil Plastic Index Ratios in Ramadi City for the Year 2025*

No.	Plastic Ratio	Area (Hectares)	Percentage%
1	8.2 - 2.9	3492.9	23.0
2	3 - 14.9	5394.0	35.4
3	15 - 25.9	2259.8	14.9
4	26 - 36.9	1116.8	7.3
5	37 - 48	2953.5	19.4
Total		15217	100

Source: Based on Map (5) and analysis using ArcGIS version 10.8.1.

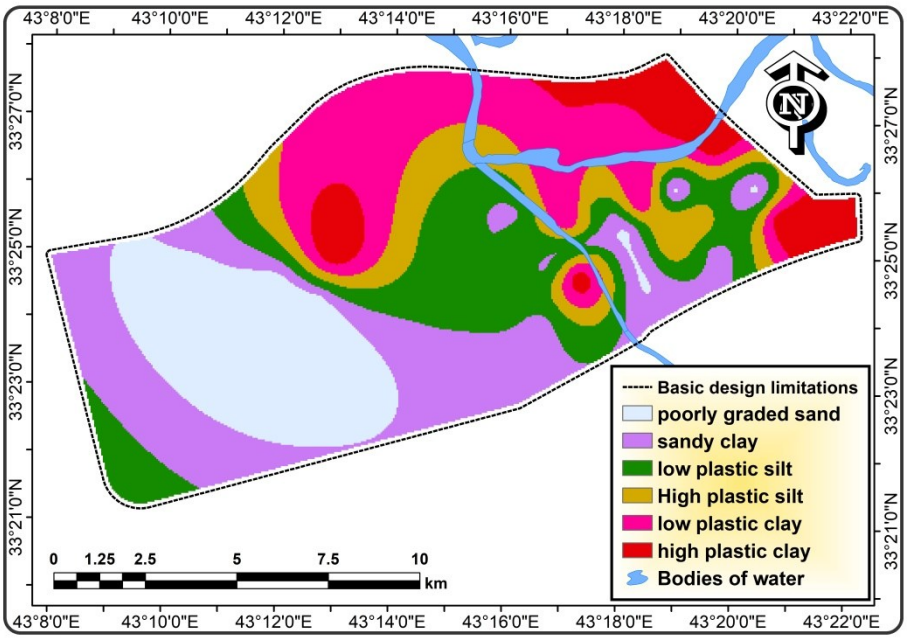
1.1.1.5 Analysis of the Global Soil Classification Map

Upon analyzing Map (5) and Table (6), the distribution of the unified global soil classification in Ramadi city was determined as follows :

1. The category classified as sandy clay covers 3,622.7 hectares, representing 23.8% of the total soil area in Ramadi This type of soil is characterised by its good ability to withstand commercial investment buildings, as most of its content is clay, while providing relatively good drainage thanks to the sand particles.
2. The poorly plastic clay category covers 2,883.6 hectares, accounting for 18.9% of the total soil area This soil is weak in strength and durability and is not cohesive when starting to sign commercial investment projects..
3. The poorly graded sand category covers 2,902.3 hectares, representing 19.1% of the total soil area This type of soil is characterized by a lack of balance in the grains and contains a group of close sizes rather than a graded mixture of fine, medium and coarse grains. This type negatively affects construction, such as reducing the strength of the concrete, increasing porosity, making it difficult to operate and increasing costs due to the need for re-treatment or replacement when starting to sign commercial investment projects..

4. The low plastic silt category covers 2,975.7 hectares, representing 19.6% of the total soil area This type of soil is characterised by low clay softness and cohesion, which negatively affects the stability of the construction of commercial and investment buildings..
5. The high plastic silt category covers 1,702.0 hectares, accounting for 11.2% of the total soil area This type of soil has a high plasticity and represents a challenge for the design of investment urban facilities, causing pressure on the foundations and leading to cracking and subsidence of buildings..
6. The high plastic clay category covers 1,130.7 hectares, representing 7.4% of the total soil area. This type of soil is considered one of the most dangerous types of soil for the foundations and buildings of commercial investment projects because it is unstable soil and can cause subsidence in the building as well as cracks in the foundations and walls.

Map (5) : *Unified Global Classification of Soils in the City of Ramadi for the Year 2025*



Source:1. Based on data from Table.(١)
2.Analysis conducted using ArcGIS version 10.8.1.
3.Satellite imagery of Ramadi city obtained from the WorldView-3 satellite (30) cm resolution, JPEG format), United States, 2025.
4.Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033.

Table (6): *Unified Global Soil Classification in Ramadi City for the Year 2025*

No.	Classification type	Area (hectares)	Percentage%
1	Poorly Graded Sand	2902.3	19.1
2	Sandy Clay	3622.7	23.8
3	Low Plastic Silt	2975.7	19.6
4	High Plastic Silt	1702.0	11.2
5	Low Plastic Clay	2883.6	18.9
6	High Plastic Clay	1130.7	7.4
Total		15217	100

Source: Based on Map (5) and analysis using ArcGIS version 10.8.1.

2.2 Geographical Distribution of Commercial Investment Projects in the City of Ramadi

Distribution is central to the work of geographers. Geography is often described as the science of the spatial distribution of phenomena, focusing on studying various features on the Earth's surface to describe, analyze, and interpret them. Therefore, distribution is the foundation of any geographical study and a crucial step in understanding the behavior of any geographical phenomenon. This section addresses the distribution of commercial investment projects as follows:

2.2.1 Commercial Malls Granted Under the Musataha System

Commercial investment projects play a vital role in the daily lives of city residents. These projects typically take the form of large shopping centers that house a variety of stores, services, and entertainment options under one roof. Malls are popular destinations for shoppers because they combine shopping and entertainment, offering convenience while stimulating commercial and economic activity in Ramadi. To examine the current status of commercial investment projects granted under the Musataha system in Ramadi, please refer to Table (7) and Map(6). The total area of the granted investment commercial malls, granted according to the Musataha system is 34,976 m2. The oldest investment commercial project in the city of Ramadi is a commercial mall located in Al-Mustaqbal neighborhood, with an area of 1025 and an investment period of 30 years, located on plot numbered 4/138. Contracting for it began on 04/10/2005 and the contract ends on 04/09/2030 . This commercial project is located near Al-Quds Street, which is one of the important and vital arterial streets in the city of Ramadi, which was an important and fundamental factor in attracting this commercial project.

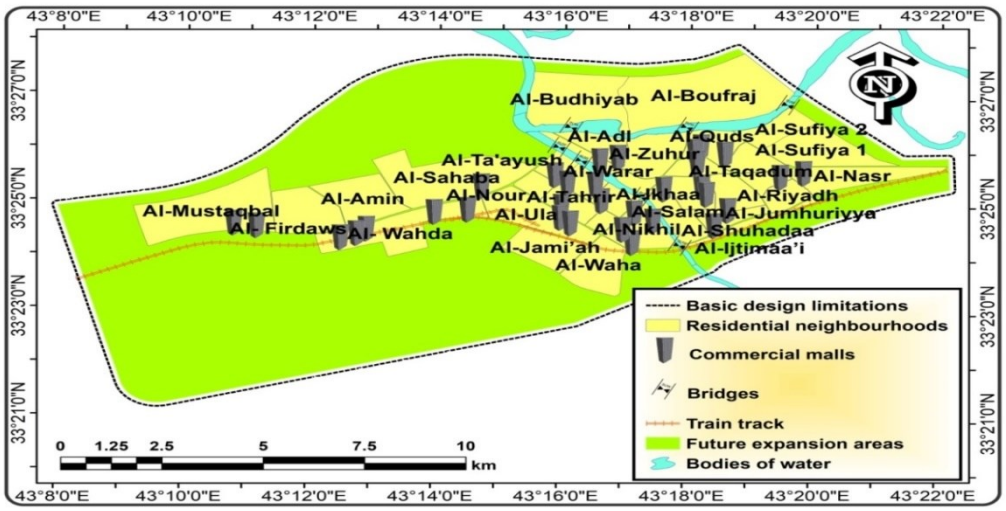
Table (7): *Current Status of Commercial Malls Granted under the Musataha Rental Law in the City of Ramadi for the Year 2025*

No	Name of Musataha	Site	Area	Rental Period Years	Part Number	Beginning Of Decade	End Of Contract
1	commercial building	AlMustaqbal	1025	20	4/138	10/04/2005	09/04/2020
2	commercial building	AlMua'lemeen	515.70	20	231/4	07/01/2010	06/01/2030
3	commercial building	Al Amjad	370,60	15	163/6528	19/11/2012	04/07/2026
4	commercial building	AlMua'lemeen	7561,96	25	149/2168	21/01/2021	20/01/2045
5	commercial market	AlIkhaa	898.66	17	162/7893	11/06/2020	10/06/2037
6	commercial market	AlShafi	300	15	162/4498	09/11/2010	08/11/2025
7	commercial building	AlQuds	476,85	20	91/36	15/07/2012	14/07/2032
8	Construction laboratory	Al Wahda	1183,42	20	83/37404	06/09/2012	05/09/2023
9	Alwa Al Rashid Marketing	Al Wahda	13562,50	25	83/8333	05/08/1995	04/08/2020
10	commercial market	AlSahaba	1253,6	20	83/18832	12/12/2016	11/12/2036
11	commercial market	AlQuds	262.10	20	19/27	09/01/2017	18/01/2037
12	commercial b10uilding	AlWarrar	363,16	18	50/53	20/11/2019	19/112037
13	commercial building	AlTahrir	408,66	20	162/7897	06/06/2017	05/06/2037
14	commercial market	AlQuds	204	15	1/409	09/05/2017	08/05/2032
15	shopping mall	Al Nakhil	2556	20	162/8049	06/06/2017	05/06/2037
16	commercial market	AlQatana	480	20	1/234	03/09/2018	02/09/2032

17	commercial building	AlSahaba	756,25	17	163/7575	01/09/2020	31/08/2037
18	commercial market	AlSalam	900	19	1/849	27/12/2020	27/12/2033
19	commercial building	AlAdl	192,50	19	1/675	19/01/2020	08/11/2039
20	commercial building	AlNasr	2180,50	21	162/8263	16/03/2023	15/03/2042
21	commercial building	AlShafi	1492,66	20	83/16522	06/06/2021	05/04/2041
22	commercial market	AlIjtimaa'i	1170	15	162/5722	26/03/2006	25/03/2021
23	commercial market	Al Nakhil	1985	19	162/8248	10/03/2021	09/03/2040
24	commercial market	Al Nakhil	1500	19	162/8244	10/03/2021	09/03/2040
25	commercial building	AlShafi	600	20	83/59695	19/04/2021	18/04/2041
26	Car showrooms	AlUla	4780	17	83/59437	19/04/2021	18/04/2038
27	commercial building	Al shuhada	361,83	20	163/6834	12/12/2016	11/12/2036
28	commercial market	AlWaha	1783,90	18	83/14292	07/06/2021	06/06/2039
29	shopping mall	AlWaha	1994.4	20	83/59443	07/06/2021	09/04/2020
30	Car showrooms	AlUla	4705	25	83/51662	03/07/2021	06/01/2030
31	shopping mall	Al Wahda	1417,5	20	83/45569	13/07/2021	04/07/2026
32	commercial building	AlMustaqbal	1500	8	83/59567	27/9/2021	20/01/2045
	Total Area						34,976 m^2

Source: (20) , (21) , (22) ***.Map (6):*** *Geographical Distribution of Commercial Malls Granted under the Musataha System for the Year 2025*

Source:



1. Data from Table (7).
2. Satellite imagery of Ramadi city obtained from the WorldView-3 satellite (30) cm resolution, JPEG format), United States, 2025.
3.Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033.

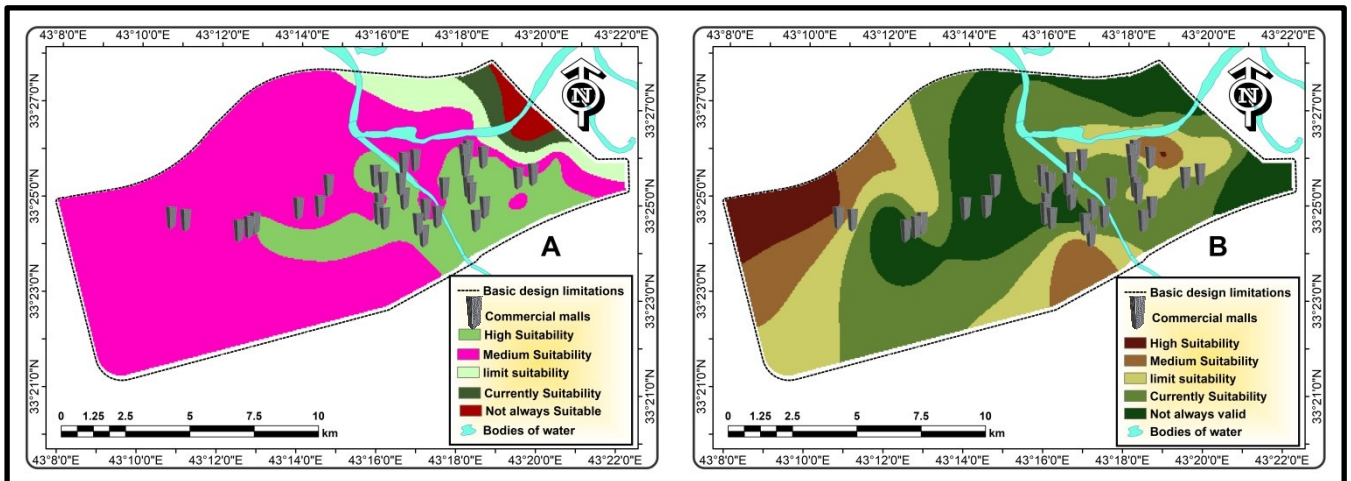
3-3 Spatial Suitability for Signing Commercial Projects in the City of Ramadi

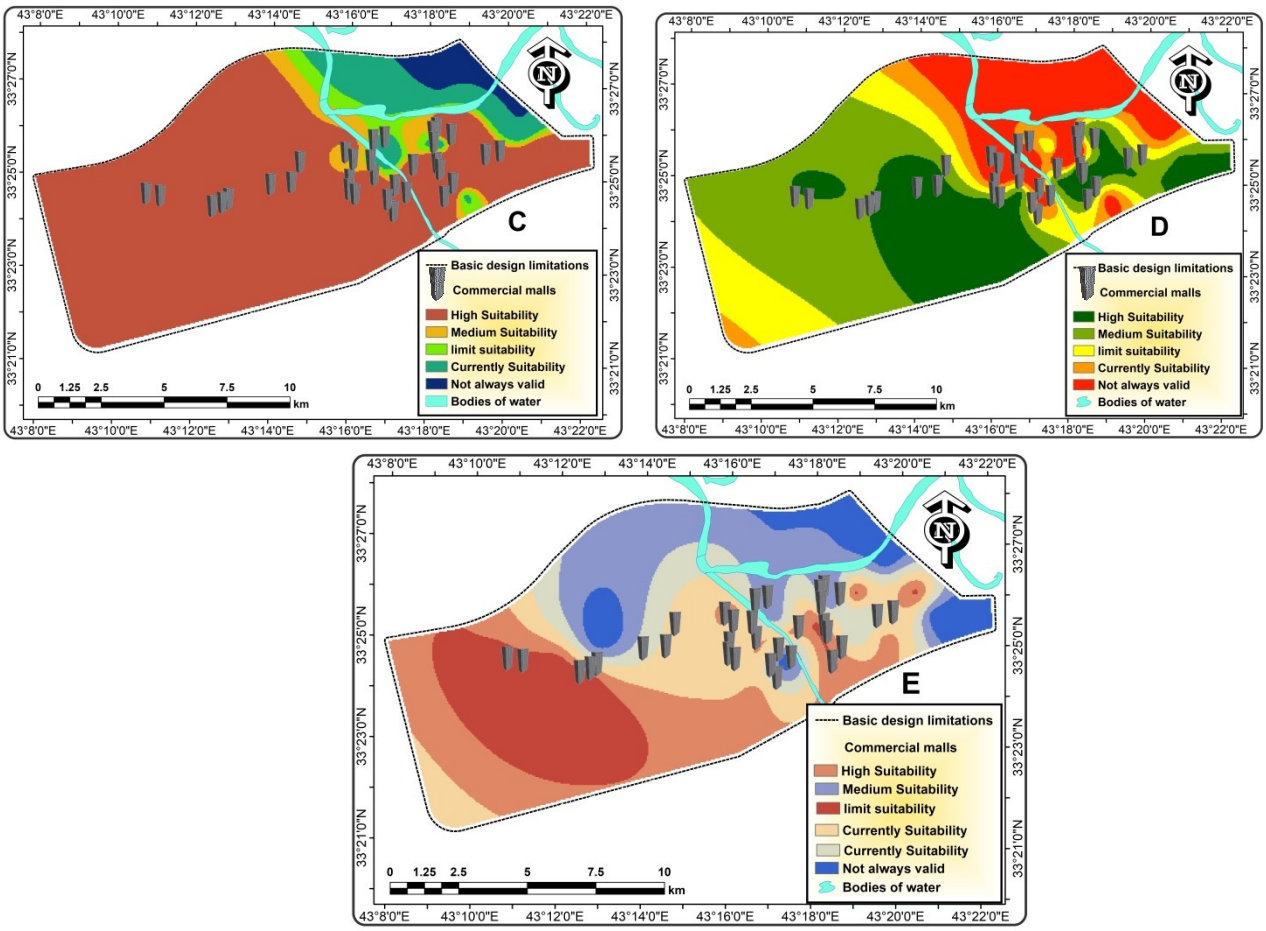
3-3-1 Soil Texture Evaluation Model

It is evident from Table (8) and Map (7-A) and comparing them with Appendix (1), that there is a noticeable variation in the spatial suitability of soil texture across the city of Ramadi. The findings are summarized as follows:

1. **High Suitability:** Its area constitutes (2.3%) of the total area of the soil in the city of Ramadi and is highly suitable and is a (sandy clay) soil. This soil is characterised by its cohesion and hardness and is not affected by the rise and fall of groundwater and its ability to be compacted is very high when signing commercial investment facilities; (19) commercial investment malls were located within these areas.
2. **Medium Suitability.:** Its area reached (5.5%) of the total area of the soil in the city of Ramadi. These areas are of medium suitability and have a soil type (mixed clay). This soil combines clay, sand and silt and is very suitable for agriculture. It can be used in signing commercial investment projects due to its ability to cut and bear loads. (13) commercial investment malls were located within these areas.
3. **Marginal Suitability:** Its area constitutes 77.7% of the total soil area in the city of Ramadi. The establishment of commercial investment facilities in it is somewhat dangerous because the soil texture (sandy mixture) here is characterised by its lack of cohesion and hardness in its usual form. No commercial investment project has been established within these areas.
4. **Currently Unsuitable:** Its area percentage was recorded as (1.6%) of the total soil area in the city of Ramadi, and this type is currently unsuitable because the soil texture is (mixed clayey silty and is not cohesive and has a weak capacity to bear the buildings of commercial urban facilities; and no commercial investment project has been signed in the study area within these areas.
5. **Not Always Suitable:** Its area represents (12.9%) of the total area of Ramadi city; the soil texture is (mixed alluvial) and these areas cannot be utilized at the present time or in the future when starting to sign commercial investment projects, due to the high humidity in the foundations and walls of investment buildings, and also affects the stability of the excavation and its sides collapse, which requires reinforcing the sides of the excavation with iron sheets in the sites of commercial investment projects due to the irregular arrangement of its grains; no commercial investment project has been signed within these areas.

Map (7): *Spatial suitability models for the physical properties of the soil in the city of Ramadi for the year 2025*





Source:1. Maps in Chapter One; compared with Appendices (1,2,3,4,5).
2. Use of ArcGIS 10.8.1.
3.Satellite view of Ramadi city from WorldView-3 satellite, resolution 30 cm, JPEG format, United States, year 2025.
4.Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033.

Table (8): *Spatial suitability categories for soil texture when signing commercial investment projects in Ramadi for 2025*

No.	Suitability class	Area (Hectares)	Percentage%
1	High validity	348.2	2.3
2	Medium validity	842.1	5.5
3	limi t validity	11812.9	77.7
4	Currently invalid	248.1	1.6

5	Not always valid	1965.7	12.9
Total		**15217**	**100**

Source: *Map (7-A), comparison with Appendix(1) and analysis using ArcGIS version 10.8.1.*

3-3-2 Soil Moisture Content Evaluation Model

It is clear from Table (9) and Map (7-B) and comparing them with Appendix (2), that there is a clear variation in the spatial suitability of the soil moisture content in the city of Ramadi, as shown below:

1. **High suitability**: Its area constitutes 5.5% of the total soil area in the city of Ramadi and can be greatly utilized in establishing commercial investment projects because it contains a low percentage of moisture and is cohesive. No commercial investment mall has been established within these areas.
2. **Medium suitability**: Its area represents (10.7%) of the total soil area in the city of Ramadi, and it can also be used to sign commercial investment projects, as the soil moisture content is acceptable. (2) commercial investment malls were located within these areas.
3. **Limit of suitability**: Its area percentage was recorded as (21.7%) of the total area of the city of Ramadi, and this category creates a kind of risk when signing commercial investment projects due to the soil moisture being higher than the approved standard; and (6) commercial investment malls were located within these areas.
4. **Currently unsuitable**: Its area constitutes (37.9%) of the total area of the city of Ramadi. These areas have largely uncohesive soil and require major engineering measures. They can be used when removing or treating the high percentage of soil moisture content when signing urban facilities for investment projects. (14) commercial investment malls were located within these areas.
5. **Not always suitable**: Its area constitutes (24.2%) of the total area of the city of Ramadi, and these areas cannot be utilized when removing or treating the limitations in the soil moisture content when signing urban facilities for investment projects due to the high percentage of soil moisture content, which leads to cracking and destruction of the foundations of investment project buildings, which leads to difficulty in closing the doors; and (9) commercial investment malls were located within these areas.

Table (9): *Spatial suitability categories for soil moisture content when signing commercial investment projects in Ramadi for 2025*

No.	Suitability class	Area (Hectares)	Percentage%
1	High validity	833.5	5.5
2	Medium validity	1630.8	10.7
3	limi t validity	3304.4	21.7
4	Currently invalid	5770.1	37.9
5	Not always valid	3678.2	24.2
	Total	**15217**	**100**

Source: *Map (7-B), comparison with Appendix(2) and analysis using ArcGIS version 10.8.1.*

3-3-3 Soil Liquid Limit Evaluation Model

It is evident from Table (10) and Map (7-C) and comparing them with Appendix (3), that there is a clear variation in the spatial suitability of the soil liquidity limit values in the city of Ramadi, which can be summarized as follows:

1. **High suitability:** Its area constitutes (78.8%) of the total soil area in the city of Ramadi, which is a very high percentage of areas and can be used in signing commercial investment projects due to the low soil liquidity limit. The lower it is, the more solid the soil becomes, and this reduces the risks of deformation and subsidence in the buildings of the investment urban facility in the city of Ramadi. (24) commercial investment malls were implemented within these areas.
2. **Medium suitability:** Its area represents (5.0%) of the total soil area in the city of Ramadi and is of medium suitability because the soil still contains a low liquidity limit for signing commercial investment projects after implementing engineering measures. (2) commercial investment malls were implemented within these areas.
3. **Limit of suitability:** Its area represents (4.3%) of the total area of Ramadi city. This type poses a risk of soil subsidence when commercial investment projects are signed in it due to the soil liquidity limit being higher than the approved standard. (1) commercial investment mall was implemented within these areas.

4. **Currently unsuitable:** Its area constituted (8.7%) of the total area of the city of Ramadi, and these areas can be utilized when removing or treating the limitations in the high limit of soil liquidity when signing urban facilities for investment projects; and no commercial investment mall was implemented within these areas.
5. **Not always suitable**: - Its area percentage reached (3.2%) of the total area of the city of Ramadi, and these areas cannot be utilized when removing or treating the limitations in the soil liquidity limit when signing urban facilities for investment projects due to the high percentage of soil liquidity limit, which causes a high percentage of salts, a rise in the groundwater level, and soil subsidence under the foundations of adjacent buildings. No commercial investment mall was located within these areas. ***Table (10):*** *Spatial suitability categories for soil fluidity limit when signing commercial investment projects in Ramadi for 2025*

No.	Suitability class	Area (Hectares)	Percentage%
1	High validity	11981.8	78.8
2	Medium validity	765.0	5.0
3	limi t validity	658.1	4.3
4	Currently invalid	1319.4	8.7
5	Not always valid	492.7	3.2
Total		**15217**	**100**

Source: *Map (7-C), comparison with Appendix(3) and analysis using ArcGIS version 10.8.1.*

3-3-4 Soil Plasticity Index Evaluation Model

It is clear from Table (11) and Map (7-D) and comparing them with Appendix (4), that there is a clear variation in the spatial suitability of the soil plasticity index values in the city of Ramadi, which is summarized as follows:

1. **High suitability**: Its area constitutes (23.0%) of the total soil area in the city of Ramadi. These are areas with a high percentage and the soil has low plasticity, which helps in its stability, hardness and cohesion. It can be used in signing commercial investment projects. (7) commercial investment projects were signed within these areas..
2. **Medium suitability**: Its area reached (35.4%) of the total area of the soil in the city of Ramadi. These are areas with a very high percentage and are soils of medium plasticity in terms of stability and hardness. They can be used in signing commercial investment projects. (9) commercial investment projects were implemented within these areas.
3. **Limit of suitability**: Its area percentage was recorded as (14.9%) of the total area of the city of Ramadi, and this category contains a kind of risk when signing commercial investment projects in it due to the high plasticity of the soil, which affects the subsidence of the soil under the foundations of commercial investment facilities; and (4) commercial investment projects were implemented within these areas.
4. **Currently unsuitable**: Its area constituted (7.3%) of the total area of Ramadi city, and these areas can be utilized when removing or treating the limitations in the height of the soil plasticity index when implementing commercial investment projects. Comprehensive geotechnical studies of the soil within these areas must be conducted in order to design suitable foundations or to resort to soil stabilization to reduce the risks of swelling. (4) commercial investment projects were implemented within these areas.
5. **Not always suitable**: Its area reached (19.4%) of the total area of Ramadi city, and these areas cannot be utilized when removing or treating the height values in the soil plasticity index, and this leads to serious structural damage such as cracking and uneven subsidence of the building when urban facilities are signed for commercial investment projects in it; and (8) commercial investment projects were implemented within these areas.

Table (11): *Spatial suitability categories for the soil plasticity index when signing commercial investment projects in the city of Ramadi for the year 2025*

No.	Suitability class	Area (Hectares)	Percentage%
1	High validity	3492.9	23.0
2	Medium validity	5394.0	35.4
3	limi t validity	2259.8	14.9

4	Currently invalid	1116.8	7.3
5	Not always valid	2953.5	19.4
Total		**15217**	**100**

Source: *Map (7-D), comparison with Appendix(4) and analysis using ArcGIS version 10.8.1.*

3-3-5 Global Soil Classification Evaluation Model

It is clear from Table (12) and Map (7-E) and comparing them with Appendix (5), that there is a clear variation in the spatial suitability of the global soil classification values in the city of Ramadi, summarized as follows:

1. **High suitability:** The classification for this category is (sandy clay) and this soil is one of the best types of soil for construction and has good water drainage and supports foundations in a stable manner and can be used in signing commercial investment projects due to its ability to bear the loads of those facilities and its ability to be compacted greatly and its area percentage reached (23.3%) of the total area of the soil in the city; and (5) commercial investment projects were signed within these areas.
2. **Medium suitability:** The classification for this category is (weak plastic clay) and has low shear resistance, which means that the foundations built on it may settle and crack over time due to the low bearing capacity and increased risk under the influence of weather factors such as rain. Its area percentage reached (18.9%) of the total soil area in the city; and (5) commercial investment projects were signed.
3. **Limit of suitability:** This category is classified as (poorly graded sand) and this type of soil is characterized by not containing a balanced mixture of particles, which negatively affects the properties of concrete such as its strength and durability, and it is susceptible to corrosion and reduces the durability of construction for commercial investment projects in the city of Ramadi. Its area percentage was recorded as (19.1%) of the total area of the city of Ramadi, and this category contains a kind of risk when signing commercial investment projects; and (4) commercial investment projects were signed within these areas.
4. **Currently unsuitable.:** The classification for this category is (weak plastic silt) and is not suitable as a base layer for the building as it lacks the ability to bear and can lead to cracks and collapses in the structure or building of the commercial investment facility. Its area constituted (19.6%) of the total area of the city of Ramadi; and (11) commercial investment projects were located within these areas.
5. **Currently unsuitable:** The classification of this category (high plasticity silt) has the ability to shrink and swell under the influence of moisture, causing cracks and pressure on the foundations of the Omani commercial buildings in the study area; its area constituted (11.2%) of the total area of the city of Ramadi, and this type of soil requires precise engineering studies and special stabilization techniques to ensure the stability and safety of that facility; and (5) commercial investment projects were signed within these areas.
6. **Not always suitable:** This category is classified as (high plasticity clay) and the increase in plasticity contributes to a decrease in the shear strength of the soil, which constitutes a negative factor on the stability of the foundations and structures of commercial buildings in the city of Ramadi, in addition to cracks in the walls. Its area constitutes (7.4%) of the total area of the city of Ramadi; and no commercial investment project has been signed within these areas.***Table (12)***: *Spatial suitability categories of the International Standard Soil Classification when signing commercial investment projects in the city of Ramadi for the year 2025*

No.	Suitability class	Area (hectares)	Percentage%
1	High validity	2902.3	19.1
2	Medium validity	3622.7	23.8
3	limi t validity	2975.7	19.6
4	Currently invalid	1702.0	11.2
5	Not always valid	2883.6	18.9
6	Not always valid	1130.7	7.4
Total		**15217**	**100**

Source: *Map (7-E), comparison with Appendix(5) and analysis using ArcGIS version 10.8.1.*

4-4 The Final Model for Evaluating the Soil Factor and Its Impact on Signing Commercial Investment Projects

It is worth noting that the physical and chemical properties of the soils were collected, and a unified weight was assigned to each factor. These weights were then integrated into the general model of geographical characteristics under the name “soils” (see Appendix 6). After that, the data were entered and reclassified following the mapping modeling process using the spatial suitability model (Model Builder) in the ArcGIS program. A model for the spatial suitability of soils in the city of Ramadi was created using the weighted overlay structure, as shown in Scheme (1), Map (8), and Table (13). There is a clear variation in the spatial suitability of the soil in Ramadi, summarized as follows:

1. **High suitability:** Its area reached (10.2) hectares, representing (0.1%) of the total soil area in the city of Ramadi. These soils are highly suitable for the development of commercial urban facilities due to their good components. Despite the locational advantages of these areas, no commercial investment projects have been implemented there, as the physical characteristics of the soil in these areas are:

a- Soil texture: The texture of these areas is sandy clay, and its soil is characterized by its hardness, cohesion, and excellent ability to withstand weather fluctuations such as rain and wind, making buildings and foundations of investment urban facilities more stable and secure in the short and long term.

b- Soil moisture content**:** The soil moisture content in these areas is very low, which is a positive indicator of the safety of the foundations and buildings of urban facilities in the study area.

c- Soil Liquidity Limit: These areas are characterized by a low soil liquidity limit. The lower the soil liquidity limit, the greater the soil hardness. This is an important and positive indicator, reducing the risk of deformation and subsidence in the buildings of the investment urban facilities in the study area.

d- Soil Plasticity Index: The soil in these areas has low plasticity, a positive indicator that contributes to its stability, hardness, and cohesion, making it less susceptible to swelling and shrinkage when commercial investment projects are implemented in the study area.

e- Global Unified Soil Classification: These areas are classified as (sandy clay). This soil is among the best types of soil for construction. It has good water drainage, supports stable foundations, and has a high capacity for compaction. This indicates the safety of commercial investment projects in the study area.

2. **Medium suitability:** Its area reached (472.0) hectares, representing (3.1%) of the total soil area in the city of Ramadi. These areas are of average suitability. (3) commercial investment projects were located within these areas. The physical characteristics of the soil on which these malls were built in the study area consisted of:

a- Soil Texture: The soil texture in these areas is (clay-mixed), which is highly suitable for agriculture. It is also of average suitability for commercial investment projects, as this soil expands and contracts with changes in humidity, causing movement and deformation of the foundations and potentially weakening the structural framework. These negative characteristics require special treatment to ensure the stability of commercial investment project buildings in the study area.

b- Soil Moisture Content: The soil moisture content in these areas was at an average level in terms of moisture content. This is a positive indicator and does not pose a risk to commercial investment projects in the study area.

c- Soil Liquidity Limit: The soil in these areas has a low liquidity limit, which constitutes a positive factor in the establishment of commercial investment projects in the study area.

d- Soil plasticity index. The soil in these areas has a medium plasticity, according to the Atterberg criteria. This soil is capable of supporting construction well and changing its shape under pressure without breaking. This is a positive indicator for the safety of commercial urban structures in the study area.

e- Global Unified Soil Classification: The classification for these areas is "poorly plastic clay," which has low shear resistance. This means that foundations built on it may settle and crack over time due to reduced bearing capacity and increased risk from weather factors such as rain. This negatively impacts the safety and security of commercial investment facilities located within these areas.

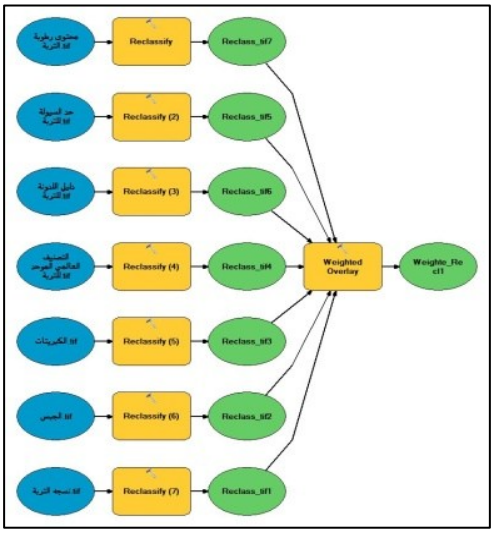
3. **Limit of suitability**: Its area is (7471.6) hectares, representing (49.1%) of the total area of Ramadi city. This soil is marginal in terms of the availability of physical soil properties in the study area. (9) commercial investment projects were located within these areas. The soil on which these commercial projects were built in the study area consisted of:

a- Soil texture: The texture of the soil (sandy mixture) constitutes a risk for commercial investment facilities within these areas, as the soil texture is characterized by its lack of cohesion and hardness in its normal form.

b- Soil moisture content: The moisture content of the soil in these areas is high, which poses a risk to the foundations and buildings of urban structures in the study area.

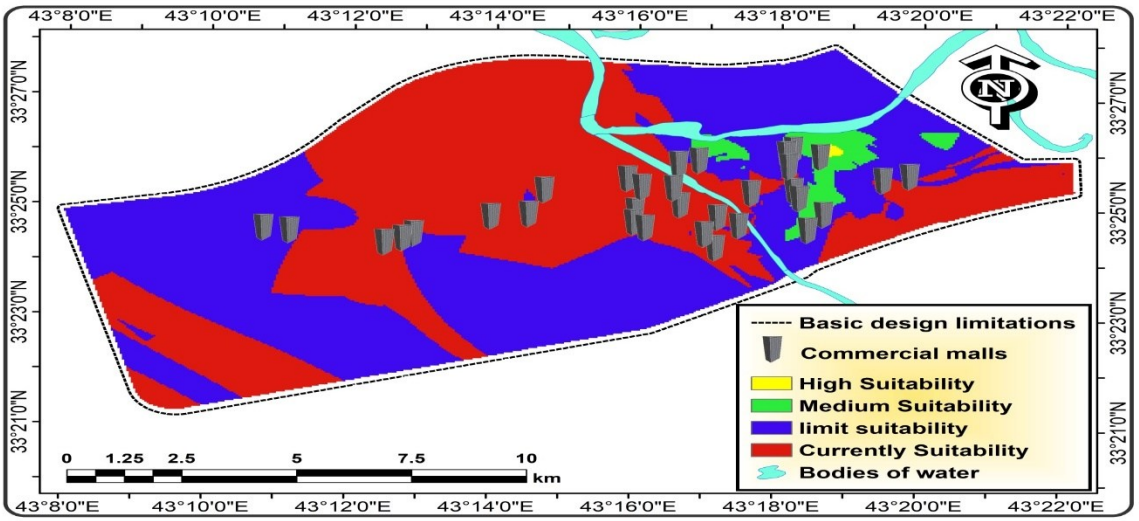
c- Soil fluidity limit: These areas are higher than the standard soil fluidity limit, which poses a risk such as soil subsidence under the foundations of urban structures in the study area.
d- Soil plasticity index: Plasticity within these areas is characterized by high elevation, affecting soil subsidence under the foundations of commercial investment facilities in the study area.
e- Global Unified Soil Classification: This category is classified as "poorly graded sand." This type of soil lacks a balanced mixture of particles, which negatively impacts concrete properties such as strength and durability. It is susceptible to corrosion, reducing the durability of construction for commercial projects in the study area.
4. **Currently unsuitable:** Its area reached (7,263.2) hectares, representing (47.7%) of the total area of Ramadi city. (20) commercial investment projects were located within these areas. These areas of soil cannot be utilized at the present time, due to the physical characteristics of the soil within these areas being formed as follows:
a- Soil texture: The texture is (a mixture of silty clay), which is not currently usable due to the high humidity in the foundations and walls of investment buildings. This also affects the stability of excavations, causing their sides to collapse, requiring the reinforcement of the excavation sides with iron sheets at the sites of commercial investment projects due to the irregular arrangement of their grains. No commercial investment projects were located within this category.
b- Soil moisture content: These areas have largely uncohesive soil, requiring significant engineering measures. These measures can be utilized to remove or address the high percentage of soil moisture content when designing urban structures for investment projects.
c- Soil Liquidity Limit: These areas have a high soil liquidity limit, causing high salt content, a rise in the groundwater level, and subsidence under the foundations of adjacent buildings.
d- Soil Plasticity Index: These areas are characterized by high soil plasticity. Comprehensive geotechnical studies of the soil within these areas are required to design appropriate foundations or resort to soil stabilization to reduce the risk of swelling affecting buildings in the study area.
e- Global Unified Soil Classification: This category is classified as (low plasticity silt) and (high plasticity silt). This classification is unsuitable as a foundation layer for buildings, as it lacks bearing capacity and can lead to cracks and pressure on the foundations of commercial buildings in the study area.

Plan (1): *Authority for Soils in Levant City for the Year 2025*



Source: Model Builder application, ArcGIS 10.8.1.

Map (8): *Soil spatial suitability model for signing commercial investment projects in the city of Ramadi for the year 2025*



Source:

1. Tables (8), (9), (10), (11), and (12).
2. Comparison with Appendix;(١)
3. Satellite view of Ramadi city from WorldView-3 satellite, resolution 30 cm, JPEG format, United States, year 2025.
4. Republic of Iraq, Ministry of Construction, Housing, Municipalities and Public Works, Directorate of Urban Planning, Ramadi City Development and Modernization Strategy, Basic Design for 2033.

Table (13): *Soil spatial suitability categories in Ramadi city for the year 2025*

No.	Classification Type	Area (Hectares)	Percentage%
1	High Suitability	10.2	0.1
2	Medium Suitability	472.0	3.1
3	Limit Suitability	7471.6	49.1
4	Currently Unsuitable	7263.2	47.7
Total		**15217**	**100**

Source: *Based on Map (8) and using ArcGIS 10.8.1.*

5-5 Research Conclusion:

The research included in the journal "Al-Aam" included a study of cartographic modeling of soil in the city of Ramadi and its impact on the design of commercial investment projects using geographic information systems. The research focused on studying the physical properties of the soil based on the results of laboratory tests obtained by the researcher. These laboratory results of soil samples were reflected in the design of commercial investment projects implemented within the basic design of the city of Ramadi. In light of the above research content, the following conclusions were reached.

5-5 -1 Results:

1- The research identified the most important physical characteristics that must be considered when designing commercial investment projects: (soil texture, with the best type being sandy clay), soil moisture content (low moisture soil is the best type), soil liquid limit (low fluid soil is the best type for designing these projects), soil plastic index (low plastic soil is the best type for designing these projects), and the unified global soil classification (sandy clay soil is the best type for designing these projects). Their distribution varied in the soil of the study area, given their significant importance to the safety and security of these commercial buildings.

2- Standard soil specifications were not taken into account when designing commercial investment projects in the study area. Some of them were located in soil with a limited suitability level, which is currently unsuitable and will never be suitable, negatively impacting the foundations and buildings of these commercial urban facilities. Leaving highly viable areas unused, despite their favorable characteristics, when signing investment projects.

3. The research found that the results of the laboratory examination of soil investigations submitted by investors when they initially signed commercial investment projects were not implemented with full seriousness and

sincerity. This is due to the fact that a number of commercial projects were located in soils outside the approved standard, within the viability limit, and currently unsuitable and unsuitable.

4. Geographic information systems enable the development of map models of the physical properties of soil, such as a map model (soil texture, soil moisture content, soil liquid limit, soil plasticindex, and the global unified classification). A final model of these physical properties is provided after assigning each factor a weight and producing a general soil model. All of these models visually simulate reality, which enhances a deeper understanding of topics, organizes ideas, facilitates information retrieval, understands spatial phenomena, and supports development plans for commercial projects in underdeveloped areas based on a precise understanding of geographical locations.

5-5 -2 Recommendations:

1. The study recommends paying attention to studying the physical properties of soil when planning commercial investment projects, both currently and in the future, in areas with well-classified soil, as indicated above, due to its direct impact on the buildings in those projects.

2. For public safety, when planning urban structures, detailed and accurate soil investigations must be undertaken before commencing investment project implementation. Soil investigations should be conducted in specialized laboratories under the supervision of the relevant departments.

3. Periodic monitoring of all investment projects located in areas (limited to validity; currently unsuitable; and permanently unsuitable) should be undertaken, as they fall outside the proper planning standards.

3. Attention should be paid to the models provided by the relevant departments, which they accessed through the geographic information systems (GIS) environment. These models demonstrate the strengths and weaknesses of investment project planning in a detailed and precise manner.

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Appendices:

Appendix (1) *shows various types of soil textures along with the percentages of their components.*

Ternary System	Fivety System	Tissue Type	Symbol	Percentage of Ingredients (Separated)%		
Sandy weave Mixed weave	rough		s	sand	Alluvial	clay
		Sand	L.S	85-100	0-15	0
		Mixed sand	s.L	70-90	0-30	0-15
Smooth weave	moderate roughness	Sandy mix	L	Less than 52	0-50	0-20
		Mixed	Si.L	Less than 52	0-50	7-27
Sandy weave	Medium texture, moderate softness	Silly mix	sl	0-50	50-80	0-70
		Silly	c.l	0-30	80-100	27-40
		Clay mix	s.c.l	20-40	40-37	20-45
		Sandy clay mix	Si.c.l	20-35	0-28	35-55
		Silly clay mix	s.c	22-40	40-37	Less than 50
Mixed weave	(minute (soft	Sandy clay	ci.c	more than 35	40-37	more than 40

		Silly clay	c	more than 40	more than 40	20-35
		clay	s	Less than 35	0-40	more than 40

Source:(23) .

Appendix (2) *shows the percentage of soil moisture content.*

No.	Soil moisture content values%	soil moisture content	Suitability class
1	8.12 – 15.5	Soil with low moisture content	High validity
2	15.5-22.9	Soil with medium moisture content	Medium validity
3	22.9 – 30.43	Soil with a limit moisture content	limi t validity
4	30.44 – 37.87	Soil with high moisture content	Currently invalid
5	37.87 – 45.3	Soil with very high moisture content	Not always valid

Source:(24).*Appendix (3)* *Classification of soils based on their liquid limit.*

No.	Liquid limit ratio%	Soil classification	Suitability class
1	20	very low	High validity
2	20-25	Low	Medium validity
3	25-30	Medium	limi t validity
4	30-50	High	Currently invalid
5	50-70	Very High	Not always valid

Source:(25).

Appendix (4) *Plastic Index values of different soil types.*

No.	plastic index ratio%	Soil classification	Suitability class
1	0	non-plastic soil	High validity
2	1-5	Somewhat ductile soil	Medium validity
3	5-10	low plastici soil	limi t validity
4	10-20	Medium plastici soil	Currently invalid
5	20-40	High plastic soil	Not always valid
6	more than 50	very high plastic soil	Not always valid

Source: (26) . ***Appendix (5)*** *Classification of soil according to Unified Soil Classification System (USCS).*

No.	Soil Type	Definition	Construction Suitability	Suitable Soil Under Foundation	Surface Suitability
1	Stone good Gradient	excellent	Excellent	Good	**Good**
2	Stone bad Gradient	excellent	Good	Acceptable to Good	bad
3	silt Stone	Bad to acceptable	Good	Acceptable to Good	Acceptable
4	clay gravel	bad	Good	Good	excellent
5	well-graded sand	excellent	Excellent	Good	Good
6	poorly graded sand	excellent	Acceptable	Acceptable to Good	bad

7	sandy silt	Bad to acceptable	Acceptable	Acceptable to Good	Acceptable
8	sandy clay	bad	Good	Bad to acceptable	Excellent
9	low plastic silt	Bad to acceptable	Acceptable	Bad to acceptable	bad
10	low plastic clay	bad	Good	Bad to acceptable	Acceptable
11	low plastic organic	bad	Acceptable	Bad	Bad
12	High plastic silt	Bad to acceptable	Bad	Bad	Bad
13	high plastic clay	Very bad	Acceptable	Bad to acceptable	Bad
14	Highly plastic organic	Very bad	Bad	Very bad to good	Bad
15	semi-charred rock wood	Bad to acceptable	unsuitable	unsuitable	unsuitable

Source:(27).

Appendix (6): *Weights for Soil Investigations and Their Impact on Signing Commercial Facilities*

No.	Worker Type	Weighting
1	Soil Texture	20
2	Soil Moisture Content	15
3	Soil Liquid Limit	15
4	Soil Plasticity Index	15
5	International Standard Soil Classification	35
Ratio		100

Source:(28).