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A Simulation of the Gypsum Content Distribution North of Baghdad

Huda W. Abdulwadood*, Reem Sh. Hameed, Abeer N. Abdul_Hammed
Department of Remote Sensing and GIS, College of Science, University of Baghdad, Baghdad, Iraq.

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Abstract

Due to its high solubility and unpredictable behavior, gypsum content is significantly challenging in engineering tests and agriculture processes. Another crucial element is that it causes long-term groundwater pollution and impacts buildings. This study explores the distribution and characteristics of gypsum soil in Salah Al-Din Governorate, Iraq, integrating field sampling, remote sensing techniques, and GIS tools. The land cover of the research area (27,751 km^2) was classified into four types: 15% bar soil, 40% structures, 16% vegetation and agricultural fields, and 8% water bodies. Gypsum content was measured using the Al-Mufty approach, while reflectance indices interpolation techniques, such as the Bar Soil Index (BSI) and the inverse distance weighted, were applied to map the distribution of gypsum. The results revealed gypsum concentrations ranging between 12.9% and 68.75% with associated SO_3 levels of 6.13% to 32.73%. Flat, low-lying areas exhibited higher gypsum and SO_3 concentrations, with spectral reflectance values of 0.01-0.5, aligning with the United States Geological Survey standards. Elevation models showed gypsum distribution primarily between 53 and 248 m above sea level. Slope and aspects analyses indicated gypsum presence in regions prone to water evaporation and distant from groundwater. Reducing on-site engineering testing by adding GIS and remote sensing tools to complement field engineering work contributes to reducing the use of equipment and transportation services and lowering time, cost, and efforts, significantly enhancing sustainable development. This study bridges a research gap in exploring the distribution of gypsum soils and associated technical and environmental challenges by integrating engineering tests with geographical information systems and remote sensing indicators. This enriches the literature, informs decision-making, and promotes sustainable development.

Keywords: gypsum soils, Gypsum Content, Google Earth, Remote Sensing technique, IDW Method.

محاكاة توزيع المحتوى الجبسي في التربة شمال مدينة بغداد

هدى وجود عبد الودود* , ريم شهاب حميد, عبير نزار عبد الحميد
قسم التحسس النائي و نظم المعلومات الجغرافية , كلية العلوم, جامعة بغداد, بغداد, العراق

الخلاصة

يعد محتوى الجبس مادة صعبة بشكل كبير في الاختبارات الهندسية المختلفة والعمليات الزراعية بسبب قابليته العالية للذوبان وسلوكه غير المتوقع. عنصر حاسم آخر هو أنه يسبب تلوث المياه الجوفية على المدى الطويل وله تأثير على المباني. تستكشف هذه الدراسة توزيع وخصائص التربة الجبسية في محافظة صلاح

* Email: huda.w@sc.uobaghdad.edu.iq

الدين, العراق, عن طريق دمج الفحوصات الهندسية مع تقنيات الاستشعار عن بعد وادوات نظم المعلومات الجغرافية. تم تصنيف الغطاء

الارضي لمنطقة البحث 27,751 كم^2 الى اربعة انواع : 15% تربة, 40% منشئات, 16% نباتات وحقول زراعية

,8% مسطحات مائية. تم قياس محتوى الجبس باستخدام طريقة المفتي, في حين تم تطبيق مؤشرات الانعكاس وتقنيات الاستيفاء, مثل مؤشر التربة , ترجيح المسافة العكسية لرسم خارطة توزيع الجبس. اظهرت النتائج ان تركيزات الجبس تتراوح بين 12.9% الى 68.7% ومستويات ثاني اوكسيد الكبريت المصاحبة تتراوح بين 6.13% الى 32.75%. اظهرت المنطق المسطحة المنخفضة تركيزات اعلى من الجبس وثاني اوكسيد الكبريت, مع قيم انعكاس طيفي تتراوح بي 0.01–0.5 بما يتوافق مع معايير المسح الجيولوجي. اظهرت نماذج الارتفاعات توزيع الجبس بشكل اساسي بين 53 و 248 متر فوق مستوى سطح البحر. و اشار تفسير المنحدرات والجوانب الى وجود الجبس في المناطق المعرضة لتبخر الماء والبعيدة عن المياه الجوفية. ان تقليل الاختبارات الهندسية في الموقع من خلال اضافة برامج نظم المعلومات الجغرافية وادوات الاستشعار عن بعد كمكمل للعمل الهندسي مما يسهم في تقليل استخدام المعدات ووسائل النقل, بالإضافة الى تقليل الوقت والتكلفة والجهد, مما يعزز التنمية المستدامة بشكل كبير. تعمل هذه الدراسة على سد فجوة بحثية في استكشاف توزيع الترب الجبسية والتحديات الفنية والبيئية المرتبطة بها من خلال دمج الاختبارات الهندسية مه ادوات الاستشعار عن بعد ونظم المعلومات الجغرافية , وهذا يثري الادبيات ويفيد صناع القرار , ويعزز التنمية المستدامة.

1. Introduction

Gypsum soil is typically found in deserts, arid or semi-dry locations where surface water evaporates and minerals such as gypsum precipitate, developing gypsum layers on the soil. Gypsum soil is particularly common in low-lying and flat places where surface water and rain do not accumulate. Soil qualities are significant in a building in this context. Soil has several chemical and physical qualities; consequently, the gypsum concentration in the soil might be one of the most essential chemical features since it directly influences the building's stability. This phenomenon occurs when gypsum dissolves in water and forms voids, causing differential deposition, structural fractures, and collapses [1]. Gypsiferous soils have a sufficient amount of ($CaSO_4.2H_2O$) gypsum-hydrated calcium sulfate, and it can be described as a soil containing more than 2% gypsum. Gypseous soil has an impact on engineering buildings since it includes soluble minerals. It is considered the worst and most harmful engineering soil if it is not water-proof. It is a white or translucent mineral with a specific density 2.32 [2].

Gypsum soil spans 125,027 m2 in Iraq, accounting for 28.6% of the country's land area and 6.7% of global gypsum lands [3]. Geographic information systems are an extremely effective technique for establishing a database of soil attributes. In general, GIS may be characterized as a pattern applied to information technology that permits us to keep and analyze data from numerous sources, whether qualitative or quantitative, and then provide a final result in the form of maps, charts, spreadsheets, models, or studies. With the development of remote sensing technologies and the multiplicity of data sources and technologies such as satellite imagery and Google Earth data integration with machine learning algorithms to classify land covers and land uses [4]. Researchers have chosen to use GIS in numerous engineering domains because of its capabilities, and much research has been undertaken to investigate the geotechnical qualities of soil worldwide.

- In 2024, T. Assami et al. offered a geographical analysis and interpretation of Riyadh's geological and geotechnical engineering database. Spatial maps were created by incorporating data from the study area's geotechnical research reports, concentrating on subsoil kinds and rock quality categorization. Using ArcMap tools and interpolation methods, the results showed that the materials and methodology used enable construction engineers to plan and implement projects more effectively, resulting in significant savings in time and financial resources associated with site investigations, as well as contributing to the region's long-term development of infrastructure [5].

- In 2024, Mamoun A. Gharaibeh et al. anticipated soil salinity and sodicity in Jordan's heavily exploited agricultural soils; the researchers used interpolation approaches such as Empirical Bayesian (EBK) and Discrete Kriging. They found that DK produced smoother and lower variance predictions than EBK. They demonstrated that EBK is more accurate than DK in geographical prediction and dealing with the inherent uncertainty in soil salinity and sodicity [6].

- In 2023, Safaa Al-Ali and Sattar Al-Khafaji estimated the geographical distribution of sand and gravel deposits and reserves in western Basra, southern Iraq; the researchers employed geostatistical interpolation methods such as inverse distance weighting (IDW) and ordinary kriging (OK) using well data. They discovered that the concrete gypsum layers varied from 1 to 3 m, while the artificial sand and gravel layers that appear as planar and occasionally lenticular deposits ranged from 3 to 8 m. The OK technique is more accurate than the IDW method for predicting sand and gravel reserves in all blocks, as indicated by the lowest ME and RMSE errors [7].

Several recent studies and investigations have linked the use of Geographic Information System (GIS) software with geotechnical engineering testing. Alaa D. Mamdooh et al., 2023 illustrate the limitations of conventional geotechnical mapping techniques, which are frequently expansive, time-consuming, and ineffective in capturing time and geographical variability. It highlights how GIS may manage, analyze, and map geotechnical data to provide more effective solutions. More than 60 studies. Conducted between 1993 and 2022, the study offers valuable details on GIS applications in geotechnical engineering, demonstrating how it may improve decision-making across industries, save cost, and increase data accessibility[8]. Alaa D. Mahmood et al., 2024 use GIS and GPS to investigate the special correlations of soil parameters in Ramadi City. Standard penetration test (SPT) measurements and 149 test holes were analyzed to produce a digital geotechnical map that accurately showed the distribution of these attributes. The study shows that combining GIS and geotechnical instrument techniques offers a quick, economical way to identify and map geotechnical features [9]. Bassma Sattar et al., 2024 illustrate that sediment transfer significantly impacts the environmental and hydrological systems, especially the rainwater collecting system, by decreasing storage and raising repair costs. To provide adequate and timely sedimentation detection, the study maps the sediment distribution in Lake Houran 3 using field surveys, observations, and GIS. The results show that GIS is essential for treating sedimentation issues at different spatial scales [10]. Reducing the site engineering tests and the use of the equipment and transporting vehicles, in addition to reducing efforts, time, and costs, will achieve and enhance sustainable development [11, 12].

This work aims to create spatially accurate maps of gypsum soil distribution in Salah al-Din Governorate. It highlights the distribution of gypsum soil using techniques such as remote sensing and GIS methodology and shows how accurate and valuable the tools are for sustainable management. Compared with previous studies, this research expands the use of GIS beyond the geotechnical properties to address the unique problems associated with gypsum soil, such as its solubility, structural effects, and groundwater pollution. This research gap lies in the limited exploration of gypsum soil distribution. Combining Inverse

Distance Weighted (IDW) interpolation, remote sensing indices, and Sport Vector Machine (SVM) classification, this study provides a novel methodology that bridges this gap, offering a specialized approach to mapping and managing gypsum soils.

2. Materials and Methods

This section reviews the materials and methods used in the study to simulate the distribution of gypsum content in some areas of central Iraq.

2.1. Study area

The research area (Salah Al-Din governorate) in Iraq (33.830 º-34.670º) N latitudes and (43.280º-44.470º) E longitudes applying the WGS 1984 system. The area is encompassed from the southwest by Tharthar Lake, and the Tigris River passes through it longitudinally. The landscape is flat [13]. The subject of the inquiry territory has a desert environment, with yearly precipitation fluctuating between 100 to 300 mm. Summertime temperatures can reach more than 50°C. Figure 1 shows the study area.

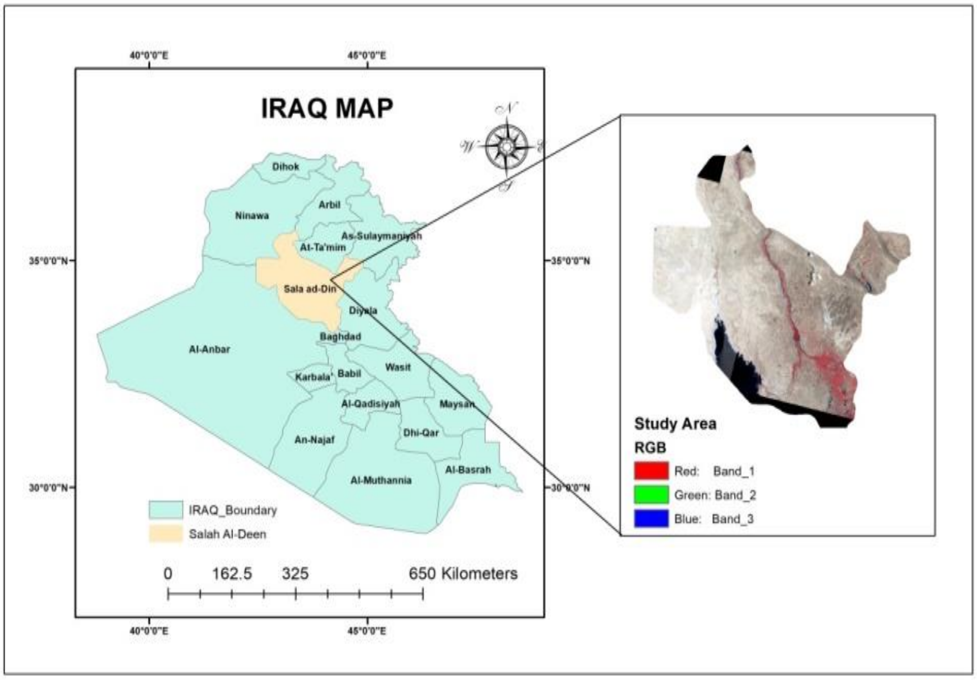

Figure 1: The Study Area

2.2. Satellite Dataset

- Landsat data were obtained from the USGS website; this dataset provides atmospherically adjusted surface reflectance and land surface temperature measurements from Landsat 9 OLI/TIRS sensors. The imagery includes five (Visible and NIR) bands, two SWIR bands for adjusted surface reflectance, and one TIR band for corrected surface temperature. It also includes intermediate bands utilized in the computation of ST products and quality control bands. Using a standard reference grid, the aggregated data slices are organized into overlapping "scenes" of roughly 170 km×183 km [14]. The Landsat 9 images were obtained on June 21, 2024, with Path 169, Row 36, Path 170, Row 36, and the Coordinates system (UTM_zon 38N).
- Google Earth Engine combines a multi-petabyte archive of imagery from satellites and GIS information with planet-scale analytical instruments. Researchers, investigators, and developers utilize Earth Engine to detect changes, illustrate structures, and locate exceptions

on the Earth's surface. The images have a resolution of 15 m by 15m. It creates the perception of multifaceted scenery, even if the visuals appear two-dimensional [15].

2.2.1. *Samples description*

Nine soil samples were collected from locations north of Baghdad Governorate and within Tikrit Governorate, Table (1). The al-Mufty technique was used to calculate gypsum content. All samples had equal masses, indicating the same density and porosity. They were evaluated in a natural indoor setting to avoid any inconsistencies.

Table 1: The soil specimens

lat	long	Gypsum Content %
376025.181	3838162.38	68.75
383248.872	383868.117	62.5
383206.359	3834708.161	39
384586.937	3867814.743	35.18
376299.345	3838297.351	32.5
373399.924	3839498.634	21.76
369275.022	3848594.781	12.9
384165.108	3834371.037	56.157
410455.377	3767807.135	55.73

2.3. Methods

ArcMap 10.4.1 was used to analyze the data and create the maps. The sample points' DEM layer was built using GPS visualization.

2.3.1. Pre-processing

Spectral bands were created, including a mosaic approach to match the images into the research region. A representation of the study region was constructed by integrating the spectral bands of the Landsat 9 images obtained on June 21, 2024 [16]. Using the Support Vector Machine technique, land coverings were divided into four categories (water, soil, vegetation, and agricultural land-buildings). Support Vector Machine is a common machine learning technique used in remote sensing image classification that achieves improved accuracy while categorizing multi-temporal satellite data [17,18]. It employs classification and regression to choose the appropriate hyperplane for defining data based on a given sample. At remote sensing, the Support Vector Machine has proved to be strong at recognizing heterogeneous and homogenous terrain [19]. The bare soil index was derived using eq1 to extract exposed soil pixels. The BSI is a spectral index that improves the identification of exposed soil surfaces and uncultivated regions using soil properties. The values range from -1 to 1, with a high value indicating the most barren soil [20].

$$BSI = \frac{(SWIR + Red) - (NIR + Blue)}{(SWIR + Red) + (NIR + Blue)} \qquad (1)$$

2.3.2. *Dehydration Method (AL-Mufty)*

The chemical composition of gypsum ($CaSO_4.2H_2O$) has two water molecules, which can be lost in oven drying at a specific degree of temperature. Gypsum ($CaSO_4.2H_2O$) forfeits its water content at about 50 $C^{o,}$ which turns into $CaSO_4.{}^1/_2$ H_2O. At about 100 $C^{o,}$ the hydration water has been lost, and the material becomes $CaSO_4$. (Al-Mufty) [21]. This method can be done by measuring the weight of the sample before and after drying at a temperature of 45 C° and at about 100 C° consecutively, Equation 2 [22]. The result is shown in Table 2.

$$X\,\% = \frac{W\ 45\ C^{O} - W\ 105\ C^{O}}{W\ 45\ C^{O}} \times 4.7778 \times 100 \tag{2}$$

X: Gypsum content.
$W\ 45\ C^{O}$: Weight of the sample at $45\ C^{O}$.
$W\ 105\ C^{O}$: Weight of the sample at $105\ C^{O}$.

2.3.3. Moisture content

Water content is one of the most important characteristics for many materials when creating a relationship between index properties and soil behavior. The phase relationships of air, water, and solids in a given volume of material are expressed using the water content of that material [23]. According to ASTM D2216, water-content determination is a standard laboratory test used to determine the amount of water in a quantity of soil in terms of its dry weight, Equation 3. The results are illustrated in Table 2.

$$\omega\,\% = \frac{W_{\omega}}{W_{s}} \times 100 \tag{3}$$

ω: Moisture content as a percentage.
W_s : Weight of soil.
W_{ω} : Weight of water.

2.3.4. Spatial IDW Interpolation

IDW Interpolation implements basic geographical regulations: things that are nearby are equivalent to ones that are not. IDW uses the established metrics for an unknown site to estimate its value [24]. These measured values (mainly near the predicted site) significantly impact the estimated value more than those not as close. The included values of the computation may be acquired by specifying and customizing the process of searching nearby, which represents the regions of the map surrounding the interesting location, in which the data points are reliant on extrapolation [25]. IDW is a "detailed" interpolator, which suggests predictions are precisely the observed values when executed at the data acquisition of the premises. This method forecasts the height of unidentified locations using distances between observed vs recognized sites. The mathematical illustration is as follows [26,27]:

$$z(x,y) = \frac{\sum_{i=1}^{n}\left[\frac{z_i}{d_i^j}\right]}{\sum_{i=1}^{n}\frac{1}{d_i^j}} \tag{4}$$

$$z(x,y) = \sum L_i \times z_i \tag{5}$$

Where $\sum L_i = 1$

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2} \tag{6}$$

In this equation, z(x,y) is the predicted value at the unmeasured site (x,y), i is the number of sample points in the defining neighborhood, and z is the known location. Li is the distance-dependent weight associated with each known location, and j represents the power parameter that defines the weight decrease rate as distance increases.

3. Results and Discussions

The land cover in the research region was classified into four types using remote sensing data and the vector support technique, Figure 2. According to Table 2, 15% of the (research area 24,751 km^2) is bare soil, whereas 40% is structures and land uses (e.g., roads, bridges, and amenities). The vegetation and agricultural fields covered around 3.961 km^2, while aquatic bodies covered 2.009 km^2.

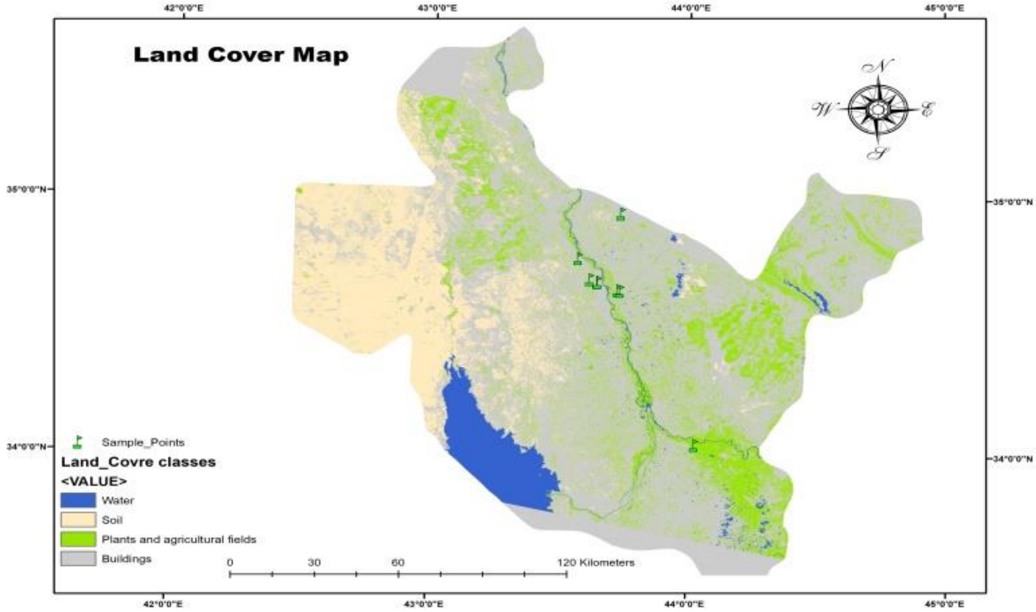

Figure 2: Land Cover Map by using ArcGIS: blue signifies water bodies, sand indicates barren earth, grey indicates structures, and green indicates vegetation.

Table 2: Land cover area

Class	Area km^2
Water	2.009
Soil	8.216
Plants and agricultural land	3.961
Building	10.565

The bare soil index, Figure 3, was calculated using Landsat spectral bands and spectral reflectance as part of the early processing processes to provide an initial estimate of the soil's spatial accuracy.

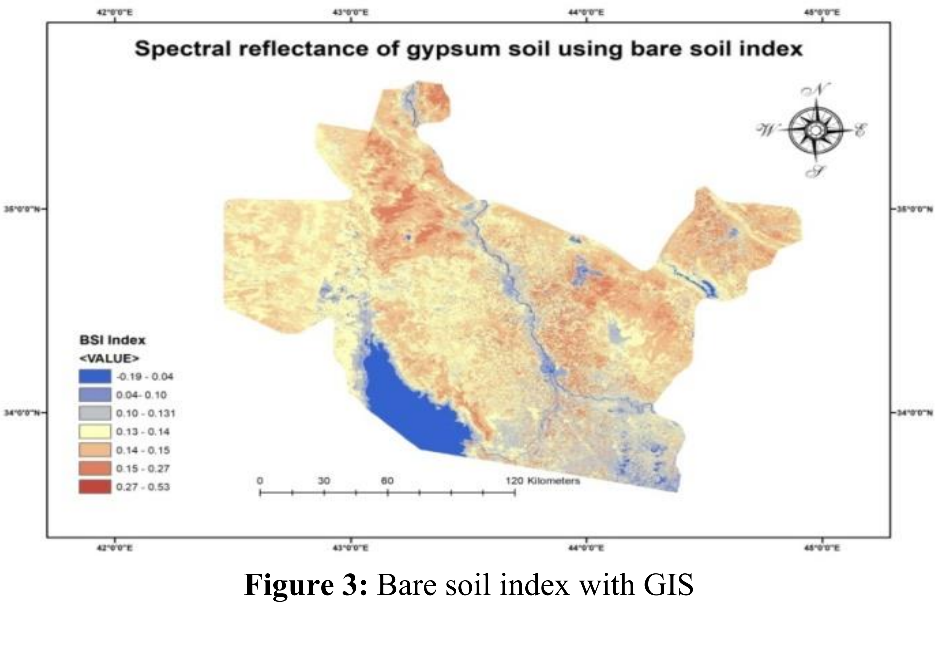

Figure 3: Bare soil index with GIS

The findings revealed that the spectrum reflectance of the soil in the research region ranged between 0.10-0.5, which is compatible with the US Geological Survey's spectral reflectance curve for gypsum soil, Figure 4.

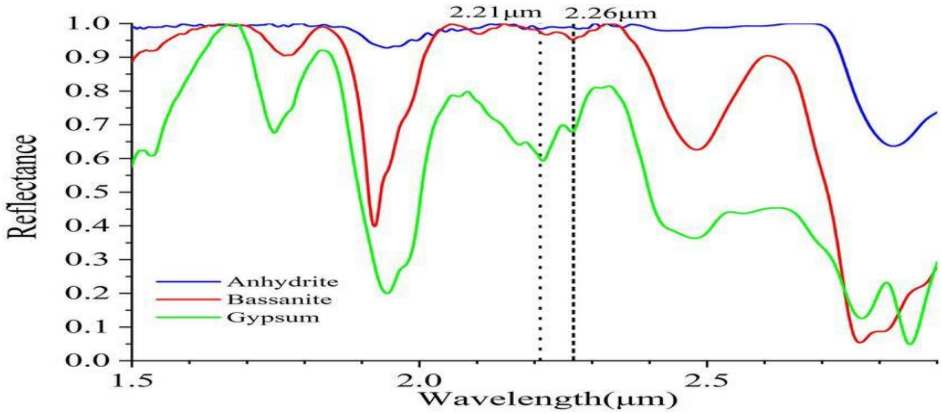

Figure 4: Spectral reflectance curve for gypsum soil

The BSI index improved the understanding of the soil in the study region. The index values were transformed into spectral data to determine the research samples' spectral reflectivity. GPS visualization website tools created a digital elevation model for the samples. IDW, especially, was employed as a finishing aid. Figure 5 depicts the findings of the distribution of gypsum soil in Salah al-Din Governorate based on the digital elevation model of the research samples. The digital elevation of the gypsum soil samples varied between 53 and 191 m. The spectrum reflectivity of the research samples was calculated and displayed in Table 3.

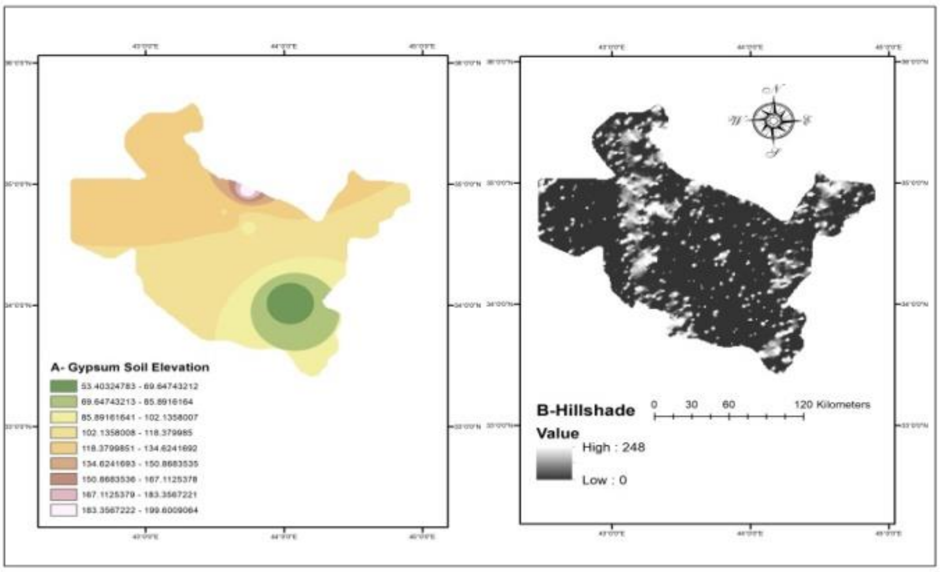

Figure 5: Gypsum soil elevation map with GIS

. **Table 3: The reflectance of gypsum soil samples from the BSI index**

Zone	Elevation (m)	Reflectance
1	248	0.29
2	91	0.28
3	199.7	0.23
4	120.9	0.15
5	125.1	0.21
6	117.6	0.14
7	97.1	0.15
8	53.4	0.28
9	132.2	0.28

A slope detail map was developed and divided into seven groups based on the study site, ranging from flat to very steep (Figure 6). The research area's aspect (faces or slope locations) was identified using a digital elevation model (DEM).

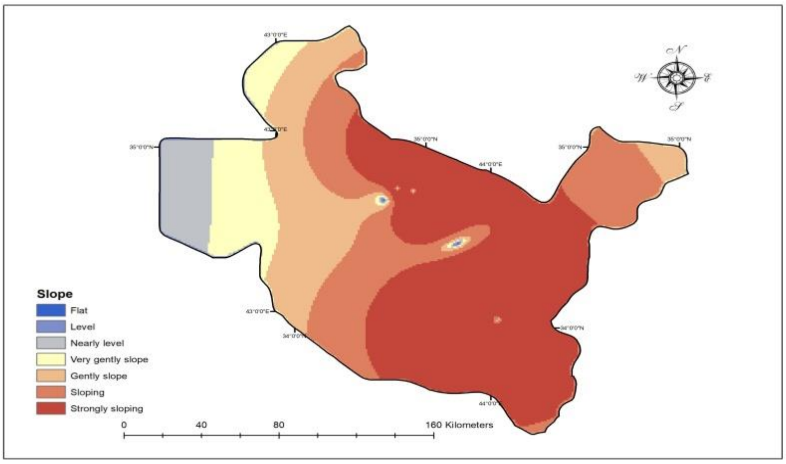

Figure 6: The slope map: GIS program

The slope aspect varied from 22.5 to 360 (N) and 159.5 to 202.5 (S). Figure 7 shows an aspect analysis of the research region.

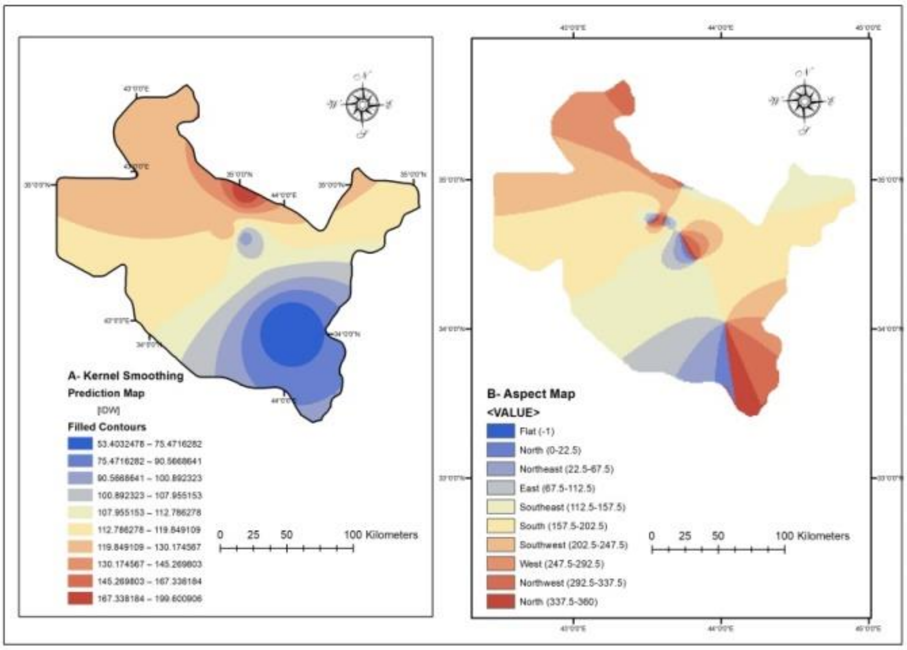

Figure 7: Aspect map: GIS program

Table 4 shows that greater SO_3 levels are related to higher gypsum concentrations since gypsum's chemical formula ($CaSO_4.2H_2O$) is the primary source of SO_3. A higher SO_3 level suggests larger quantities of gypsum, which is helpful in some sectors, such as cement manufacturing. Figures 8, 9, and 10.

Table 4: The Results of Gypsum, Moisture, and SO3 Contents

Zone	Gypsum Content %	Water Content %	SO_3 Content %
1	68.75	1.4	32.73
2	62.5	2.07	29.78
3	39	2.16	18.58
4	35.18	2.087	23.77
5	32.5	7.5	15.5
6	21.76	1.46	10.36
7	12.9	2.78	6.13
8	56.157	5.57	26.74
9	55.73	0.7	26.5

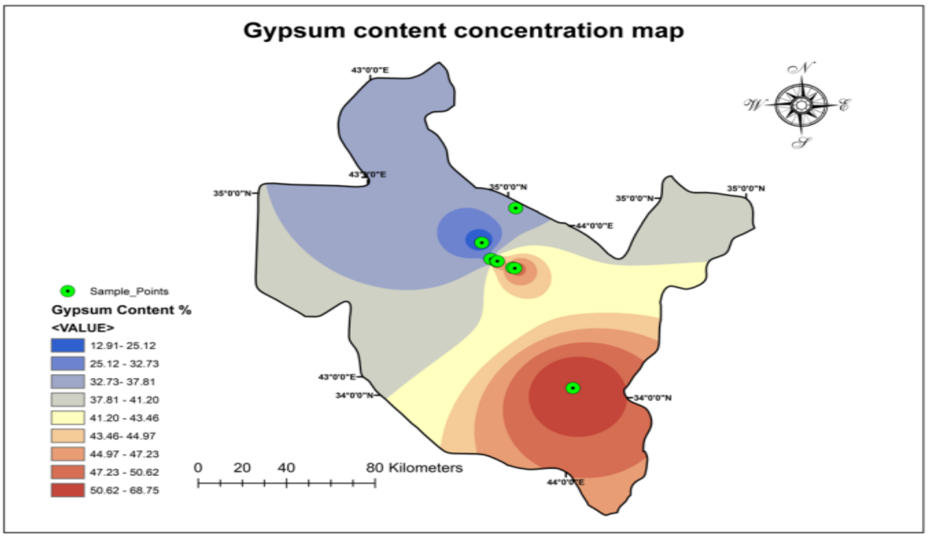

Figure 8: Gypsum content map

Show the geographic distributions of SO_3, water content, and gypsum in soils, as calculated with different interpolation approaches and ArcGIS software. The SO_3 and gypsum have similar geographical distributions but contain less water.

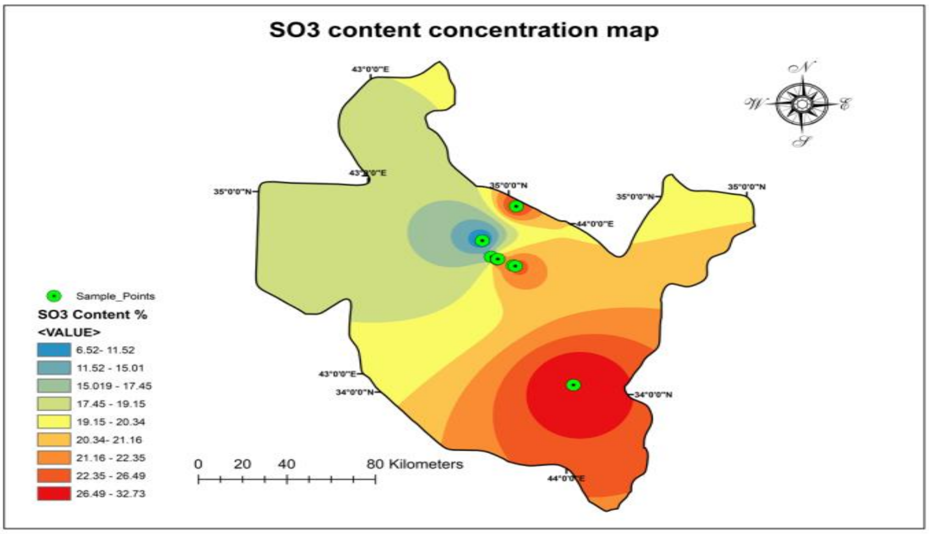

Figure 9: Sulfur Trioxide (SO_3) content map

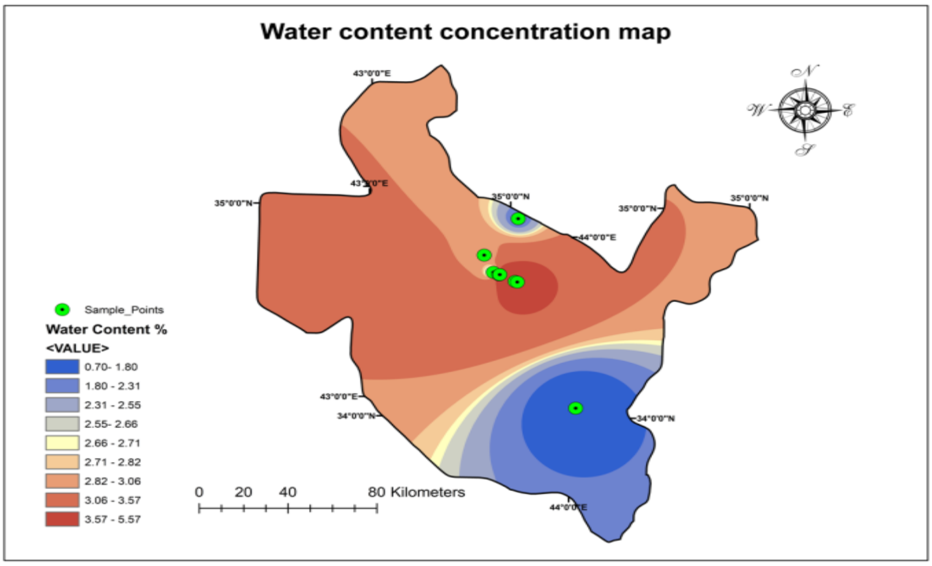

Figure 10: Water content map

The geographical distribution of gypsum soil was anticipated using study area samples, chemical analysis data, and spectral information from satellite imagery. Figure 11 depicts the regional distribution of each gypsum soil. The results showed that the methods used allowed the geographical distribution of gypsum soil to be calculated with great precision.

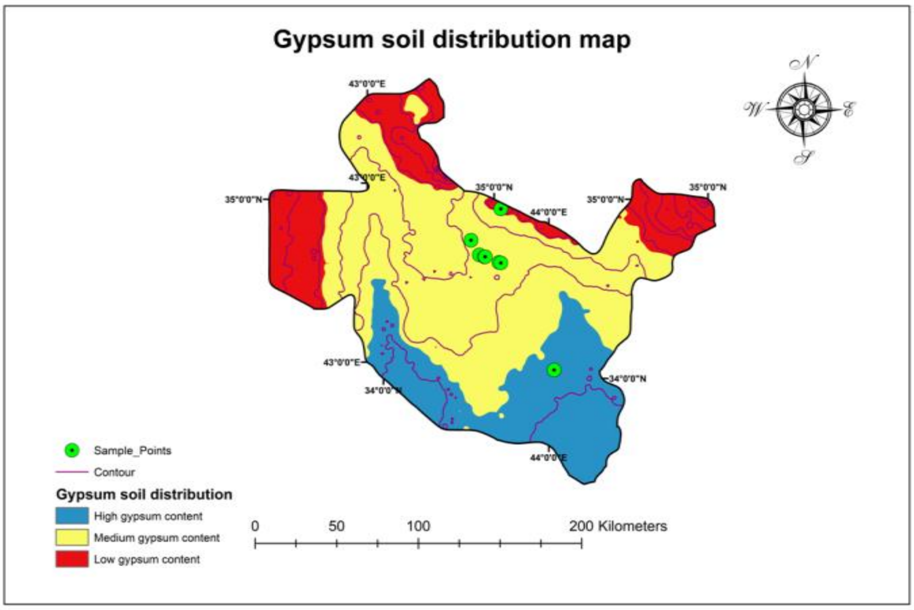

Figure 11: Spatial distribution map of gypsum soil

Comparing the results of this investigation with those of the previously mentioned geological and geotechnical analysis studies, some developed models for geographic interpretation and employed tools for predicting soil salinity. In contrast, other studies used geographic information systems to predict engineering properties and investigated sedimentation in dams and chemical treatments; this research employed tools like IDW and SVM in addition to satellite data to generate accurate maps of gypsum distribution in the region, which expands the scope of these tools utilized and focuses on spatial distribution based on chemical and spectral data. This helps to expand the application for various locations across several regions and enhance sustainable planning by reducing engineering project costs. The research gap lies in the lack of studies that explore the spatial distribution of gypsum soils and their engineering and environmental challenges using advanced GIS tools. This study presents a methodology that bridges this gap by combining GIS and remote sensing indices. Also, it contributes to enriching the literature and emphasizing the importance of sustainable development and decision-making processes.

4. Conclusions

Assessing land appropriateness can aid in achieving sustainability goals. The IDW approach and remote sensing data are excellent for mapping land cover and predicting geographical distribution. The research area's land covers were categorized using the machine learning technique Support Vector Machines. Interpolation algorithms and ground truth samples were used to forecast the gypsum content distribution. The findings are essential in detecting gypsum content because of its impacts on buildings and agriculture in the research region, as well as assisting decision-makers in managing environmental resources and enhancing services.

This study aims to identify the distribution levels of gypsum soil in the subject area related to some particular soil properties. The results include:

1- Gypsum content range: the study successfully determined the range of gypsum content in the area, with values predicted to fill in the gaps between actual sample locations.

2- Flat and low-lying areas were identified as having high gypsum content, high SO_3 concentrations, and low water content, as shown in Figures 8, 9, and 10.

3- Chemical bonding: a strong correlation is observed between higher concentrations of SO_3 and more significant proportions of gypsum due to the chemical compositions of gypsum ($CaSO4.2H_2O$), the primary source of SO_3.

4- Geographic insights: areas with significant gypsum deposits are flat areas experiencing regular water evaporation and relatively limited interaction with groundwater, as shown in Maps 8 and 10.

5- A database built on geographic information systems: using engineering tests and GIS analysis, Map 11 was developed to provide a reliable database for distributing gypsum content in the study area.

6- This study demonstrates the great benefit of integrating advanced GIS techniques with interpolation and spectral analysis algorithms for environmental and geotechnical applications. The results support decision-making processes related to sustainable land use and environmental management and address vital issues related to the impact of gypsum soils on infrastructure and agriculture in the region.

The study provides recommendations to support future studies and enhance infrastructure management in areas containing gypsum soil using geographic information systems tools. The recommendations include:

1. Expand the scope of the study to other regions suffering from gypsum soil problems to validate the approach and create a comprehensive database for the distribution of gypsum soil across different regions.
2. Additional studies will be conducted to explore the effect of the chemical properties of gypsum soil on agriculture and groundwater supplies.
3. Strengthening cooperation between researchers and decision-makers to use the results to improve urban planning and reduce the effects of gypsum soil on infrastructure.

References:

[1] A. K. H. Al-Rubaiee and M. L. Hussein, "Effect of Adding Cement Dust Waste on the Geotechnical Properties Behavior of Selected Gypseous Soil in Al-Najaf City," *Iraqi Geol. J.,* vol. 55, no. 2, pp. 165–181, 2022, doi: 10.46717/igj.55.2A.12Ms-2022-07-28.

[2] N. M. Toma and M. Th Al-Hadidi, "The effect of soaking and wetting on the properties of the gypsum soil treated with polyurethane," *Assoc. Arab Univ. J. Eng. Sci.,* vol. 29, no. 2, pp. 1–08, 2022, [Online]. Available: https://doi.org/10.33261/jaaru.2022.29.2.001.

[3] S. Almamoori, "Gypsum Content Horizontal and Vertical Distribution of An-Najaf and Al-Kufa Cities' Soil by Using GIS," *Basrah J. Eng. Sci.,* vol. 17, no. 1, pp. 48–60, 2017, doi: 10.33971/bjes.17.1.7.

[4] A.D. Lanki. and C.A.Onwu, "Geographic information system (GIS) application in soil fertility management: A review," *Journal of Global Agriculture and Ecology,* vol. 16, no. 2, pp. 29–40, 2024.

[5] M. Aziz et al., "Spatial Analysis and Interpretation of Geological and Geotechnical Database: A Case Study of Riyadh, Saudi Arabia," *Arab. J. Sci. Eng.,* no. June, 2024, doi: 10.1007/s13369-024-09244-7.

[6] M. A. Gharaibeh, A. A. Albalasmeh, N. Moos, O. Mohawesh, C. Pratt, and A. El Hanandeh, "A comparative analysis to forecast salinity and sodicity distributions using empirical Bayesian and disjunctive kriging in irrigated soils of the Jordan valley," *Environ. Earth Sci.,* vol. 83, no. 8, 2024.

[7] M. A. Wulder et al., "Current status of Landsat program, science, and applications," *Remote Sens. Environ.,* vol. 225, no. November 2018, pp. 127–147, 2019, doi: 10.1016/j.rse.2019.02.015.

[8] A. D. Mamdooh, R. Khalid, and K. N. Aljanabi, "GIS-based approach for geotechnical mapping: A review," AIP Conference Proceedings, vol. 2775, no. 1, 2023.

[9] A. D. Mamdooh, K. R. Aljanabi, and K. N. Sayl, "Using GIS tools for the prediction of CBR and Su values for Ramadi city's soils," *in AIP Conference Proceedings, 2024,* vol. 3009, Pp. 030061.

[10] B. Sattar, K. Sayl, and R. Rashid, "Modeling of spatially distributed sedimentation in Houran dam H-3," *in 2ND INTERNATIONAL CONFERENCE FOR ENGINEERING SCIENCES AND INFORMATION TECHNOLOGY (ESIT 2022): ESIT2022 Conference Proceedings, 2024.*

[11] H. W. Abdulwadood, R. S. Hameed, and R. I. Mustafa, "Assessing the environmental footprint of the cement industry: A pathway to sustainable development," *IOP Conf. Ser*. Earth Environ. Sci., vol. 1374, no. 1, Pp. 012017, 2024.

[12] G. S. H. Al-Hassany, H. W. Abdulwadood, and R. I. Mustafa, "Analysis the results of laboratory tests of gypsum soil samples at Salah-Aldeen city by using the GIS program," *J. Phys. Conf. Ser.,* vol. 1804, no. 1, Pp. 012052, 2021.

[13] M. S. Mohammed, M. F. Hasan, and K. S. Al-bayati, "Geotechnical maps for Salah Al-Deen-Iraq," *IOP Conf. Ser. Mater. Sci. Eng.,* vol. 737, no. 1, p. 012224, 2020.

[14] R. Mahmoud, M. Hassanin, H. Al-Feel, and R. M. Badry, "Machine Learning-Based Land Use and Land Cover Mapping Using Multi-Spectral Satellite Imagery: A Case Study in Egypt," *Sustain.,* vol. 15, no. 12, pp. 1–21, 2023, doi: 10.3390/su15129467.

[15] T. Adugna, W. Xu, and J. Fan, "Comparison of Random Forest and Support Vector Machine Classifiers for Regional Land Cover Mapping Using Coarse Resolution FY-3C Images," *Remote Sens.,* vol. 14, no. 3, pp. 1–22, 2022, doi: 10.3390/rs14030574.

[16] A. N. Abdul-Hammed and A. S. Mahdi, "Monitoring Vegetation Area in Baghdad Using Normalized Difference Vegetation Index," *Iraqi J. Sci.,* vol. 63, no. 3, pp. 1394–1401, 2022, doi: 10.24996/ijs.2022.63.3.40.

[17] C. T. Nguyen, A. Chidthaisong, P. K. Diem, and L. Z. Huo, "A modified bare soil index to identify bare land features during agricultural fallow-period in southeast Asia using Landsat 8," *Land,* vol. 10, no. 3, pp. 1–18, 2021, doi: 10.3390/land10030231.

[18] A. T. Assaf, K. N. Sayl, and A. Adham, "Surface water detection method for water resources management," *J. Phys. Conf. Ser.,* vol. 1973, no. 1, Pp. 012149, 2021.

[19] I. M. S. Chowdhury, "Comparison of accuracy and reliability of random forest, support vector machine, artificial neural network and maximum likelihood method in land use/cover classification of urban setting," *Environ. Challenges,* vol. 14, no. November 2023, p. 100800, 2024, doi: 10.1016/j.envc.2023.100800.

[20] M. S. Sulaiman, S. K. Sinnakaudan, S. F. Ng, and K. Strom, "Application of automated grain sizing technique (AGS) for bed load samples at Rasil River: A case study for supply limited channel," *Catena*, vol. 121, no. October, pp. 330–343, 2014, doi: 10.1016/j.catena.2014.05.013.

[21] A. A. Al-Mufty and I. H. Nashat, "Gypsum content determination in gypseous soils and rocks," *3rd International Jordanian Conference on Mining*, vol. 2, pp. 485–492, 2000.

[22] B. Zhang, H.-L. Kang, X.-H. Zhang, X.-B. Lu, and Y.-T. Li, "On the responses of soil layers surrounding a suction bucket under cyclic loads," *Mar. Georesour. Geotechnol.,* vol. 38, no. 10, pp. 1141–1150, 2020.

[23] ASTM Standard D2216-19: Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass. West Conshohocken, PA: ASTM International.

[24] A. Sagitha, A. D. Puspita, R. P. Dwi, and A. Salasa, "Optimization of gypsum composition against setting time and compressive strength in clinker for PCC (Portland Composite Cement)," *in IOP Conference Series: Materials Science and Engineering,* vol. 1053, IOP Publishing, 2021.

[25] H. W. Abdulwadood, G. S. H. Al-Hassany, and R. I. Mustafa, "IDW Interpolation of Soil Moisture Retention Curve Utilizing GIS*," IOP Conf. Ser. Earth Environ. Sci.,* Vol. 856, No. 1, 2021, doi: 10.1088/1755-1315/856/1/012040.

[26] Z. Liu, B. Xu, B. Cheng, and X. Hu, "Interpolation Parameters in Inverse Distance-Weighted Interpolation Algorithm on DEM Interpolation Error," *J. Sensors,* vol. 2021, 2021, doi: 10.1155/2021/3535195.

[27] L. A. Jawad, H. W. Abdulwadud, and Z. A. Hameed, "The utilization of remote sensing imagery and Inverse Distance Weighted scheme to simulate the white oil effects on soil geotechnical properties," Iraqi J. Sci., pp. 2824–2833, 2021.