

Mapping Of Geotechnical Properties Using Arcgis: A Case Study of Abubakar Tafawa Balewa University Bauchi, Gubi Campus

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Abstract- *Geographic Information System (GIS) has been used in geotechnical engineering as a part of geotechnical site investigation to create a site portrait and in preliminary geotechnical site assessments. This study explores the application ArcGIS 10.1 for mapping soil properties of Abubakar Tafawa Balewa University (ATBU) Bauchi, Gubi campus for use in preliminary designs, using the kriging spatial interpolation capability. For this purpose, 40 trial pits distributed within the study area were used and their coordinates were recorded. The samples were subjected to various laboratory tests to determine their geotechnical properties. The obtained laboratory results and corresponding recorded coordinates were used to develop mapped database in GIS software and after which, analysis-using kriging was carried out. The analysis results show maps of various soil properties. The result provides estimated data for preliminary designing and planning within the study area.*

Indexed Terms- *Geographic Information System (GIS), Mapping, interpolation, kriging.*

I. INTRODUCTION

Within the last two decades, developments in Geographic information system (GIS) has led to its use in manipulating and managing geospatial data. GIS is a framework for gathering, monitoring, and analyzing data. Rooted in the science of geography, it integrates many types of data, analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. The GIS provides data, which are geographically aligned to their actual locations and with the help of satellite, data is collected in form of raster images, which helps in storing, sharing, analyzing, interpreting, reusing and

modification with current condition and requirements [1].

Civil engineers make use of GIS to manage and share data that can easily be analyzed, visualized, understood and can be communicated to others [2]. Geotechnical investigation is a vital aspect in civil engineering project, but most at times, this aspect is ignored which is due to ignorance, negligence or absence of sufficient fund to carry out such task [3]. However, geotechnical data gathered from various governments and private organizations can be used by the application of GIS to form a fundamental part of civil engineering construction framework. Thus, the intent of this work is to map out the soil geotechnical properties of Abubakar Tafawa Balewa University (ATBU) Gubi main campus of Bauchi state in Nigeria, in order to help reduce the time taken to obtain these properties and reduce cost, which causes serious delays in civil engineering construction works. The ordinary kriging method for spatial analysis of the ArcGIS software is been utilized to estimate the soil geotechnical properties. This analysis gives visual and numerical interpretation of the soil properties of some sections of the case study area. A guide map of the physical properties of soil is created and relied upon to give helpful bits of knowledge that is needed for development, construction and planning of future projects in ATBU Gubi campus.

II. LITERATURE REVIEW

Application of GIS in Civil and Geotechnical Engineering is receiving much interest in the current literature. [2], highlighted the GIS application by reviewing case studies. The three GIS components identified by the authors are databases, graphics interfaces and data analysis. A method of mapping the

swelling potential of soil was developed using GIS by [4]. The research used a digital map of a region, data from the area and GIS to propose zoning of maps, evaluate various mechanisms that caused soil swelling and indicate an area with high and low-risk of soil swelling. The maps were used in the development planning and in reducing the risk of damage caused by soil swelling. The cost of constructing projects also reduces by permitting designers to avoid places with dangers for soils swelling.

Player [5] as cited by [6] introduced applications of GIS technology in geological hazards identification. The research planned and tracked fieldwork. Communication improved by creating figures and maps. Foyer et al. [1] estimated recharge using GIS that identifying possible combinations of soil type and vegetation. In Athens of Greece, [7] reported the application of GIS to produce thematic maps of the geotechnical, geological, seismological and geomorphological data of the area. In Brazil, [8] used GIS for geotechnical and environmental risk management of oil pipeline. Thiesen [9] conducted GIS Mapping of geotechnical data of Blumenau city in Brazil using a digital terrain model. The result provided information on the geographic features and urban growth. Ali Keshavarzi et al [10]. used various interpolation methods for analysis of spatial variation of soil alkalinity and salinity in Ziari region, Qazvin province in. However, the effectiveness of any interpolation technique exists in the type of the spatial interpolation used, sampling scheme as well as numbers of sampling points used for interpolation.

Furthermore [11] reviewed the application of GIS in Geotechnical Engineering. The review covered the capabilities and uses of the technology of GIS in Civil Engineering. Other similar researches were carried out using numerous applications of GIS like those of [12]-[14]. However, application GIS for mapping soil properties for use in preliminary design is the intent of this study. Therefore, effort is been made, to conduct Mapping of geotechnical properties using kriging spatial interpolation capability of ArcGIS in the case study of A.T.B.U Gubi campus, Bauchi, Nigeria.

III. METHODOLOGY

A. Study Area

The study area is Abubakar Tafawa Balewa University (A.T.B.U) Gubi Campus, which is the permanent site of Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria. The area is located 25 kilometer away from Bauchi metropolis. It has a total land area of 48km² and lies within Savanna zone at Latitude 10° 45'N and longitude 9° 82'E with an annual average rain fall of 250 mm occurring mainly during the month of June to September with August been the wettest month having 335mm of rainfall.

B. Sampling and Laboratory Test

Due to the large area, the study area was divided into sections and one section was selected for the study. The selected section was further divided into 40 grids so as to obtain an approximate total area of 12 km². A total of 40 samples were collected with their respected co-ordinate recorded from the selected section (i.e. each sample corresponds to each grid). Figure 1 below shows the location of the study area and sampling point's location. After the samples were collected, laboratory tests were carried out on the samples as per BS 1377 [15] procedures to determine their geotechnical properties. The tests conducted includes; natural moisture content, particle sieve distribution, Index properties test, compaction test, triaxial test and California bearing ratio (CBR).

C. Kriging Spatial Interpolation

Spatial Interpolation is a method of estimating attributes at point locations which are not sampled or at which we do not have the data, by using the attributes at point locations for which we have the data. Geostatistical analyst extension in ArcMap is used for interpolating the Geotechnical data and predict the data at unknown locations. Kriging is a type of spatial interpolation method that makes predictions at unsampled locations using a linear combination of observations at nearby sampled locations. The influence of each observation on the kriging prediction is based on several factors: which are, its geographical proximity to the unsampled location, the spatial arrangement of all observations (i.e., data configuration, such as clustering of observations in oversampled areas), and the pattern of spatial correlation of the data. The kriging interpolation

provides us with predictions of each soil property at every location of the study area in the form of continuous maps. Thus, all the obtained test result are used in the ArcGIS software using the kriging method of spatial variation to predict accurately other areas.

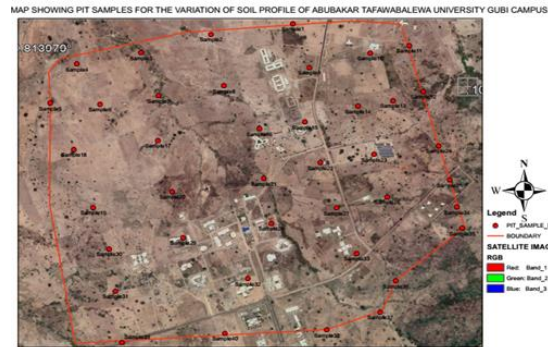


Figure 1: Satellite image of study area showing sampling point's location.

IV. RESULTS AND DISCUSSIONS

Taking samples at every position in the study area for investigation of soil property could be very expensive. As a substitute, a measure of the soil properties of the representative sample at selected locations and then predicting other values in all other locations using the kriging interpolation tool of ArcGIS can save cost and time. Input points (trial pits) were obtained as previously described. The result of analyzed uploaded soil properties in the map database are presented in figures 2-9 respectively.

Figure 2 shows the distribution of natural moisture content over the study area, colour variations denote the results; each colour layer indicates range percent of moisture content; grey and white colour layers denotes areas with higher moisture content. Similarly, Figure 3 shows the distribution of the liquid limit over the study area. The various colour ranges indicate the amount of moisture content present in the area. The variation in the moisture content is due to the variation in the soil type. The area with loose soils showed lower natural moisture content as well as and lower values of liquid limit & plastic limit.

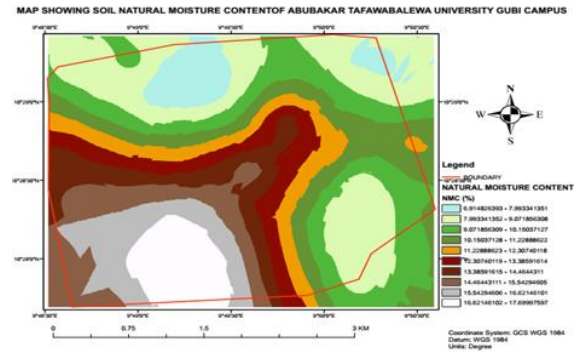


Figure 2. Map of study area showing spatial variation of natural moisture content

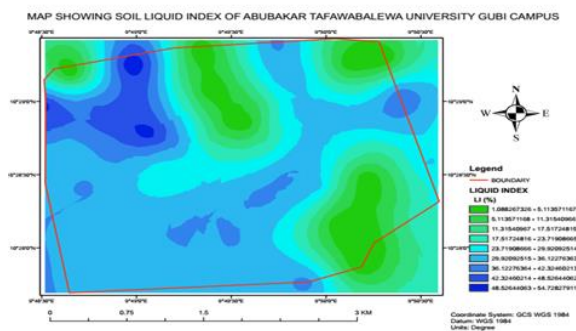


Figure 3. Map of study area showing spatial variation of liquid limit values

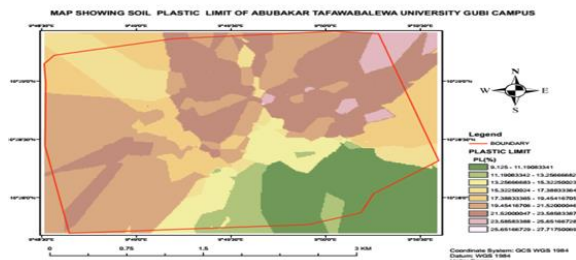


Figure 4. Map of study area showing spatial variation of plastic limit

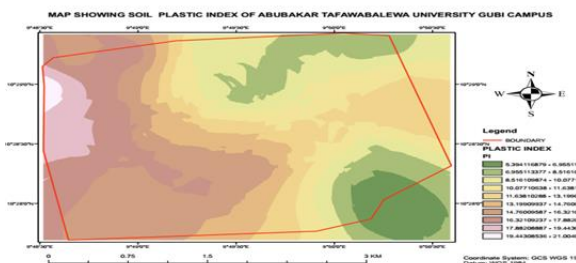


Figure 5. Map of study area showing spatial variation of plastic index

Furthermore, Figures 6 and 7 shows the distribution of compaction characteristics (maximum dry density & optimum moisture content) in the study area. The central portion of the study area tends to have similar MDD and OMC, this is attributed to the fact that a good number of borrow pits within the area have similar values. Similar thematic maps for CBR, cohesion and angle of internal friction are shown in figures 8 – 10.

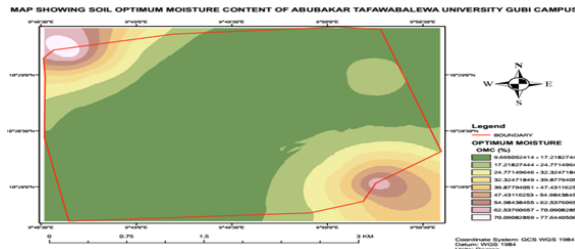


Figure 6. Map of study area showing spatial variation of optimum moisture content values

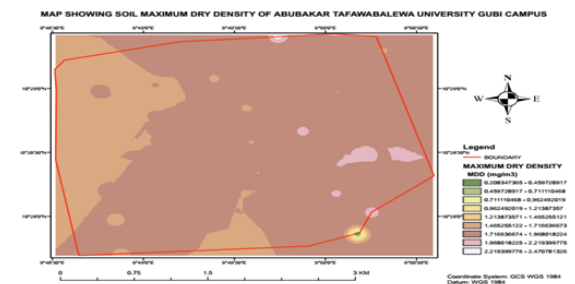


Figure 7. Map of study area showing spatial variation of maximum dry density values

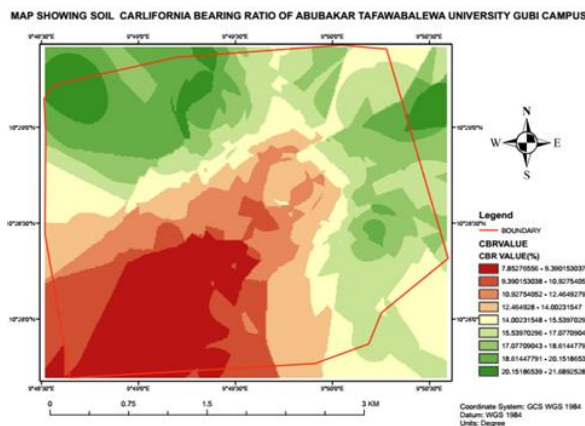


Figure 8. Map of study area showing spatial variation of CBR values

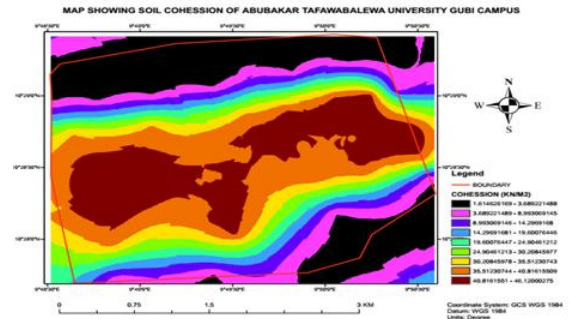


Figure 9. Map of study area showing spatial variation of soil cohesion

Thus, for figures 8 and 9, the central portion has the highest values and this is highly expected as these are areas that have the potential to retain water. With regards to figure 10, the higher values are at the borrow points with very low liquid limits, moisture content and high MDD. These are expected areas that contain soil type that is more suitable for construction purposes and are not likely to give trouble to shallow foundation due the high strength symbolized by high CBR and MDD and lower OMC values respectively.

CONCLUSION

This study explores the application ArcGIS for mapping geotechnical properties of A.T.B.U Gubi campus soil for use in preliminary designs, using kriging spatial interpolation capability of ArcGIS and the following conclusions were drawn:

- i. A GIS-based user-friendly system developed using kriging spatial interpolation tool can help in producing thematic maps based on soil properties there by giving valuable information about the soil properties within the study area, especially during planning and preliminary designs work.
- ii. The system also provides a means of identifying areas suitable for construction and civil engineering works and areas with potential problem within the study area with a view to avoid them during feasibility studies of future development.

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