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Spatial Interpolation and Mapping of Soil Geotechnical Properties of Udham Singh Nagar District using GIS

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Abstract - **Mapping of Geotechnical properties like specific gravity, Maximum Dry Density, Optimum Moisture Content of soil of an area can be spatially interpolated for its ready use in Civil Engineering construction using Geographical Information System (GIS).GIS provides an easy to use atmosphere for geospatial analysis of different soil properties. The main aim of the study is to predict the spatial variability of geotechnical properties of soil using well known spatial interpolation methods like Inverse Distance Weighted (IDW).The map of study area of Udham Singh Nagar district of Uttarakhand state was digitized up to tehsils and village level and then divided into rectangular grids having known latitudes and longitudes of sampling points. The handheld Global Positioning System (GPS) was used to reach the known latitudes and longitudes of known sampling points of grid and soil samples were collected. IDW method of spatial interpolation was applied for preparation of thematic maps of soil properties. The accuracy of predicted maps was determined using Root Mean Square (RMS) Error and Goodness of prediction (GOP) values by comparing predicted values with the actual values. Small to medium RMS values for most of the properties showed more accuracy in predicted values of soil properties and positive values for G indicated that most of the predictions are reliable. The methodology presented in this study can be used to create thematic maps of soil properties at a much larger scale. Different methods of spatial Interpolation like IDW, Kriging, and Splines etc. can be used and predicted surfaces from different methods can be compared for more accurate prediction. Since most of the methods of interpolation are based on different assumptions and these methods are used to provide estimates of the values of un-sampled locations on the basis of known values, hence these methods always have some inaccuracy in their output results.**

Keywords— Spatial Interpolation, Inverse Distance Weighted, Kriging, Geographical Information System, Root Mean Square, Soil Mapping.

I. INTRODUCTION

The identification of soil and geotechnical properties helps the geotechnical engineers to develop an understanding about its suitability as a foundation laying material. Traditionally engineers have been trying hard to predict the variation of soil and its properties by sketch maps and manual diagrams. Most of these old methods are cumbersome and uneconomical. Preparation of digital soil maps based on different themes consistent with the soil like its specific gravity, particle size distribution, and optimum moisture content using GIS based technology provides an easy and economical platform in the field of geotechnical engineering. Availability of soil data of an area in a single query within seconds provides the most easiest and advanced innovation in soil engineering. The basis of this study is to know the spatial variability of some geotechnical properties of soil and thus predict these properties of soil of an area at un-sampled locations with the help of different spatial interpolation methods like Inverse Distance Weighted (IDW).The literature of digital mapping of terrain properties are very rarely available and there is need to produce thematic maps based on soil classification and its properties so as to help furnish geotechnical engineers with an overview about the construction site and help them in deciding the soil suitability for the structure they are concerned with. Suhail Idrees Abdulqader Khattab et al. used GIS techniques for correlating soil properties on the basis of swelling behavior in the left side of Mosul city [2]. Ali Keshavarzi et al. used various interpolation methods for analysis of spatial variation of soil alkalinity and salinity in Ziaran region, Qazvin province in Iran [4]. Keshav k. Deshmukh et al. compared IDW and Kriging for analysis of particles size of Soils of Sangamner area, Maharashtra, India and found that interpolation methods helped to predict the continuous information of terrain at much precise level [5]. However the effectiveness of any interpolation technique exist in the type of the spatial interpolation used, sampling scheme as well as number of sampling points.

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Inverse Distance weighted (IDW) - a REVIEW The basis of interpolation is expressed implicitly in Tobler's law of Geography. It states that

"Everything is related to everything else, but near things are more related than distant things."

Prediction of values of attributes at sites which have not been sampled is the basis of any interpolation method. It can also be used to prepare continuous fields of any required attribute from the data collected from point observations, thus also providing with the spatial variability of that attribute. IDW method predicts the values at un-visited locations by assuming that the attribute values at all locations are distance weighted functions of values at known locations and values change inversely with distance. If Z_p be the value to be predicted then,

$$Zp = \frac{\sum_{i=1}^{N}(Z_i / d_i^p)}{\sum_{i=1}^{N}(1/d_i^p)}$$

Where Z_i is the value at known location and the distance between sampled value Z_i and predicted value Z_p is 'di'. P is the power parameter. More the value of P, less is the importance given to points at larger distances.

III. VALIDATION AND PREDICTION ACCURACY

A. Root mean square error (RMSE)

RMSE is a tool used to measure the variation between predicted values (by any model) and the observed values called as residuals .RMSE is given by,

$$RMSE = [\sum_{i=1}^{N}(Z_p - Z_o)^2/N]^{1/2}$$

For a model to be more reliable, the RMSE should be small.

B. Goodness of Prediction Values (GOP)

Goodness of Prediction, also referred to as 'Goodness of fit' is a statistical term used to determine the accuracy of a prediction model.

$$GOP = \left\{1 - \frac{\sum_{I=1}^{N}(Z_i - Z_p)^2}{\sum_{I=1}^{N}(Z_i - Z_m)^2}\right\} * 100\ \%$$

Where Z_i and Z_p have their usual meanings and Z_m stands for the sample mean. More the GOP value, more accurate the prediction is in comparison to mean.

Table 1. Training samples database for Bazpur city of Udham Singh Nagar District

Sample	Latitude (Degree Decimal)	Longitude (Degree Decimal)	Specific Gravity G	Maximum Dry Density (MDD)gm/cc	Optimum Moisture Content (OMC)%
S1	29.1404	79.1863	2.700	1.80	16.00
S2	29.2316	79.1847	2.780	1.85	16.50
S3	29.0949	79.1871	2.400	2.02	12.80
S4	29.1850	79.1134	2.810	1.88	18.10
S5	29.2306	79.1125	2.600	1.76	14.00
S6	29.1860	79.1855	2.740	1.76	18.40
S7	29.1395	79.1142	2.640	1.74	17.40
S8	29.1627	79.1498	2.530	1.69	20.00
Mean			2.670	1.82	16.65

IV. STUDY AREA

Udham Singh Nagar is the southernmost district belonging to the state Uttarakhand having geographical area of about 3055 km2. The area is separated on the basis of physiography from the rest of the area, also called as Tarai. It is located between latitude 28o 53' N and 290 23' N and extending laterally between longitudes 78° 45' E and 80° 08' E. The Sarada River describes the international boundary between India and Nepal. The area comes under Survey of India (SOI) Toposheets (Quadrangle Maps) Nos. 62D, 53K, O, and P.

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V. SAMPLING, TESTING AND DATABASE CREATION

The toposheets were downloaded from SOI website and were digitized and geo-referenced using Arcmap software. The area was divided into tehsils and villages using raster images collected from ISRO's Geoportal "BHUVAN" website. The area was again divided into scheme of grids and samples were collected from the latitude and longitude of center of each grid. Total 8 training sample sets for the Bazpur Tehsil from Udham Singh Nagar district have been tested in the laboratory and database is prepared using MS Excel which is linked with the database generated into the Arc map software (Table 1). The point data at the center of grid represents the soil properties at that particular latitude and longitude. Therefore it is interpolated using IDW interpolation to obtain values of attributes at locations where samples were not collected. The IDW method prepares continuous fields of attributes at all locations. Two test sample were collected randomly from the area and data for one sample was collected from previous soil laboratory reports to check the validity of interpolation method used

Table 2. RMS Error and GOP Values using Test sets

Soil Property	RMS Error	GOP Values (Percent)
G	.329	23.68
MDD	.133	10.37
OMC	.189	5.39

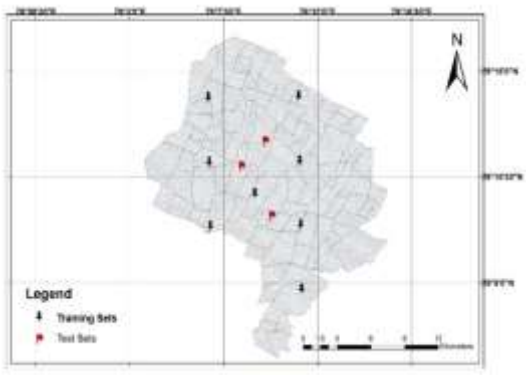

Fig1. Location of Grid sampling and Points of Training and Testing Sets

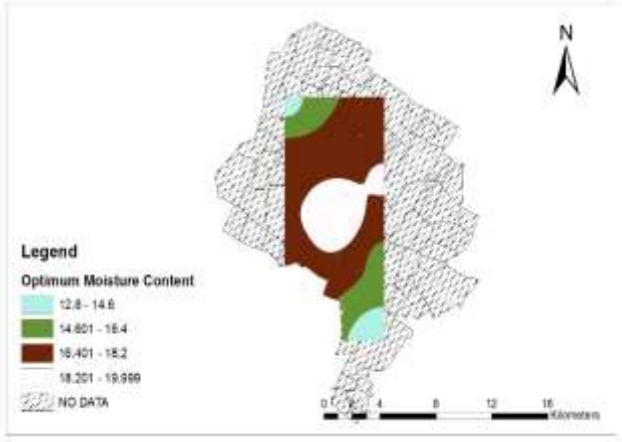

Fig2(a). Spatial Variation of OMC vaues

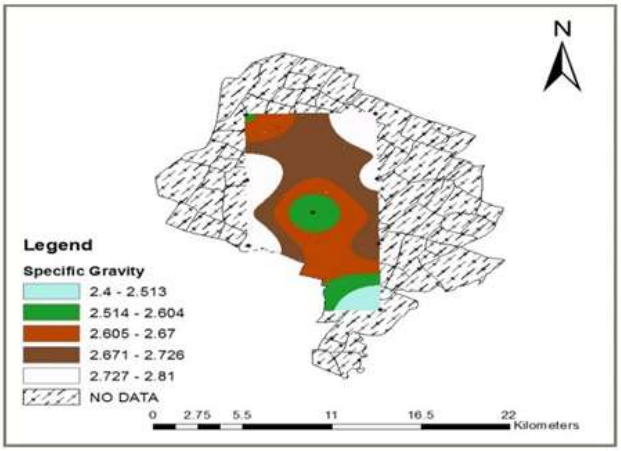

Fig 2 (b). Spatial Variation of Specific gravity

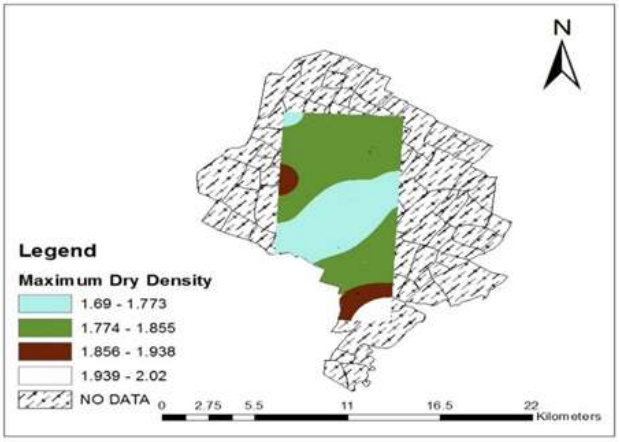

Fig 2 (c). Spatial variation of MDD value

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VI. CONCLUSION

IDW method can be efficiently used for the prediction of geotechnical properties at locations which are not sampled if thematic maps of these properties are prepared using GIS techniques. In the present study, the thematic maps of MDD, OMC and Specific gravity are prepared which can be used by different agencies like PWD, Irrigation Department etc. to estimate the geotechnical properties of soils of Udham Singh Nagar District at un-sampled locations.

The study indicates that the central portion of the Bazpur city has high OMC value indicating the presence of high fine content like silt and clay. The problem with fine soils (i.e. more percentage of clay) is the retention of water within its voids for larger period, thus having less MDD. This moisture then takes time to seep out and thus causes unwanted settlement of the structure even after years of construction. Therefore soil in these areas require more treatment and stabilization than at other places. Therefore it can be concluded that this study can be helpful for better policy implementation at places that are highly sensitive to damage. The validation of these predictions was checked using RMS Error and GOP values.

The low values of RMS of all the three properties indicates less values of the residuals (Z_p - Z_o) and thus the predictions can be said to be reliable. And positive values for GOP indicates reliable predictions in comparison to mean.

VII. ACKNOWLEDGEMENT

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