

## **Spatial Interpolation of Fine Content of Soils at a Regional Scale**

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### ***Abstract***

*Spatial interpolation was used in the estimation of the fine content of soils at unsampled locations in Isoko South L.G.A of Delta State. The ability to model and map the fine content of soils for the region was demonstrated using Geostatistics. Soil samples were collected at nine communities in Isoko South LGA of Delta State. The fine content for the various soils samples were determined in accordance with British Standards. The range of the soil fine content was between 9.37% to 55.34%. The skewness value of 0.44 and kurtosis value of -0.96 indicated that the data were slightly skewed with reference to the normal distribution. An exponential model was considered to be the best fit for empirical semivariogram of the soil data. Based on the exponential model a kriged contour map was developed for the region. This mapping of the degree of fine content of soils in the region can be used for engineering preliminary design and planning of construction works.*

**Keywords:** Geostatistics, Fine content, Variogram, and Delta State

### **1.0 Introduction**

Fine content is a basic physical property soils that affect many important soil attributes. It is useful for the understanding of various soil mechanical and physical properties such as shear strength, bearing capacity, compressibility and shrinkage-swelling potential[1,2]. USCS[3] and AASHTO[4] system base their classification of soils for engineering purposes partly on fine content. Since it can be measured relatively easily and quickly, it has been used in the past as surrogate data for the indirect estimation of soil strength parameters [5,6], liquid limit [7]. USCS [5] and AASHTO [6] define fines as soil particles passing through sieve No. 200(75µm opening). The fines consist of clay and silt.

Soil varies considerably from location to location [8]. Adequate understanding of the variability in soil properties as a function of space is necessary for developing empirical models of soil and landscape processes [9,10]. Geostatistics, a widely used approach, has been used to identify the spatial structure in the variability of soil attributes [11,12,13]. In conventional soil survey soil properties are recorded at representative sites and assigned to entire mapping unit, which are delineated following one of the physiographic, physiognomic and geopedologic approaches. Although soil surveyors are very well aware of the spatial variability of soil properties, conventionally prepared soil maps do not reflect it as soil units are limited by boundaries[14]. To have accurate estimation of soil properties these continuous variability

should be considered. The traditional method of soil analysis and interpretation are laborious, time consuming, hence becoming expensive.

Isoko South Local Government Area of Delta State is of great socio-economic importance to Nigeria because of its huge reserves of petroleum and natural gas. There are various construction works being executed in the area. Information on the fine content of the soils in the area are scarce and data very difficult to access in the region. The area lies within the lowland rainforest with swampy forest occurring in flat-floored valleys and adjoining low-lying areas that are seasonally or permanently waterlogged. The soils are deeply weathered and nutrient deficient, being derived mainly from unconsolidated sediments of sandstone and are predominantly sandy [15]. The development of a geospatial map to provide a quick and easy estimation of the fine content of soils in the area is significant and needed for preliminary engineering design and planning and execution of site investigation programmes.

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## 2.0 Materials and Methods

### 2.1 Sampling and Sampling Locations

Delta state is one of the states in Nigeria (Figure 1), it has twenty-five local government areas (Figure 2). Soils samples were collected at several communities namely; Oleh, Umeh, Uzere, Aviara, Emede, Enweh, Igbide, Irri and Olomoro from Isoko South Local Government Area of Delta State (Figure 3). Disturbed soil samples were obtained at different depths using hand auger. A total of nine soil samples were collected. The sieve analysis test to obtain the percentage of fine was performed in accordance with BS 1377: 1990. [16]

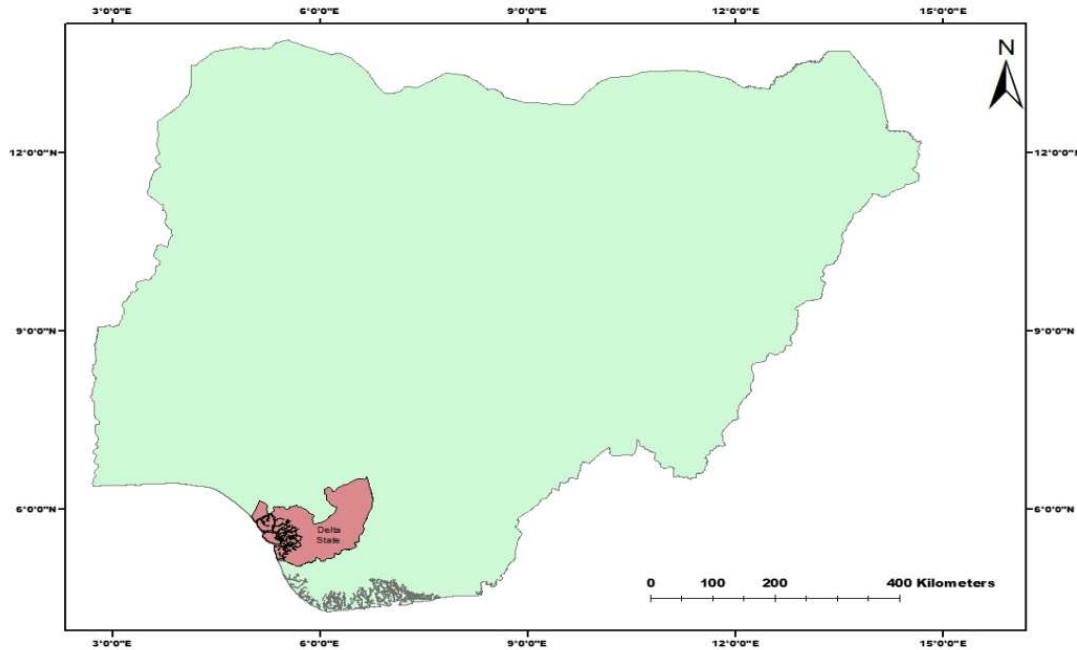
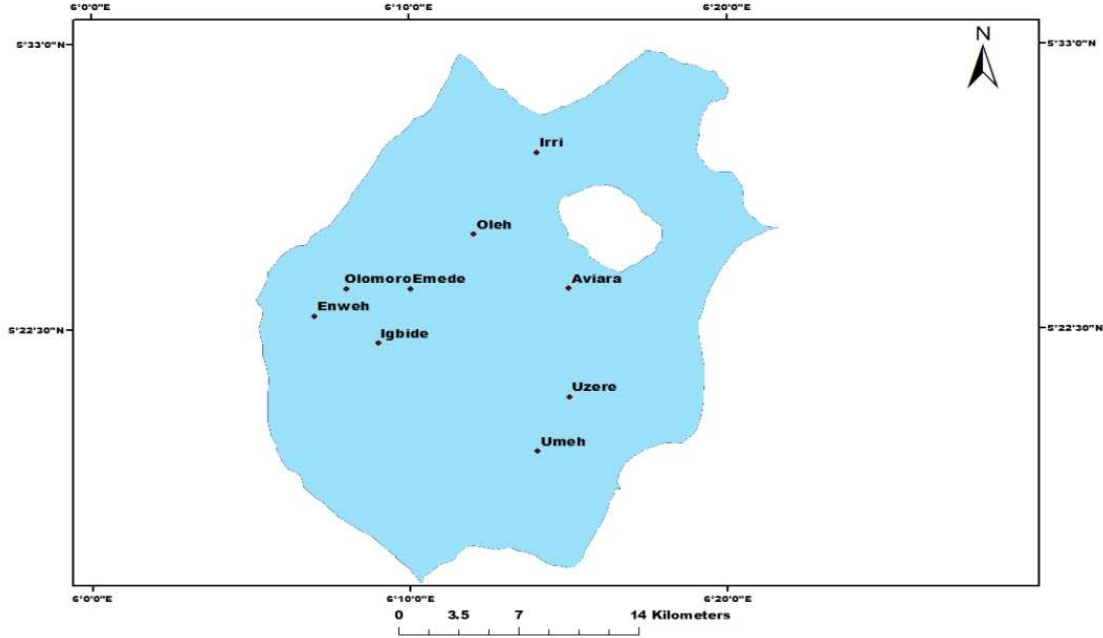


Figure 1: Map of Nigeria Showing Delta State





**Figure 3:** Map of Isoko South Local Government Area Showing Soils Sample Points

## 2.2 Geostatistics Modeling

The sample variogram was computed by Matheron's method of moments estimator. The spatial variance between the soil properties at any two distinct points would depend on their separation distance, lag  $h$ . The semivariance,  $\gamma(h)$ , between any two points at a lag ( $h$ ), can be expressed as

$$\gamma(h) = \frac{1}{2} E[z(x) - z(x+h)]^2 \quad (1)$$

where:  $\gamma(h)$  is the semivariance at lag distance  $h$ ;  $z(x)$  is the soil property at location  $x$ . In the region of interest, suppose there will be  $m(h)$  pairs of soil properties separated by a particular lag  $h$ . their semivariance is given by

$$\hat{\gamma}(h) = \frac{1}{2m(h)} \sum_{i=1}^{m(h)} [z(x_i) - z(x_i+h)]^2 \quad (2)$$

Where  $\hat{\gamma}(h)$  is an unbiased estimate of the variance of these  $m(h)$  pairs of soil properties;  $m(h)$  is the number of points separated by a lag  $h$  for  $I = 1, 2, \dots, m(h)$ ;  $z(x_i)$  and  $z(x_i+h)$  are the soil properties at locations  $x$  and  $x+h$  respectively.

When the variogram is plotted using discrete experimental data points, it is called an experimental or sample variogram. A theoretical model can be fitted through the experimental data points to quantify spatial patterns. The most commonly used models namely are;

Spherical model: 
$$\gamma(h) = C_o + C \left[ 1.5 \left( \frac{h}{A_o} \right) - 0.5 \left( \frac{h}{A_o} \right)^3 \right] \quad (3)$$

Gaussian model: 
$$\gamma(h) = C_o + C \left[ 1 - \exp\left(-\frac{h^2}{A_o^2}\right) \right] \quad (4)$$

Exponential model: 
$$\gamma(h) = C_o + C \left[ 1 - \exp\left(-\frac{h}{A_o}\right) \right] \quad (5)$$

$$\gamma(h) = C_o + [h(\frac{C}{A_o})] \quad (6)$$

Linear model:

Where  $C_o$  = nugget;  $C$  = sill;  $A_o$  = range and  $h$  = distance.

The spatial prediction of the values of a soil variable  $Z$  at an unsampled point  $x_o$  is given by

$$\hat{Z}(x_o) = \sum_{i=1}^n \lambda_i z(x_i) \quad (7)$$

where  $x$  denotes the set of spatial coordinates  $\{x_1, x_2\}$ ,  $\lambda_i$  are the weights associated with the sampling points  $x_i$  and the  $i$ th observation point.

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In kriging the weights are chosen so that the estimates  $\hat{z}(x_o)$  of the true value  $z(x_o)$  is unbiased and the prediction variance  $\sigma^2(x_o)$  is minimized. That is;

$$E[\hat{z}(x_o) - z(x_o)] = 0 \quad (8)$$

and

$$\sigma^2(x_o) = \text{var}[\hat{Z}(x_o) - Z(x_o)] = \text{minimum} \quad (9)$$

To ensure that the prediction is unbiased the weights placed on each neighboring point must satisfy;

$$\sum_{i=1}^n \lambda_i = 1 \quad (10)$$

### 3.0 Results and Discussions

The test results for the soils fine content is shown in Table 1.

**Table 1:** Soil Test Data for Modeling Procedure

S/N	Locations	Fine Content (%)
1	Oleh	19.97
2	Umeh	30.07
3	Uzere	55.34
4	Aviara	9.37
5	Emede	23.84
6	Enweh	25.32
7	Igbide	50.57
8	Irri	23.09
9	Olomoro	44.68

The descriptive statistics for the test results is presented in Table 2.

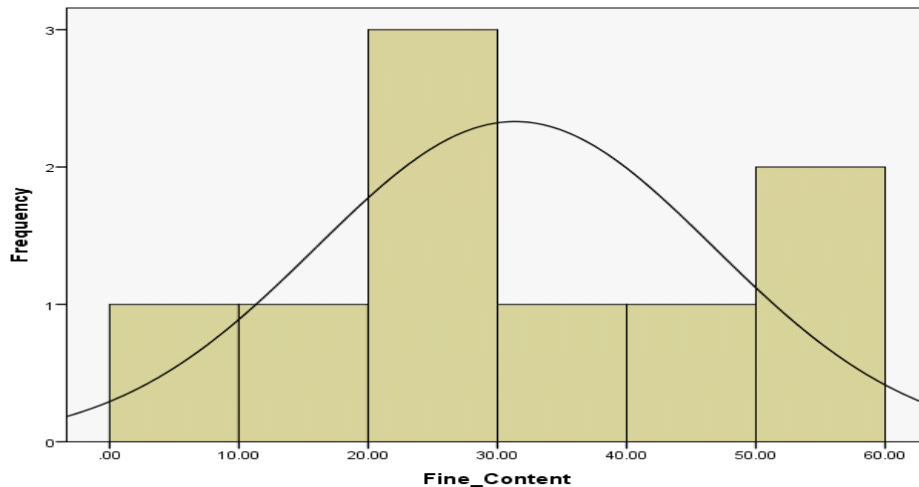
**Table 2:** Basic Descriptive Statistics for the Soil Data

Statistics	Fine Content(%)
Minimum	9.37
Maximum	55.34
Medium	25.32
Average	31.36
Standard deviation	15.40

Skewness	0.44
Kurtosis	-0.96
n	9

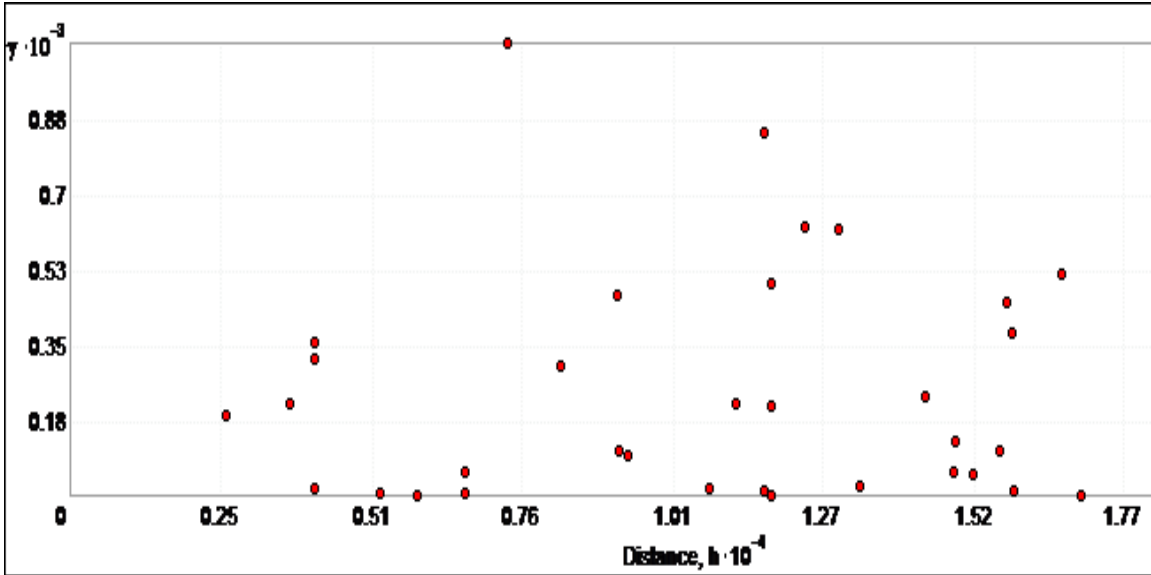
The tests result for the soils fine content varied between 9.37% to 55.34%. It can be seen from the table that the medium and average values for the soil parameter are quite close together. This indicates that the distribution has approximately a normal distribution curve. In addition, the skewness value is positive, which indicates that the sample distribution has a skewed shape with reference to the normal distribution. Another parameter, kurtosis value, is -0.96 and this implies that the asymmetry degree of sample degree of sample distribution around the arithmetic mean is closer to negative values. In order to get a closer look at the frequencies of the considered variables, histograms are given in Figure 4. The variations of the measured variables and deviations from normal distributions can be seen from the Figure 4.

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**Figure 4:** Histogram of the Measured Specific Gravity Values for the Soils  
The nine soil data will generate thirty-six pairs of data. The plot of the square difference of the soil specific gravity values for all pairs of location and the distance that separates the location is shown in Figure 5.

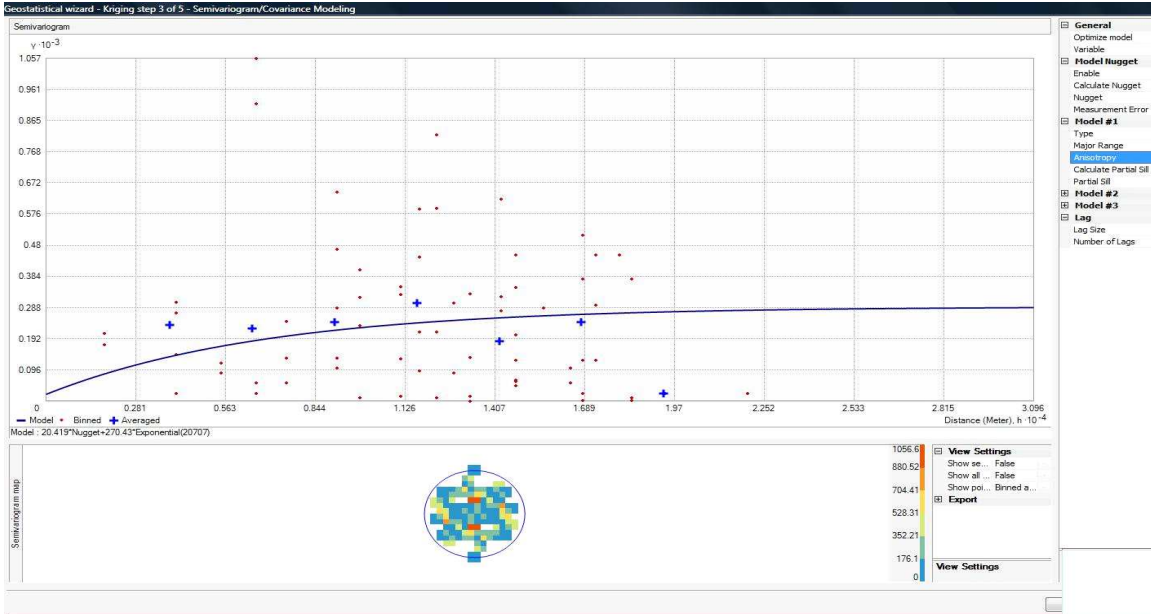
semivariance



**Figure 5:** Semivariogram Cloud for Specific Gravity Values

There are so many points that the plot becomes congested and little can be interpreted from it. To reduce the number of points in the semivariogram cloud, the pairs of locations will be grouped based on their distance from one another. The binned points and a model that provides the best fit through the points is presented in Figure 6.

### semivariance

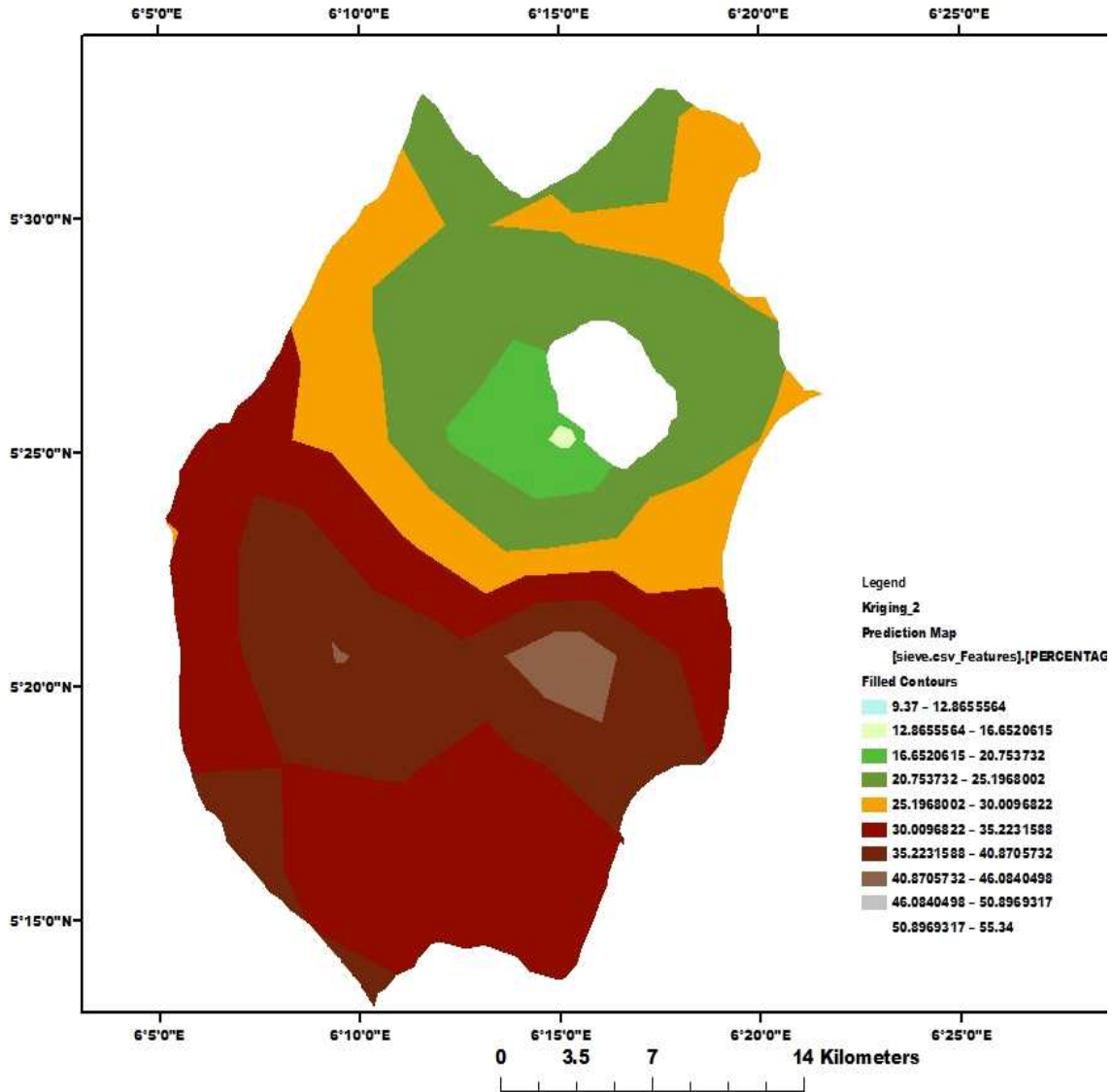


**Figure 6:** Fitted Exponential Model for Specific Gravity Values of Binned Points

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$$\gamma(h) = 20.42 + 270.43 \left[ 1 - \exp\left(-\frac{h}{20707.16}\right) \right] \quad (11)$$

Based on the exponential model from the semivariogram, kriging weights are assigned to each measured value and the prediction for locations with the unknown values is shown in Figure 7.



**Figure 7:** Spatial Distribution of Fine Content of Soils in Isoko South Local Government Area.

#### 4.0 Conclusion

The range of fine content of soils in the area lies between 9.37% to 55.34%. A total of nine (9) soil samples were obtained from nine different communities in the area. Based on the skewness value of 0.44 and kurtosis value of -0.96 the data distribution was slightly skewed with reference to the normal distribution curve. Exponential model was fitted to the semivariograms of the soil variables. The semivariogram revealed spatial variability in the spatial structures of soil fine content property. The kriged contour maps of soil variables showed positional similarities with each other. The kriged contour maps can be used

in the estimation of the fine content of soil in the area for preliminary design and management decisions.

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