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SPATIAL DISTRIBUTION OF LEAD IN AMAONYE FOREST SOILS OF ISHIAGU COMMUNITIES IN EBONYI STATE OF NIGERIA

E. Atikpo[1,*] and N. I. Ihimekpen[2]

[1] DEPT. OF CIVIL ENGINEERING, DELTA STATE UNIVERSITY, OLEH CAMPUS, PMB 1, ABRAKA, DELTA STATE, NIGERIA.
[2] DEPARTMENT OF CIVIL ENGINEERING, UNIVERSITY OF BENIN, PMB 1154, BENIN CITY, EDO STATE, NIGERIA.
E-mail addresses: [1] *eguasbridge@gmail.com;* [2] *n.ihimekpen@uniben.edu*

ABSTRACT
Geostatistical technique was applied to study the spatial distributions of lead (Pb) in Amaonye forest soil of Ishiagu communities in Ebonyi State, Nigeria. A total of 605 soil samples were collected at depths of 10, 20, 30, 40 and 50 cm from all grid points in an area of 1km x 1km gridded at 100 m grids and were analysed for Pb concentration. Using the ArcGIS geostatistical extension, the metal distribution was modeled and shown on concentration maps. The variogram (C_o/C) ratio values obtained as 0% at 10, 20 and 30 cm, 11.1% at 40 cm and 9.9% at 50 cm indicated strong spatial dependence. The study shows that the metal has irregular spatial distribution in the studied area, with the highest accumulation around the stream channel and spread in the direction of water-flow into the forest soil as influenced by the topography of the landscape.

Keywords: *Lead, Ishiagu, geostatistics, pollution risk.*

1. INTRODUCTION
Soils constitute part of vital environmental, ecological and agricultural resource that has to be protected [1]. They are key components of terrestrial ecosystem both natural and agricultural, being vital for plants growth, the decomposition and recycling of dead biomass [2]. Man depends on soil uncontaminated by toxic elements to produce his food [3].

Ishiagu is a clan of important economic communities. Its inhabitants are essentially farmers who produce large quantities of root crops and leafy vegetables for their consumption and for food supplies to other parts of Nigeria. Ishiagu communities are also known as habitants for local and industrial miners [1,4].

As reported by [1, 4, 5, 6], some areas in Ishiagu are polluted with lead due the wastes from mining. When it rains, the ponds with mining wastes overflow their banks resulting in pollution even outside the area of mining [5].

The research conducted by [1] showed that by following the tolerable concentration of 35 mg/kg in normal soils [7], the soils were polluted at Ugwuajirija 1, Uguajirija 11, Eziator, Amagu 1, Okwe 1 and Amaokwe 1 communities with values of 1573.5 mg/kg, 13671 mg/kg, 782 mg/kg 128 mg/kg, 90.5 mg/kg and 52 mg/kg respectively.

Analyzed root crops from mining areas of Ishiagu showed high concentration of lead in cassava, yam, cocoyam and potato grown in the soils of Ihetutu, Amita, Amaeke, Amagu, Amaonye and Amaeze communities which was attributed to the mining activities in the areas [4].

An experiment conducted by [6] on soils from Ishiagu reveled strong lead pollution as 360.52 mg/kg for pit soil; 305.46 mg/kg, 216.24 mg/kg and 105.31 mg/kg at 5, 10, 100 m depths respectively. While the concentration of Pb in control sample was 36.16 mg/kg.

Lead is the commonest metal pollutant found in soils, it does not have biological significance; and it is potentially injurious to microscopic lives [8]. Lead is very objectionable and has very acute health effects even at minute concentration [10]. Lead causes mental drawback in children [9], colic anemia and renal diseases [11].

Heavy metals, including Pb contamination of soil is an alarming issue because of their adverse effects on lives in the environment [10]; and due to the world wide experiences of the serious ecological consequences of soils contaminated with heavy metal, there is a need to take preventive and attenuation measures [12].

*** Corresponding author tel: +234 – 803 – 866 – 5352**

For proper identification of the hot-spots of this metal pollution as a prerequisite to appropriate action, a study on the spatial distribution and variation of the metal in soil is necessary [13, 14]. The aim of this work therefore, is to study the spatial distribution of lead in soils of Amaonye forest in Ishiagu communities of Ebonyi State in Nigeria by using geostatistical method and geographical information system (GIS).

Geostatistics offers an advanced method facilitating spatial interpolation and measurement of spatial variability of variables in soil; and has become a helpful instrument for analyzing spatial probability and danger assessment [15]. It utilizes the method of variogram to ascertain the spatial variableness of a regionalized variable, and gives the input data for Kriging modelling [16, 17]. Kriging identifies the error of predictions reflected in variogram model [18].

ArcGIS Geostatistical Analyst is an extension to ArcGIS desktop that makes available strong tools for spatial data exploration and surface generation. It effectively connects geostatistics and GIS analysis by aiding us to model spatial phenomena, interpolate and provide prediction within the study area [19].

2. MATERIALS AND METHODS

2.1. Materials

The materials include: depth calibrated augers; global positioning system (GPS) receiver (Garmin GPS 72); hot plate; 250 ml Pyrex conical flask; 100 ml volumetric flask; Whatman 0.45µm filter paper; and Atomic Absorption Spectrophotometer GBC SensAA Model no. A6358; the reagents include perchloric acid (product code: 311421, 99.999% purity); nitric acid (product code: 438073, 70% purity); and sulphuric acid (product code: 339741, 99.999% purity). Reagents are the products of Sigma-Aldrich Co. 3050 Spruce street, St. Louis, MO 63103, USA) www.sigmaadlrich.com.

2.2. Methods

Geostatiscal techniques require inputs data set for analyses. These data are usually the initial properties of the medium to be studied. For this purpose, an approach to the acquisition of initial Pb concentration in the soils was designed and utilized.

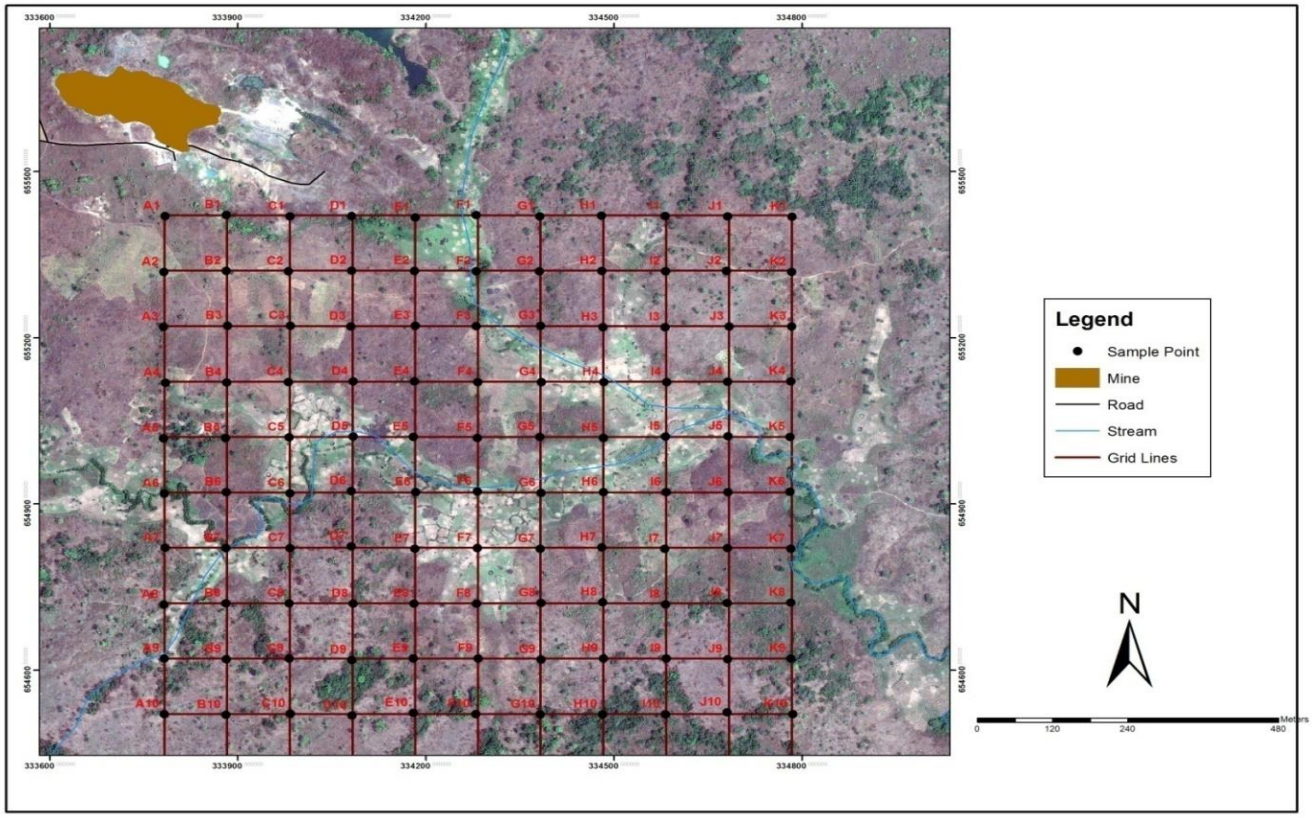

Figure 1: Grid Lines showing Sample Location at 100 m Grids Superimposed on Image Map

2.2.1. Soil Sampling

To determine the current level of lead concentration as input data for spatial studies of Pb in the soil, soil sampling was systematically conducted in the field. Satellite imagery of the study area was obtained, a working area of 1 km by 1 km was gridded at 100 m intervals as shown in Figure 1; and samples obtained at the grid points with depth calibrated augers at depths 10, 20, 30, 40 and 50 cm. The coordinates of samples location were captured with a hand-held global positioning system (GPS) receiver (Garmin GPS 72) and registered. The samples were analyzed in a laboratory for Pb concentration.

2.2.2. Determination of Soil Lead Content

Mixture ratio 1:2:2 for perchloric acid, nitric acid and sulphuric acid was designed and a digestion mixture was developed in that ratio. 2g of air dried, 2 mm sieved soil was weighed into a 250 ml conical flask, and mixed with 40 ml digestion mixture. The flask and content were placed on a hot plate in a fume-hood and digested for 20 minutes until a clear solution appeared. On cooling, 20 ml of distilled water was added and cooled. The solution was filtered into a 100 ml volumetric flask and diluted to mark and analyzed for Pb concentration with Atomic Absorption Spectrophotometer (GBC SensAA Model no. A6358).

2.2.3. Geostatistical Techniques

The steps in the geostatistical modeling include: data transformation; variogram models fitting; spatial dependency determination; and Kriging.

Histogram was employed to assess normality of raw Pb data. The data set which failed the normality test were transformed using Box-Cox transformation [20].

The Box-Cox transformed data were fitted with variogram model expressed in equation (1).

$$r(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2 \qquad (1)$$

Where N(h) denotes the number of data pairs at (h) step width; $Z(x_i)$ and $Z(x_i + h)$ are the values of x at x_i and $(x_i + h)$ respective locations; i is the samples position; and r(h) is for the vertical coordinate mapping [17, 21].

The variogram Nuggets (Co), sill (C) and range (R) were determined. The spatial dependencies of the metal in soil were evaluated using the variogram Nugget/sill ratio as a criterion [21]. The ratio of 25 % (0.25) and 75 % (0.75) are two thresholds for the relative strength index of spatial dependency [17]. The metal concentration was determined in the locations without samples with the ordinary kriging model expressed in equation (2).

$$Z(x) = \sum_{i=1}^{n} \lambda_i Z(x_i) \qquad (2)$$

Where $Z(x)$ is the measured value at the i^{th} location, λ_i is an unknown weight for the measured value at the i^{th} location, x is the prediction location and n is the number of measured values [17, 21]. These predictions were cross validated, and the pollution maps produced

3. RESULTS AND DISCUSSION

3.1. Data Assessment and Transformation

Summary statistics of raw data were assessed to determine the normality of data as a necessity for optimal geostatistical analysis results [20]. From established fact, data variogram model and the subsequent kriging interpolation will not yield accurate result with data that fall out of normality [14, 20]. Histograms of Pb raw data set were engaged to study data normality. Raw data set at 20, 30, 40 and 50 cm fell out of normality, and were transformed with Box-Cox transformation.

3.2. Variography

Variograms of data set were fitted using the geostatistical analyst extension of ArcGIS package, and shown in Figure 2. The parameters [nugget (C_0) of 0, 0, 0, 205.41, and 158; sill (C) of 2781.66, 2381.49, 2180.501, 1851.14 and 1591.90; range (R) of 660, 660, 720, 660, and 660 m] at the respective sampling depths were determined. Several fitting was necessary to determine the most fitted variograms [20, 18] as the exponential model.

The models, from nugget/sill (C_0/C) ratio of less than 25% at every depth (values of 0 % at 10 cm, 0 % at 20 cm, 0 % at 30 cm, 11.1 % at 40 cm and 9.9 % at 50 cm) showed strong spatial dependencies. Spatial dependency guided into the knowledge of the factors affecting soil pollutant variability - whether extrinsic or intrinsic factors [22, 23]. In geostatistics, if nugget/sill ratio is less than 25%, the variable has strong spatial dependence, between 25% and 75%, the variable has moderate spatial dependence; and greater than 75%, variable shows only weak spatial dependence [14].

The nugget value of zero percent at 10, 20 and 30 cm indicated high degree of accuracy in the sampling and measurement; while the nugget values of 204.41 and 158.17 at 40 and 50 cm indicated the presence of measurement errors which could have been due to errors in measurement device, human recording error, changes in measurement condition and data integration [21, 20].

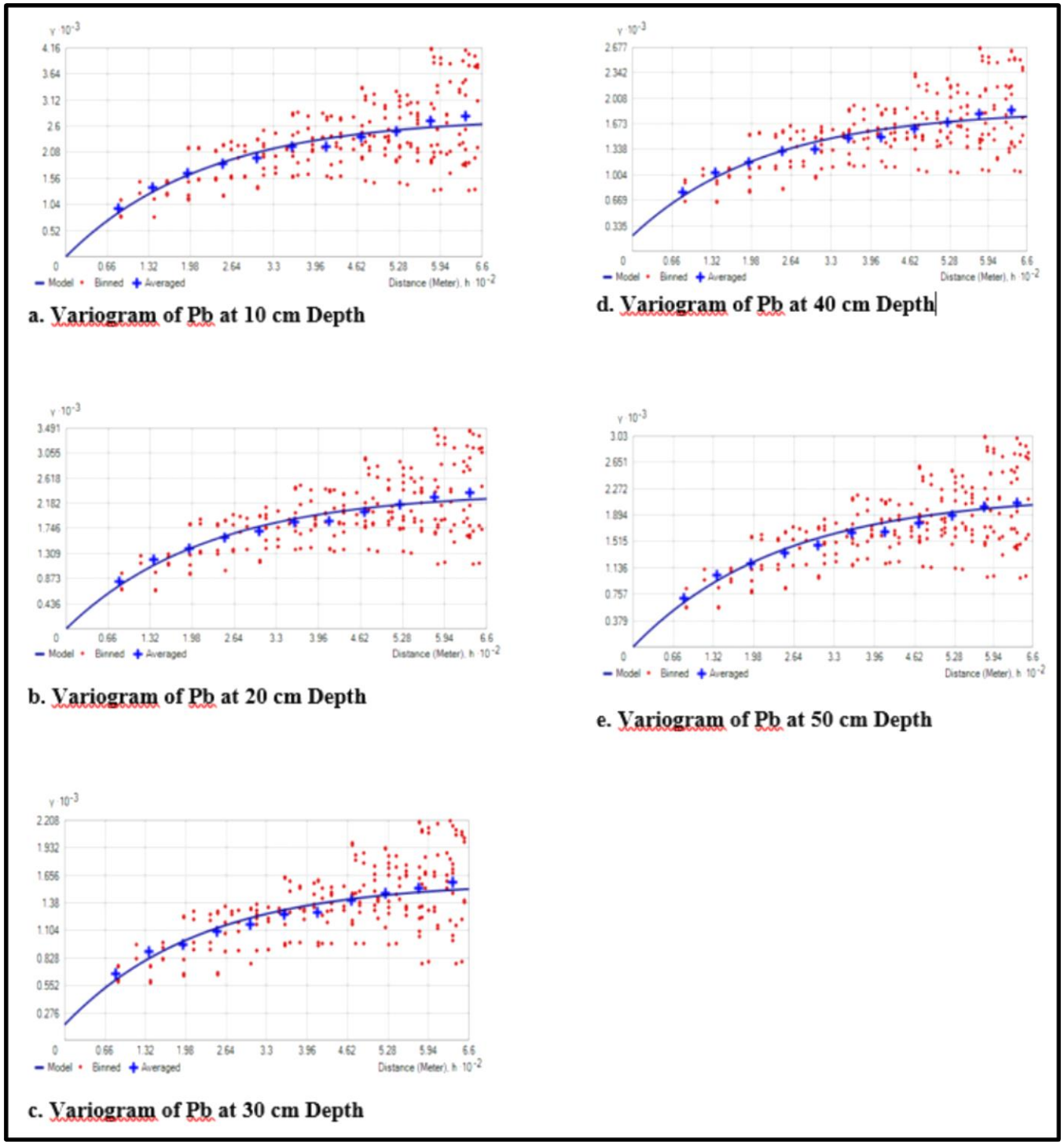

Figure 2: Variograms of Pb at the sampling Depths

3.3. Concentration Variability and Pollution Risk Assessment

Spatial locations and source capturing of soils heavy metals are essential for identification of pollution hot-spot zones, and assessment of potential pollutants generators [14]. Information from pollution risk assessment maps is necessary for these purposes.

Spatial distribution of heavy metals in soils is commonly determined by interpolation and presented in maps [24]. Through this process which suffixed cross validation, concentration distribution and the predicted concentrations were determined as shown in Figure 3 to 7. These figures present the spatial pattern of lead at all layers.

Cross validation gave information of how good the model predictions are; and thus aided in selecting the best model for the study. The parameters engaged in cross validating the suitability of the model utilized are: mean standardized error values of 0.0162, 0.0172, 0.0161, 0.0167 and 0.0189; and root-mean-square standardized error values of 0.9188, 0.9140, 0.9119, 0.9383 and 0.9863 at the respective depths.

The pollution assessment maps in Figure 3 to 7 is the delineation of the polluted portions from the unpolluted. It aided the understanding of the pollution status of the soils, and reveled the pollution hot-spots in the forest. The pollution delineation was illustrated with colour-code. A colour-coded Pb maximum allowable concentration value of 100 mg/kg in soil [25, 26] served as the bench mark for distinguishing polluted portions; and identification of the changes in pollution across the ground surface. The pollution maps revealed similarities in the metal pollution distribution at all layers.

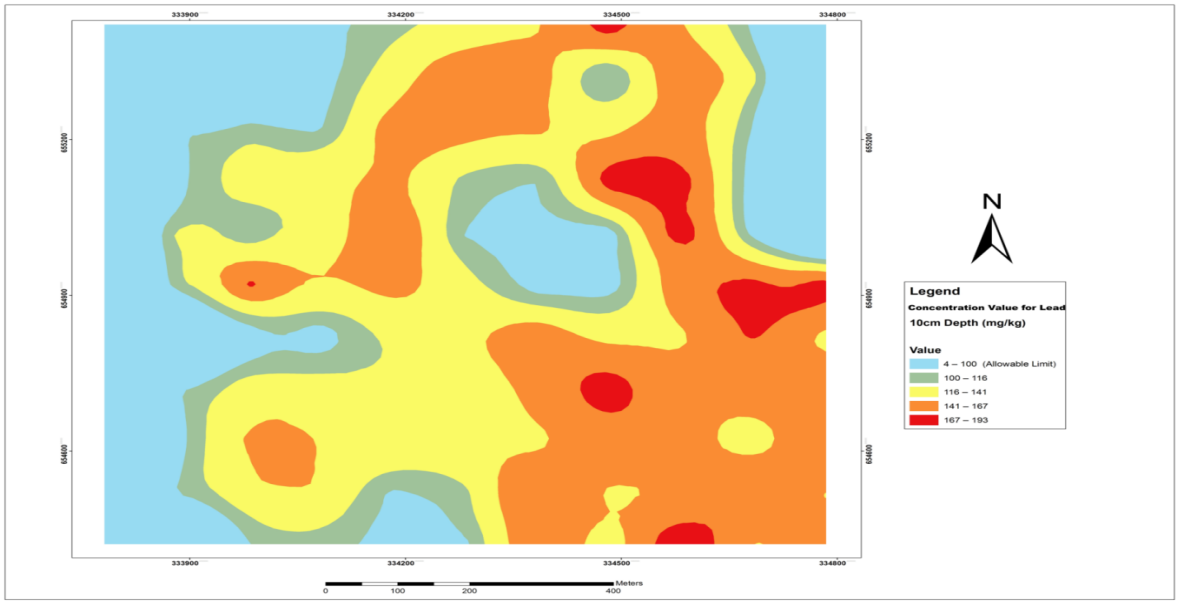

Figure 3: Pollution Assessment Map at 10 cm Depth

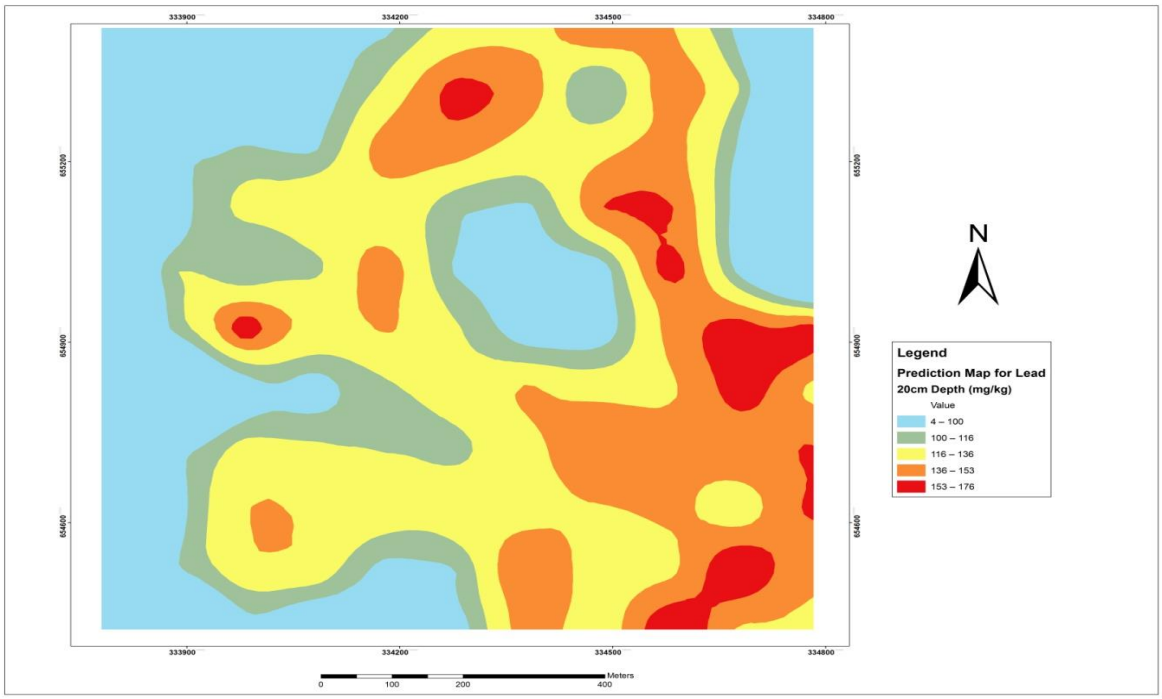

Figure 4: Pollution Assessment Map at 20 cm Depth

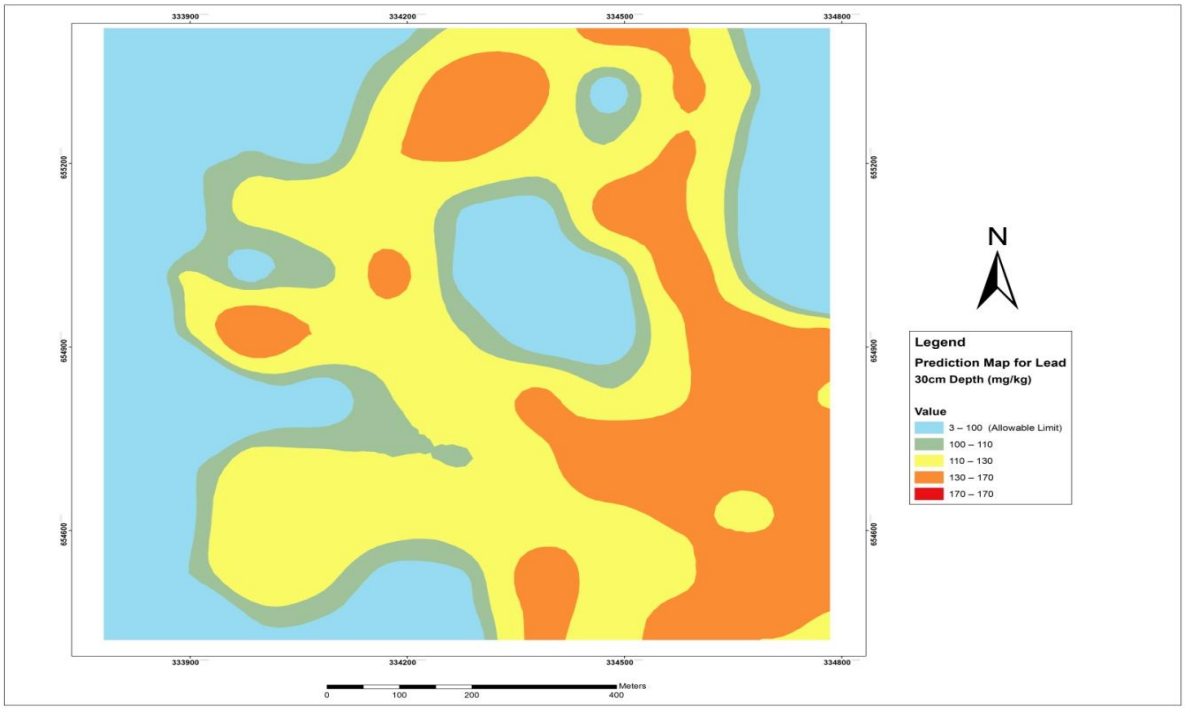

Figure 5: Pollution Assessment Map at 30 cm Depth

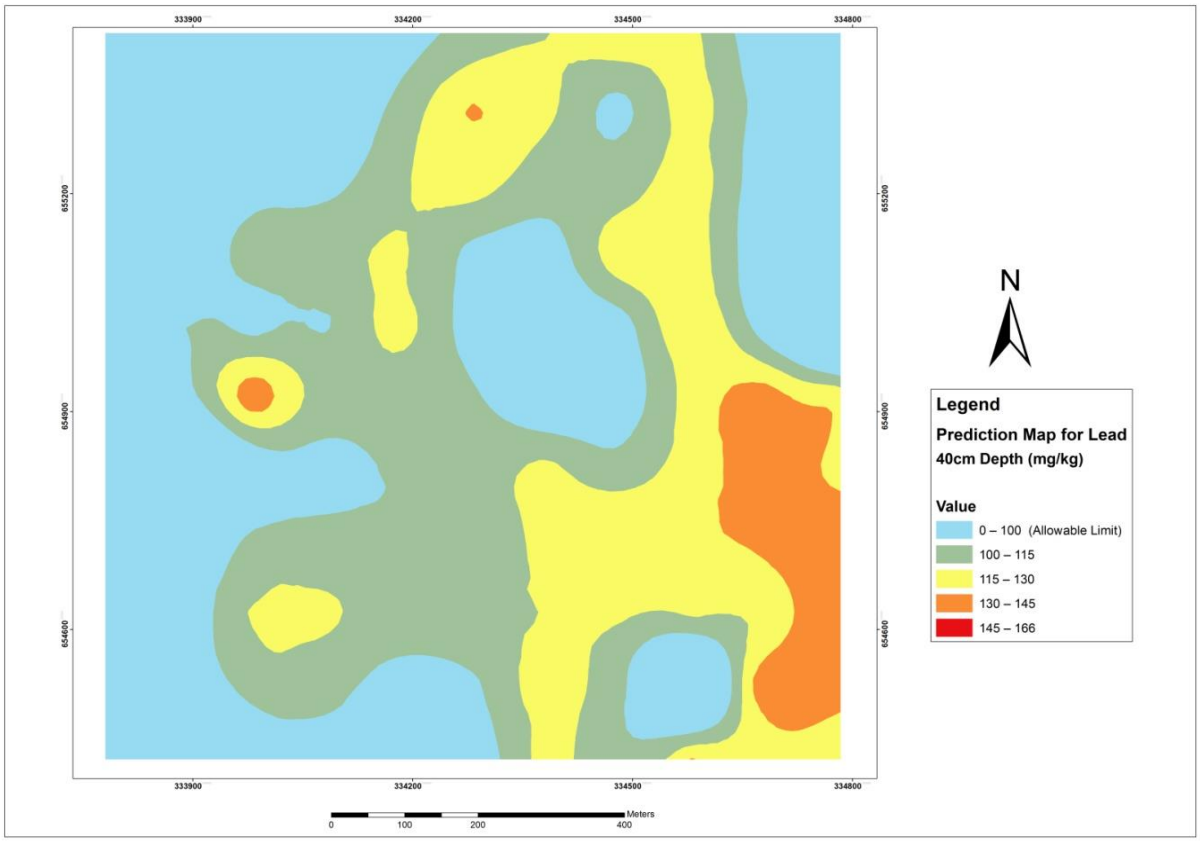

Figure 6: Pollution Assessment Map at 40 cm Depth

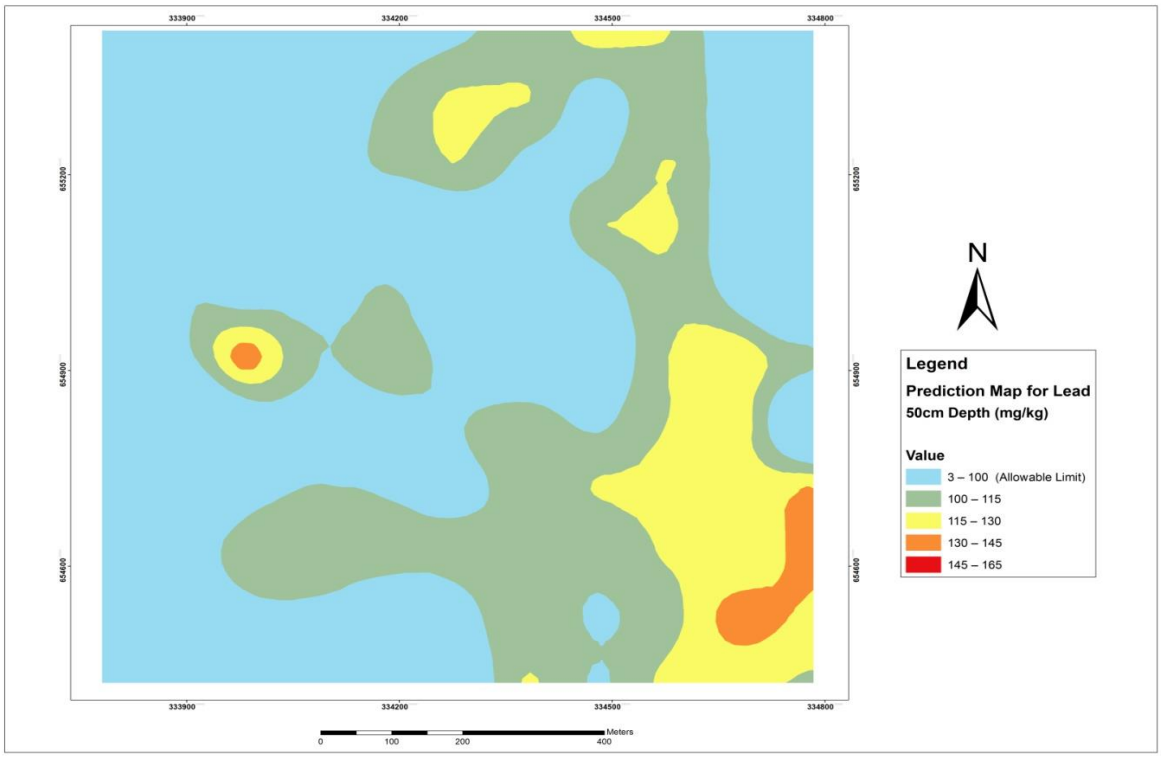

Figure 7: Pollution Assessment Map at 50 cm Depth

Lead concentration was higher around the stream and spread in the direction of water flowing in the stream into the forest land. This is similar to a finding in the research conducted by [5]. Lead pollution was strongest in first layer and grew weaker with vertical downward change in layers, with some deviations from this pollution distribution pattern at some points vertically down the layers.

From the maps, a clear risk of pollution is evident. The land, been found to be heavily polluted is a great treat to agricultural use. This is especially obvious from the contrast of these soils Pb concentration with the report in [25, 26]. Besides, the concentration of Pb in the study area was much higher than 11.3 mg/kg, 10.7 mg/kg and 8.1 mg/kg of three control samples obtained outside the mining locations in this forest.

The pollution spatial pattern revealed that the forest soil pollution was linked to mining activities in the area. This became obvious as the objectionable concentration of Pb was found around the stream channel receiving mining wastes, and the portions of the forest soil to which the stream water had flowed; which is in agreement with the research of [5, 6].

4. CONCLUSIONS

This work looked into the present load of lead in forest soils of Amaonye in Ishiagu. It incorporated some omissions in previous research of [1, 5] by the use of kriging to expose Pb pollution at points between sampling locations.

The study showed that Pb concentration is at risk level in the soils. It revealed that the pollution hot-spots are in the major portions of the forest; and forms a reference for judging the Pb pollution status of an area of about 3.5 km x 70 km covered by mining waste streamflow in the forest. The findings of this study are reliable for soils contamination control planning; implementation; and soils protection sensitization programs in the area.

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