A Practical Application of Inverse Distance Weighting Method to Identify Cobalt Anomaly Distribution in Laterite Deposit (Case study in Block R, Wasile Subdistrict, East Halmahera)

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Abstract. Selection of a suitable interpolation method for predicting ore grade at un-sampled location is a key factor to map the anomaly distribution and resources estimation. Objective of this study is to apply and to assess the performance of the inverse distance weighting (IDW) with manipulating exponent of one to five to identify cobalt grade distribution and potential resources in laterite deposit. In this study the ArcGIS 10.2 with Geostatistical Analyst Extensions was used in exploratory data analysis. To choose the value of power with the best performance were used statistic parameter of the root mean square error (RMSE) value which was obtained from cross-validation procedure. The method with the smallest RMSE value was chosen as the best performance. Result reveal that IDW power of 1 performed best for cobalt grade while IDW power of 2 procedures gave the best result when applied to limonite thickness. Cobalt distribution with grade separation of 0.1% reveal that the areas with cobalt grade > 0.1%, as an anomaly area, distributed to the north and narrowed in the southern part of the study area. Resource estimation indicated 15,956,776 ton of limonite ore with average grade of 0.12% Co or equivalent to 16,576.53 ton of Cobalt.

Keyword: ArcGIS, cross validation, IDW, RMSE

1. Introduction

The use of interpolation methods to estimate value at un-measured location to map ore distribution and resources estimation are widely implemented. One of the methods that often used is inverse distance weighting (IDW). This method has been developed by computer tool and if a comparison is made with other metods, for example method of kriging, the IDW method is simpler to programe and more easily to be understood. Moreover, the IDW method is applicable to datasets of small size for which the modeled variograms, as a preliminary modelling step before kriging itself is conducted, are difficult to fit [1].

The accuracy of the IDW method by manipulating power values indicated variability of result. Several studies have been done for spatial estimating soil properties. Data set with skewness > 2.5 were often best used by a power of four and for most data set with skewness < 1 a power of one resulted the most accurate predicted [2] [3]. While other researcher reported that data set with skewness value within range of four to six were best estimated with using a power of one [4]. For spatial estimation organic matter indicated that data with a low coefficient of variation (CV) < 0.25 better by using a high power, in most cases with an exponent of four, while a dataset with a high coefficient of variation have best result with using power of one [5].

The aim of this research is to implement and assess the accuracy of the inverse distance weighting interpolation method, with various the power value of one to five, for mapping Cobalt (Co) grade and to estimate Co resource in the limonite zone of the laterite deposit.

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2. Study area and data

The area of research is located in Wasile sub-district, East Halmahera, North Maluku Province of Indonesia (Figure 1). A total of 256 bore holes with various depths from 3 to 32m and spacing between each bore hole are 50m. Samples were collected in 1m interval for every hole and those samples were assayed for Co (Figure 2).

Geologically the study area is located in the north east arm of Halmahera. The area is underlined by ophiolite undifferentiated rocks complex with main structure oriented to the north west – south east and northeast – south west [6] see Figure 3. The ophiolite rock consist of dunite, peridotite and pyroxenite [7]. The ultramafic rocks type is known as a potential source of a laterite deposit in this area. The laterite deposit derived from ultramafic rooks contain metals of Ni, Fe and Co, is result of intensive weathering of ultrabasic rocks and their serpentinized equivalents. In general, from bottom to the top, profile of the laterite deposit can be divided into bed rock, saprolite zone and limonite zone [8].

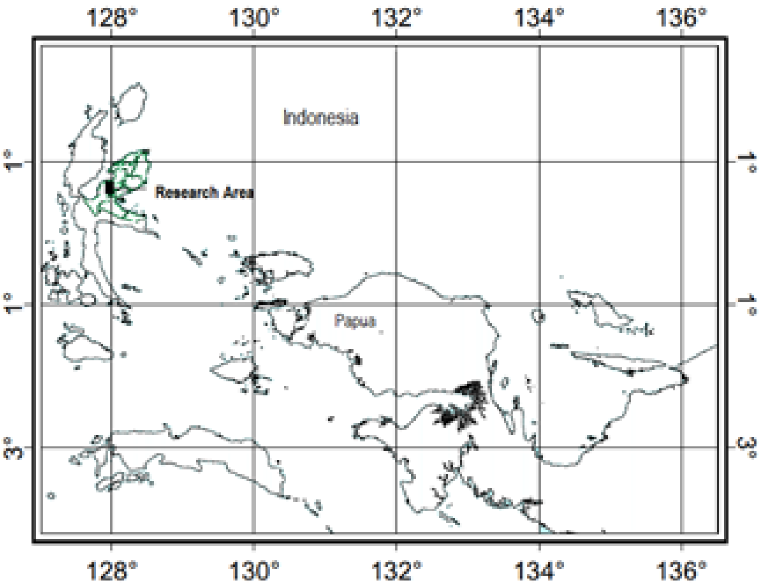


Fig. 1: Location of the research area

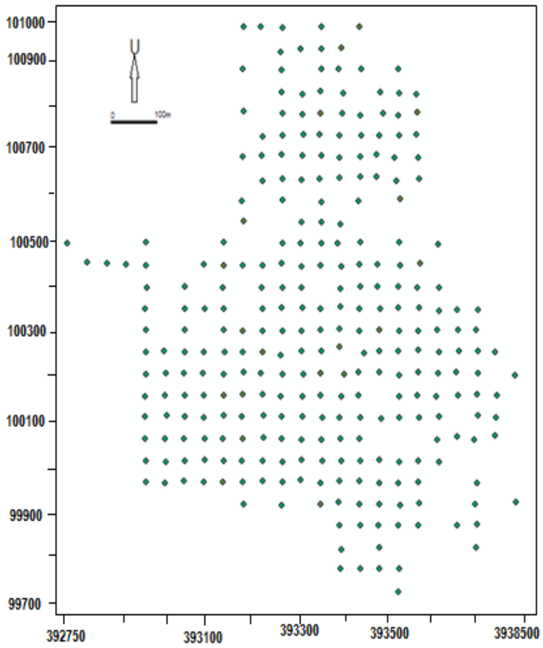


Fig. 2. Distribution of bore hole location in the research area

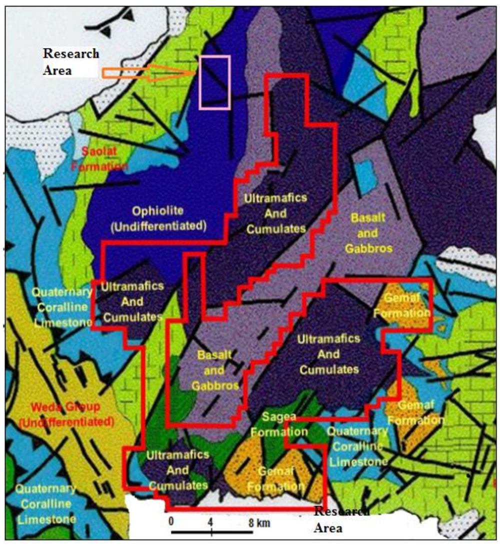


Fig. 3. Geology in the research area [6]

3. Research and approach

A summary method applied in this research for spatial interpolation and assessing of cobalt and thickness are given in Figure 4. This method is started by visual analysis for screening the data values to identify incorrect coordinate information, cobalt grade and thickness of the limonite layer. Composite value of cobalt grade at each bore hole was counted as a base data. Distribution of data was summarized by using basic statistics such as maximum, minimum, mean, median, standard deviation, skewness, kurtosis and coefficient of variation. IDW estimations were performed by varying number of powers from 1 to 5. To choose the value of power with the best performance was used the lowest RMSE value which obtained from cross-validation procedure.

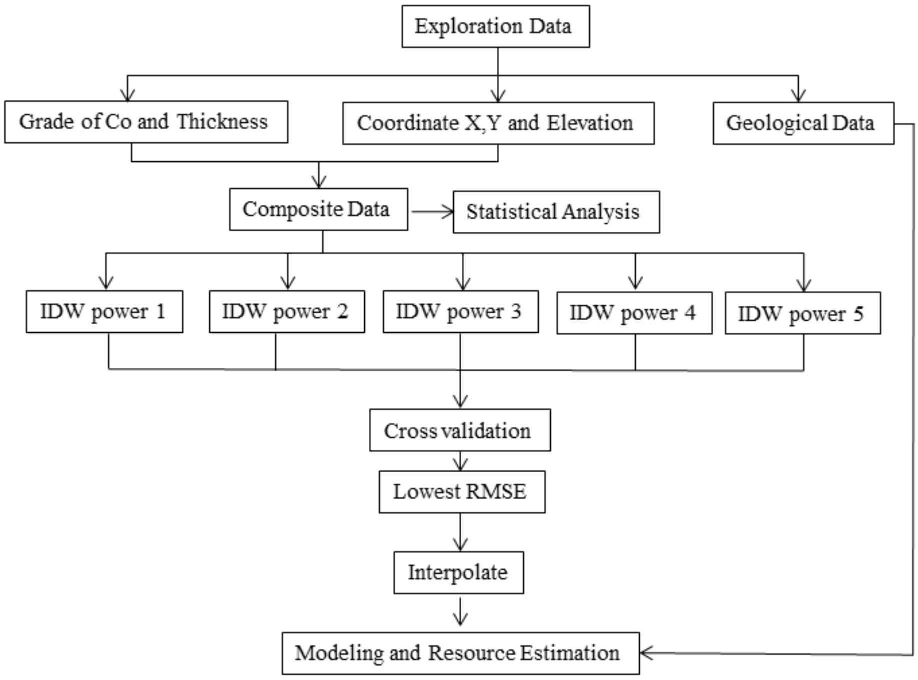


Figure 4: Research methodology

3.1. Inverse Distance Weighting (IDW)

Inverse distance weighting is an exact deterministic interpolator that it calculated based on distance relationship only. This method assumed that degree of correlations and similarities between neighbors is proportional to the distance between them. The method giving weighs to every data point, located within a given search radius centred on the point estimate, in averaging function based on the inverse of the distance to the point of estimate. The IDW equation is expressed as below [9]:

$$w_i = \frac{\frac{1}{di^k}}{\sum_{i=1}^{n} \frac{1}{di^k}} \qquad (1)$$

To estimate a predicted point is used equation:

$$\hat{Z}_0 = \sum_{i=1}^{n} w_i . Z_i \tag{2}$$

where:

$\hat{Z}_0$: A point where the value should be estimated.
w_i : A sample weight in point *i*.
d_i : A distance between points *i* and a prediction point.
k : A power parameter.
Z_i : A sample value in point *i*.

3.2. Criteria for comparison

To select the best estimation result of the IDW method with various power value are used a statistic parameter of root mean square error (RMSE). The RMSE can be obtained from a cross validation technique, and it is counted with the equation below [10]:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(\hat{Z}(x_i) - Z(x_i)\right)^2} \tag{3}$$

where:

$\hat{Z}(x_i)$: The estimation values.
$Z(x_i)$: A mean value.
n : Total number of the estimation.

The estimation result is slightly deviate if a root mean square error value is low. Hence the best predicting result is chosen by the lowest RMSE value.

4. Result and discussion

In this study, thickness of the limonite layer and geochemical assay data of Co were obtained from 256 bore holes. The cobalt distribution map and prediction of limonite thickness were generated using the Geostatistical Analyst extension of ArcGIS 10.2. Summary statistic for Co and limonite thickness are given in Table 1.

Table 1: Descriptive statistics for Cobalt and Thickness of limonite zone

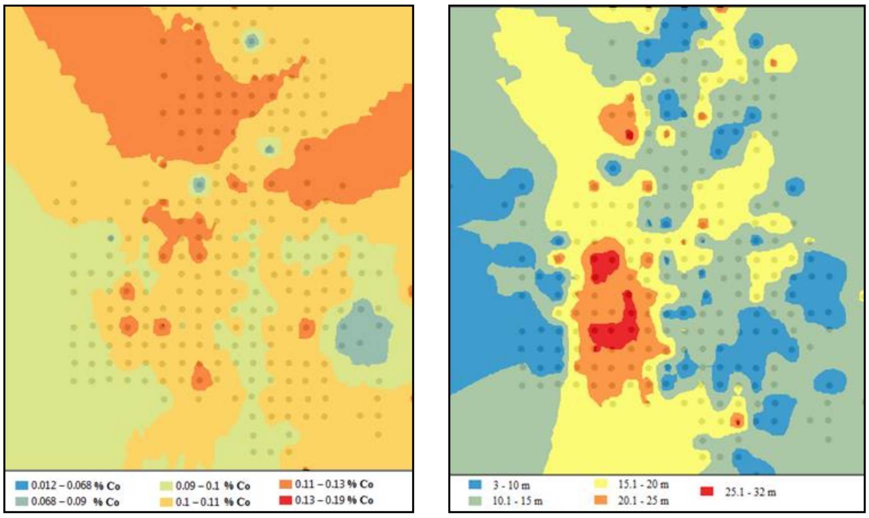
Variable	CV	Mean	Min	Max	Standard deviation	Skewness	Kurtosis	No of observation
Co	0.19	0.10	0.01	0.19	0.02	1.14	7.71	256
Thickness	0.49	14.33	3	32	7.09	0.28	3.23	256

The IDW predictions were assessed by varying number of powers, from 1 to 5, with a given number of the closest neighbouring points with ranging from 5 to 20. Result of the RMSE value according to IDW power of 1, 2, 3, 4 and 5 were given in Table 2. The result indicated that the interpolation methods with the lowest RMSE values were IDW power of 1 for Co grade, and IDW power of 2 for limonite ore thickness. Parameters statistic show that data with low coefficient of variance (CV= 0.19) best estimated with a power of one while data with high coefficient of variance (CV= 0.49) best predicted by a power of two.

Table 2. Result of the RMSE value according to IDW powers of 1-5

Zone	Variable	Interpolation Method	RMSE
limonite	Co	IDW 1	0.019971
		IDW 2	0.020506
		IDW 3	0.021344
		IDW 4	0.021951
		IDW 5	0.022510
	Thickness	IDW 1	6.271720
		IDW 2	6.246243
		IDW 3	6.288895
		IDW 4	6.374380
		IDW 5	6.473682

Result of the interpolated map of cobalt grade and limonite ore thickness were produced from the best techniques of have been selected base on the lowest RMSE values are presented in Figure 4



(a) (b)

Fig. 4. Interpolated maps (a) Cobalt grade with using IDW-1 (b) Limonite ore thickness by using IDW-2

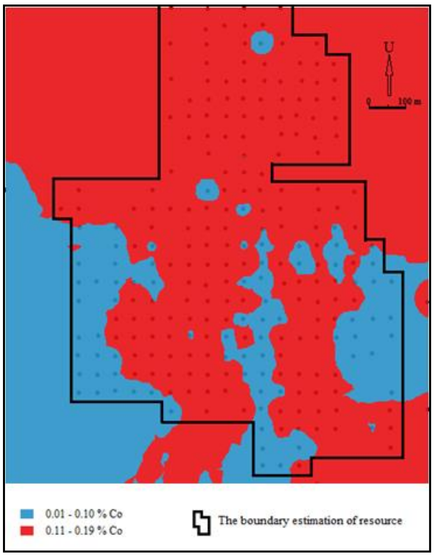


Fig. 5. Interpolated map of cobalt with separation of grade 0.1% by using IDW 1

The interpolation map of cobalt with grade separation of 0.1% show that the areas with cobalt grade > 0.1%, as an anomaly area, distribute to the north and narrowed in the southern part of the study area (Figure 5).

Estimation of cobalt resources were obtained based on the two-dimensional model. The tonnage of the resources was countered from the result of the multiplication of the volume and limonite ore density, whereas the volume was obtained from the result of between thickness of limonite ore by square of the drill hole grid (50m x 50m). By assuming the limonite ore density was 1.6 ton/m^3 with cutoff grade was 0.1% Co, the amount of resources indicated 15,956,776 ton limonite ore with average grade of 0.12 % Co or equivalent to 16,576.53 ton of cobalt metal (Table 3). The map of cobalt anomaly indicates that additional potential cobalt resources in the limonite zone can be extended to the North and Southeast of the research area (Figure 5).

Table 3: Tonnage of cobalt resources

Zone	Element	Ore tonnage (ton)	Average grade (%)	Metal tonnage (ton)
Limonite	Co	15,956,776	0.12	16,576.53

5. Conclusion

In implementation of IDW with manipulating power from one to five indicate the power of one is the best choice for cobalt grade and power of two is the best suitable for limonite thickness. In this study show that data with low coefficient of variance (CV= 0,19) best estimated with a power of one while data with high coefficient of variance (CV= 0,49) best predicted by a power of two.

Result of the interpolation show the distribution of cobalt with grading > 0.1 % still open to the north and to the southest of the research area. Resource estimation indicated 15,956,776 ton of limonite ore with average grade of 0.12% Co or equivalent to 16,576.53 ton of Cobalt.

Additional potential cobalt resources in the limonite zone can be extended to the North and Southeast of the research area.

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