RESEARCHERID
THOMSON REUTERS

[Permana, 6(7): July 2019]
DOI- 10.5281/zenodo.3351436

ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

ORDINARY KRIGING ACCURACY EVALUATION FOR NICKEL LATERITE RESOURCES ESTIMATION

Andreaditia Permana*[1] & Waterman Sulistyana B[2]

*[1]Student of Magister Mining Engineering, UPN "Veteran" Yogyakarta, 55283 SWK 104 Yogyakarta, Indonesia

[2]Lecturer of Magister Mining Engineering, UPN "Veteran" Yogyakarta, 55283 SWK 104 Yogyakarta, Indonesia

ABSTRACT

Using accurate interpolation technique for predicting nickel grade in unknown location is an important issue in mineral resources estimations. The use of kriging variance on geostatistics method for measuring of confidence level is difficultt apply directly. In this study the accuracy of the estimation performance will be compared using cross validation and will produce root mean square error (RMSE) and linear regression values in the selection of the best variogram model. In this study, use OK (ordinary kriging) techniques for nickel late rite resource estimation. Estimation result indicates good accuracy with RMSE value at 0.261 and R2 value at 0.8345. Resource calculations were calculated based on the cut off grade (COG) 1.30%, resulting nickel ore deposit of 8,015,438 tons with an average nickel grade content is 1.93%.

Keywords: *geostatistics, resource estimation, nickel laterite, RMSE.*

I. INTRODUCTION

Due to the importance of estimating and calculating the volume of nickel ore, it is necessary to conduct an analysis and modeling of nickel ore resources There are several interpolation method was developed by using computer tool can be used to estimate the potential resources and reserves, among other is Ordinary Kriging (OK) method. In the process OK requires preliminary modeling step of the relationship between a variance and distance. [1]. Kriging has been used due to provides best linear unbiased estimates [2]. OK procedure were applied to evaluate laterite nickel resources in this research. Nickel laterite is product of intensive deep weathering of olivine rich ultramafic rocks and their serpentinized equivalents.

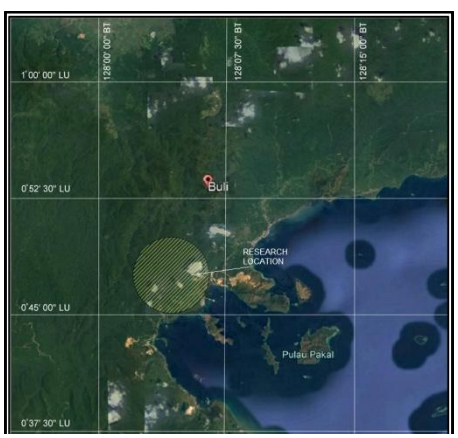

Figure 1: Location of The Research Area in Halmahera Indonesia

The research area is located in East Halmahera regency, North Maluku Province of Indonesia which is a region nickel deposit well developed (Figure 1). Geologically the area (see Figure 2) is located in east arm of Halmahera that is widely occupied by ultrabasic rocks complex, as a resource potential of nickel laterite, with predominant north- east and north – northeast trending structure [5].

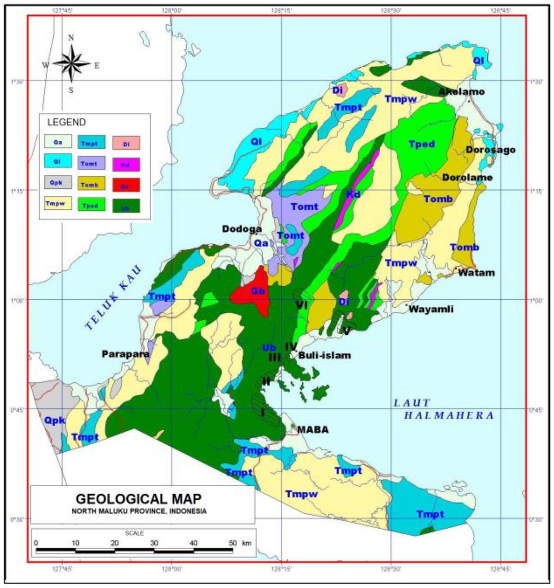

Figure 2 :Regional Geological Map of East Halmahera Indonesia

Objective of the research was to evaluate the accuracy performance of the OK in predictingamount of nickel, based on root mean square error (RMSE) value, and to analyze the relationship between statistic parameters and performance of the methods.

II. METHODS AND MATERIAL

Kriging is spatial prediction technique for linear optimum unbiased interpolation with a minimum mean interpolation error [6]. This method work with the parameter obtained from the result of fitting between semivariogram experimental and theoretical model as main base [7]. The most widely used models are spherical, exponential and Gaussian [8]. In this study to select a semivariogram theoretical model is based on the root mean square error (RMSE) value whereas the smallest value was chosen as the best model [9]

A semivariogram experimental defined by equation below [8].

$$\gamma(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [Z(x_1) - Z(x_{i+h})]^2 \qquad (1)$$

where:
$Z(x_i)$: Sample value of the variable at point x_i
$Z(x_i + h)$: Sample value of the variable at a point distance h from pointx_i.
$\gamma(h)$: The experimental semivariogram value at the distance interval h.
$n(h)$: Number of sample pairs within the distance interval h.

The Ordinary Kriging (OK) method was developed by the Matheron in 1963 in estimating the average level of a block using the weighting of the surrounding sample data based on semivariogram. OK is a practical and simple method in the concept of stationarity models to estimate the levels using data around the block [11]. In this method, it is assumed that the mean is unknown and has a constant value.

[Permana, 6(7): July 2019]
DOI- 10.5281/zenodo.3351436

ISSN 2348 – 8034
Impact Factor- 5.070

OK prediction at an unsampled location $\hat{Z}$ is defined by an equation:

$$\hat{Z} = \sum_{=1}^{n} \lambda_i . Z_i \qquad (2)$$

The weight$\lambda_i$calculated by a formula:

$$\sum_{i}^{n} \lambda_i . C(i,j) + \square = C(i,0), with \ \sum_{i=1}^{n} \lambda_i = 1(3)$$

Kriging variance can be expressed with the following equation:

$$\sigma_R^2 = C(0) - ((\sum_{i=1}^{n} \lambda_i C_{i0}) + \square) \qquad (3)$$

where:
Z_i : A sample value at point *i*.
$C(i,j)$: Covariance between sample *i* and sample *j*.
μ : Lagrange multiplier.
$C(i,0)$: Covariance between sample and block.

To compare the accuracy of interpolation method was used parameter of root mean square error (RMSE). The RMSE indicated deviate from the measured value and it is calculated with equation [1]:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(\hat{Z}(x_i) - Z(x_i)\right)^2} \qquad (4)$$

where:
$\hat{Z}(x_i)$: The estimation value.
$Z(x_i)$: The observed value.
n : Total number of the estimation.

The prediction is not much deviate if a root mean square error value is low

III. RESULT AND DISCUSSION

Assay data, consisted of Ni grade value, and thickness used in this research were obtained from 488 drill holes.The assay data then discriminated and composited into each meter interval resulting 9662 composite data. Basic statistic for all variables obtained from 9662 composite data given in Table 1.

Table 1. Basis Statistic of Composite Data

Variable	CV	Mean	Standard deviation	Skewness	Kurtosis
Ni	0.44	0.00	0.83	0.50	3.47

Semivariogram experimental were calculated to identify the possible spatial structure of different direction. In this study 18 variograms is used, with increase in every 10degre of direction. Using lag equal to the average distance between drill holes. From the varogram analysis we got variogram map that can be use to determine the major direction os special correltion (Figure 3)

Resource estimation were carried out using software assistance with a cut off grade at 1.3%. In estimating resources, the data used is based on Ni content in the block domain that was previously created. The estimation results can be seen in Table 2.

ISSN 2348 – 8034
Impact Factor- 5.070

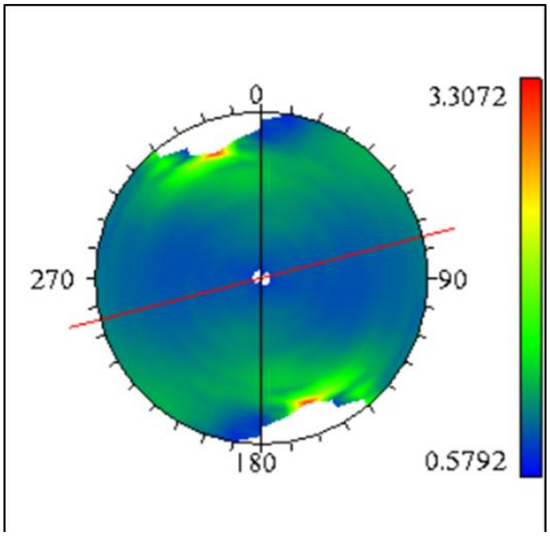

Figure 3: Variogram Map With Major direction 75.5°

Table 2. Resource Estimation of Ni

Grade Value (%	Ore Volume (m3)	Ore Tonage (Ton)	Average (% Ni)
1.3 - 1.5	734,297	1,138,160	1.41
1.5 - 1.7	1,035,000	1,604,250	1.60
1.7 - 1.9	1,067,695	1,654,928	1.80
1.9 - 2.1	871,406	1,350,680	2.00
2.1 - 2.3	572,695	887,678	2.19
2.3 - 2.5	365,039	565,811	2.39
2.5 - 2.7	207,773	322,049	2.60
2.7 - 2.9	143,086	221,783	2.80
2.9 - 3.1	85,664	132,779	2.99
3.1 - 3.3	43,125	66,844	3.18
3.3 - 3.5	25,195	39,053	3.37
3.5 - 3.7	12,891	19,980	3.59
3.7 - 3.9	2,930	4,541	3.80
3.9 - 4.1	2,578	3,996	3.96
4.1 - 4.3	1,875	2,906	4.23
Total	5.171.249	8.015.438	1.93

The estimation results of the total resources obtained total nickel ore resources of 8,015,438 tons, with an average content 1.93% Ni. From Table 2 it can be seen that the Ni content of 1.7% -1.9% has the largest ore deposit, which is 1,654,928 tons. While the Ni content of 4.1% - 4.3% has the smallest amount for 2,906 tons ore deposit.

Using cross validation the composite content (true grade) will be compared with theprediction results (estimated grade)(figure 4). Evaluation of the accuracy performance is done by cross validation analysis. The results of cross validation show the relationship between estimated Ni content and Ni exploration data with regression parameters slope, SE, R^2, Y intercept, and RMSE.

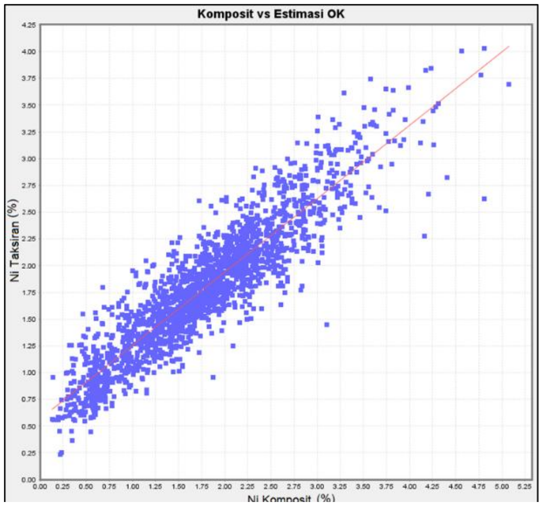

Figure 4: Cross validation True Grade vs Estimated Grade

Estimation result indicates good accuracy linear regression with a correlation coefficient approaching one that is 0.9135, r2 0.8345, slope 0.6866 with a value of Y intercept 0.5676, and Root Mean Square Error (RMSE) 0.261 (Table 3).

Table 3. Linier Regression of Cross Validation

Slope	*Correlation Coefficient (R)*	r^2	Y *intercept*	*Root Mean Square Error (RMSE)*
0.6866	0.9135	0.8345	0.5676	0.261

IV. CONCLUSION

Based on the discussion above, some conclusions can be noted:

a) Resource estimation using Ordinary Kriging method in research area resulting nickel ore deposit of8,015,438 tons with an average nickel grade content is 1.93%.
b) Estimation result indicates good accuracy with RMSE value at 0.261 and r^2 value at 0.8345

REFERENCES

1. *Yasrebi, J., Saffari, M., Fathi, H., Karimian, N., Moazallahi, M., &Gazni, R. (2009). Evaluation and comparison of ordinary kriging and inverse distance weighting methods for prediction of spatial variability of some soil chemical parameters. Research Journal of Biological Sciences, 4(1), 93-102.*
2. *Almasi, A., Jalalian, A., &Toomanian, N. (2014). Using OK and IDWmethods for prediction thespatial variability of a horizon depth and OM in soils of Shahrekord, Iran. Agrochimica, 58(1).*
3. *Butt, C. R., &Cluzel, D. (2013). Nickel laterite ore deposits: weathered serpentinites. Elements, 9(2), 123-128.*
4. *Elias, M. (2002). Nickel laterite deposits-geological overview, resources and exploitation. Giant ore deposits: Characteristics, genesis and exploration. CODES Special Publication, 4, 205-220.*
5. *Apandi, T., &Sudana, D. (1980). Geologic map of the Ternate quadrangle, North Maluku. Geological Research and Development Centre, Bandung, Indonesia.*
6. *Mousavifazl, H., Alizadh, A., &Ghahraman, B. (2013). Application of Geostatistical Methods for determining nitrate concentrations in Groundwater (case study of Mashhad plain, Iran). International Journal of Agriculture and Crop Sciences, 5(4), 318.*

7. *Bargawa, W. S., &Amri, N. A. (2016, February). Mineral resources estimation based on block modeling. In Progress in AppliedMathematics in Science and Engineering Proceedings (Vol. 1705, p. 020001). AIP Publishing.*
8. *Isaaks, E. H. (1989). Applied geostatistics (No. 551.72 I86). Oxford University Press.*
9. *Suryani, S., Sibaroni, Y., &Heriawan, M. N. (2016). Spatial Analysis 3d Geology Nickel Using Ordinary Kriging Method. JurnalTeknologi, 78(5).*
10. *Armstrong, M. (1998). Basic linear geostatistics. Springer Science & Business Media.*
11. *Cambardella, C. A., Moorman, T. B., Parkin, T. B., Karlen, D. L., Novak, J. M., Turco, R. F., & Konopka, A. E. (1994). Field-scale variability of soil properties in Central Iowa.*