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COMPARISON OF KRIGING AND INVERSE DISTANCE WEIGHTED (IDW) INTERPOLATION METHODS IN LINEAMENT EXTRACTION AND ANALYSIS

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Abstract

Analysis that is based on geostatistics eliminates many corresponding defects and limitations compared to classical statistics which have been developed by random distribution theory of processes and variables. Interpolation is important for local analysis by GIS, because many maps used for GIS operation are made by interpolation. In this research, two different methods which is Kriging method and Inverse Distance Weighted (IDW) method was examined for developing Digital Elevation Model image. Each method's advantages and disadvantages were considered.

The study are, Kepil, is within Kulon Progo physiographic and stratigraphic area, located in the western part of Yogyakarta city. This area is located close to the Java Island Subduction Zone, hence influence of tectonic plate movement is relatively dominant. Geological structures become a main factor that shapes the recent morphology. This study area also has many settlements and has high weathering and erosion rate.

Lineaments are extracted based on Digital Elevation Model to provide assistance in delineating geological structures. The structural geology analysis and an understanding of tectonic phase of the area provide useful information for geological mapping. Accuracy of lineament depends on extraction and imagery parameters used. In this study, the extraction was conducted by two different raster methods, namely Kriging and Inverse Distance Weighted (IDW) with the same resolution of 30 meters. Lineament extracted automatically (digitally) with certain parameter settings.

Keywords: *Kriging, inverse distance weighted, interpolation, lineament, random distribution, digital elevation model.*

1 Introduction

Lineament analysis is performed by using Digital Elevation Model (DEM) data. DEM contains elevation and slope information that made interpretation easier. In Indonesia, the rate of weathering and erosion rate makes field mapping of geological structures becomes difficult without the aid of satellite imagery mapping. DEM is basically a numerical representation of topography that is usually stored in equalized grid cells, each with a value of elevation. Its simple data structure and widespread availability has made it a popular tool for land characterization. Because topography is a key parameter in controlling the function of natural ecosystems, DEMs are highly useful to deal with ever-increasing environmental issues.

The topographic modeler must be particularly careful when selecting the technique for interpolation between the initial sampling data

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points of altitude, as this may have a great effect on the quality of DEMs. The main objective of this study is to evaluate the effects of landform types, the density of original data, and interpolation techniques on the accuracy of DEM generation to be used for digital lineament extraction.

Prior to the structural lineament analysis, there are three aspects to consider: the type of lineament, the establishment of lineament, and manifestations that led to form lineament. Furthermore, this lineament analysis is intended to be able to analyze geological structures in some area which contains many eroded or modified structures. Geological structures may have large dimensions that is not apparent in the field. In addition, the civil settlement obscure some parts of the strucures in the field. Simple identifications can be performed by using satellite imagery, and there are more than one raster available to use. Comparing two or more raster will make identification easier.

Study area

The study area (Figure 1) is within Kulon Progo Hills physiographic and stratigraphic zone. This area is located close to Java Island subduction zone, hence the influence of tectonic plate movement is relatively dominant. Geological structures become a main factor that shapes the recent morphology. The study to analyze the forces that comprise them becomes important. Hills in the study area are formed due to the influence of deformation force. This deformation takes place in several stages; its manifestation that can be observed in present circumstances is a mixture of all phases that has ever been happened.

This area has been studied earlier by Bemmelen (1949) who argued that Kulonprogo experienced three tectonic phases: the first phase was Ijo, Gajah, and Menoreh Volcano formation; the second phase was a transgression event that formed Jonggrangan and Sentolo Formation; and third phase was lifting that produce morphological Kulonprogo recent time. Pulunggono *et al.* (1994) argued that Java Island was formed by three main structural patterns: Meratus pattern trending NE-SW (Paleocene), Sunda pattern trending N-S (Eocene-Late Oligocene), and Java pattern trending W-E (Late Oligocene-Earlier Miocene). By using Landsat-7 ETM+ and panchromatic aerial photographs, Sudrajat *et al.* (2010) argued that Kulonprogo Hills and surroundings had trends in three different phases starting from oldest to youngest were NE-SW, NNW-SSE, and E-W.

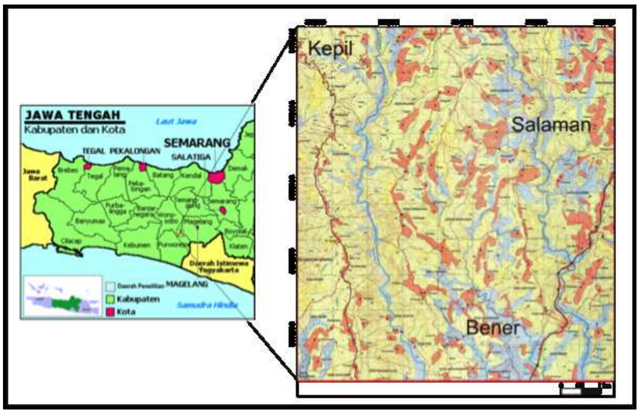

Figure 1: Study area.

This study of lineament analysis compares two interpolation methods to improve the results obtained from lineament extraction using automatic (digital) and manual correction. The interpolation methods are Kriging and IDW.

2 Methodology

The aim of this study is to investigate the differences in the automation of lineament analysis between Kriging and IDW interpolation methods. Analysis is based on DEM data. The methodology used in this study is shown in Figure 2.

2.1 Interpolation method

DEM is usually produced from sampled data. Ideally, the data sources would be used without interpolation. For example, only contour lines themselves may represent a model of terrain. They can be acquired directly (e.g. by photogrammetry from stereo model) or indirectly (e.g. from analogue cartographic data, satellite images, by surveying, etc.). Interpolation is also not necessary in cases where data source is very precise and having high density, and

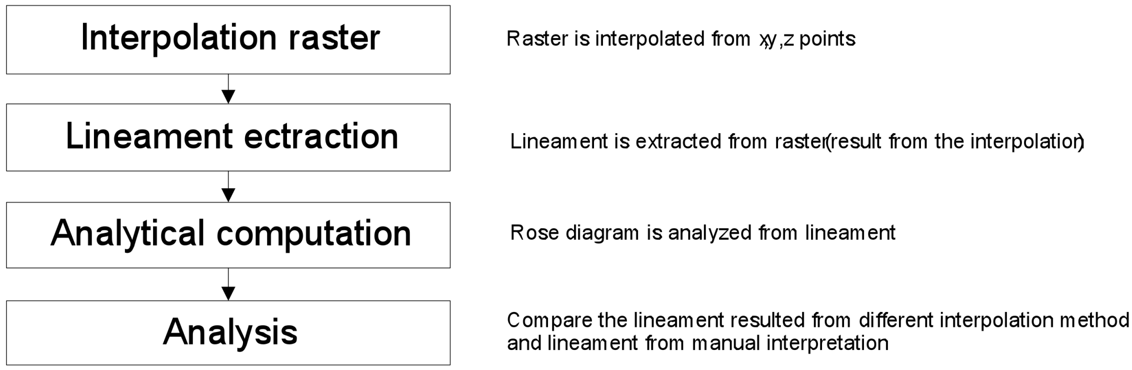

Figure 2: The major methodology of lineament analysis.

especially if the data is acquired directly into regular grid (DEM). But interpolation of data sources to produce DEM is necessary if the data sources themselves do not predict treated landscape phenomena.

Interpolation techniques are based on the principles of spatial autocorrelation which assumes that objects close together are more similar than objects far apart. On the edges of the interpolated area, extrapolation is also reasonable. Unfortunately, no interpolation technique is universal for all data sources, geomorphologic phenomenon, or purposes. We should be aware that in the praxis, different interpolation methods and interpolation parameters on the same data sources lead to different results. The best chosen algorithms on fair data sources should not differentiate much from nominal ground, that is idealization of our desired model and which is commonly similar to actual Earth's surface. Divergences between results of interpolation and from nominal ground are especially consequences of the following circumstances:

1. Available data sources do not approximate terrain (distribution, density, accuracy, etc. of the sources is not appropriate),
2. Selected interpolation algorithm is is not enough robust on the employed data sources,
3. Chosen interpolation algorithms or data structure are not suitable for selected terrain geomorphology or application,
4. Perception or interpretation of Earth's surface (better: nominal ground) is not the same when more DEM operators work on the same problem; operator's own imagination is common and reasonable problem in DEM production.

Application requirements play important role to expected characteristics of the DEM. For example, we need high geomorphologic quality of DEM for regional-small scale analysis and for calculating average altitudes, although geomorphologic accuracy is more sensitive for visibility analysis and even more for analysis that uses algorithms based on derivates like slope, aspect, cost surface, drainage, path simulation, etc.

2.2 Ordinary Kriging (K)

Ordinary Kriging is one of the most basic of Kriging methods. It provides an estimate at an unobserved location of variable z, based on the weighted average of adjacent observed sites within a given area. The theory is derived from that of regionalized variables (Deutsch and Journel, 1998) and can be briefly described by considering an intrinsic random function denoted by $z(s_i)$, where s_i represents all sample locations, i = 1, 2, ..., n. An estimate of the weighted average given by the ordinary Kriging predictor at an unsampled site $z(s_0)$ is defined by:

$$Z(s_0) = \sum_{i=1}^{n} \lambda_i z(s_i) \tag{1}$$

where, λ are the weights assigned to each of the observed samples. These weights sum to unity so that the predictor provides an unbiased estimation:

$$\sum_{i=1}^{n} \lambda_i = 1 \tag{2}$$

The weights are calculated from the matrix equation:

$$C = A^{-1} \times b \tag{3}$$

where:

A = A matrix of semi ariances between the data points.

b = A vector of estimated semivariances between the data points and the points at which the variable z is to be predicted.

c = The resulting weights.

2.3 Inverse Distance Weighting (IDW)

All interpolation methods have been developed based on the theory that points closer to each other have more correlations and similarities than those farther. In IDW method, it is assumed substantially that the rate of correlations and similarities between neighbors is proportional to the distance between them that can be defined as a distance reverse function of every point from neighboring points. It is necessary to remember that the definition of neighboring radius and the related power to the distance reverse function are considered as important problems in this method. This method will be used by a state in which there are enough sample points (at least 14 points) with a suitable dispersion in local scale levels. The main factor affecting the accuracy of inverse distance interpolator is the value of the power parameter p (Burrough and McDonnell, 1998). In addition, the size of the neighborhood and the number of neighbors are also relevant to the accuracy of the results.

$$Z_0 = \frac{\sum_{i=1}^{N} z_i \cdot d_i^{-n}}{\sum_{i=1}^{N} d_i^{-n}} \tag{4}$$

where:

Table 1: Parameter raster interpolation using ArcGIS.

Parameter	Kriging	IDW
Z value	Elevation	Elevation
Method	universal	-
Output cell size	30 meters	30 meters
Search radius	12	12

Z_0 = The estimation value of variable z in point I.

z_i = The sample value in point I.

d_i = The distance of sample point to estimated point.

N = The coefficient that determines weigh based on a distance.

n = The total number of predictions for each validation case.

3 Results

According to ESRI (2004), Kriging is one of the most complex interpolators. It applies sophisticated statistical methods that consider the unique characteristics of dataset. IDW takes the concept of spatial autocorrelation literally. It assumes that the nearer a sample point is to the cell whose value is to be estimated, the more closely the cell's value will resemble the sample point's value. The parameters of both interpolation methods are seen in Table 1.

The accuracy of both Inverse Distance Weighted and Kriging is almost the same. In this study, since nominal data was used to get the result, IDW has more simple procedure and fewer steps in comparison Kriging. The advantage of IDW is that it is intuitive and efficient hence recommended for the type of data. However, for more informative data, Kriging is more preferable. Indeed, Kriging provides a more reliable interpolation because it examines specific sample points to obtain a value for spatial autocorrelation that is only used for estimating around that particular point, rather than assigning a universal distance power value. Furthermore, Kriging allows for interpolated

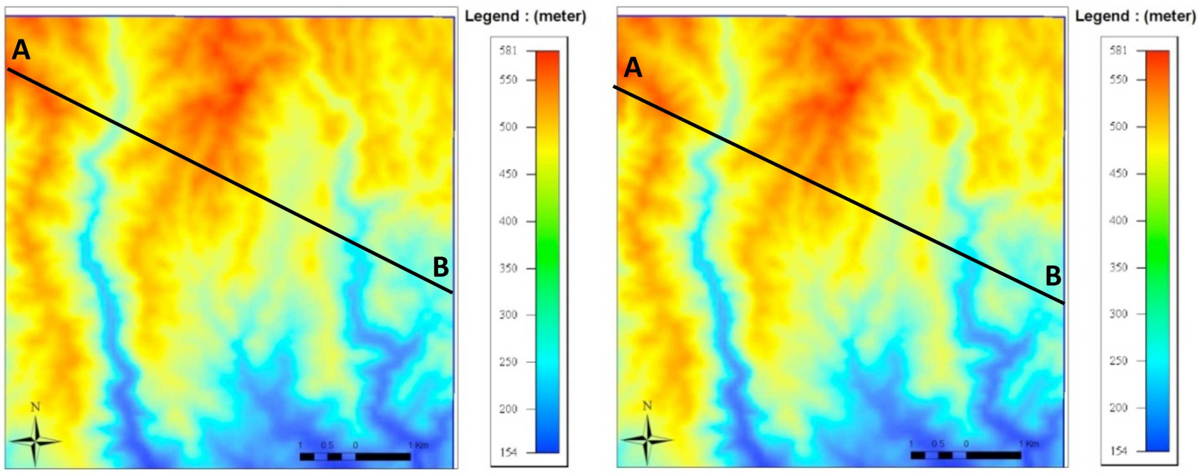

Figure 3: Kriging (left) and IDW (right), black line is profile line.

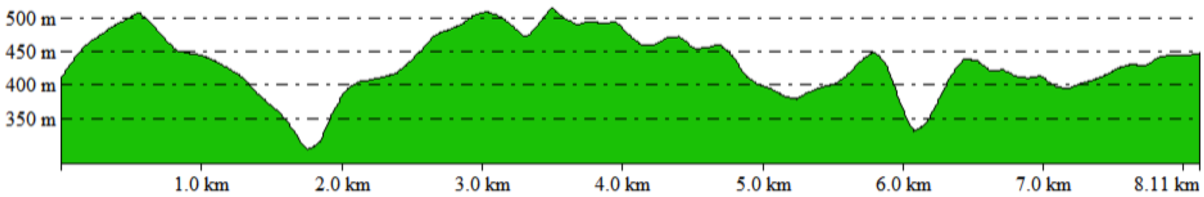

Figure 4: Profile from DEM of Kriging interpolation.

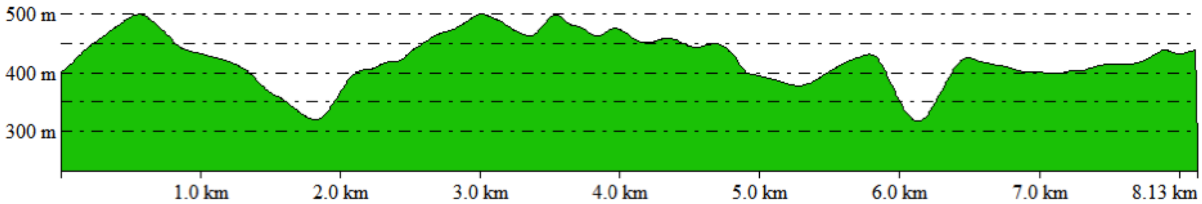

Figure 5: Profile from DEM of IDW interpolation.

cells to exceed the boundaries of the sample range.

3.1 Lineament Extraction

Lineament extraction can be conducted in two main ways, which is manual and automatic (digital). Manual lineament extraction requires full interpretation and pure user analysis. Automatic lineament extraction uses 3D image (DEM) or in this study is resulted from two raster interpolation.

Both raster used for comparison were analyzed with same lineament extraction parameters (Table 2). There are six parameters are used as RADI (Radius of filter in pixels), GTHR (threshold for edge gradient), LTHR (threshold for curve length), FTHR (threshold for line fitting error), ATHR (threshold for angular difference), and DTHR (threshold for linking distance). After that, error correction is conducted by erasing the lineament as hills or ridge. This correction is based on the assumption that the lineaments are structural lineaments that identified as valley, river, or erosion line. Comparison between two extraction lineaments can be seen in Figure 6.

3.2 Analysis

That lineament extraction is analyzed by using statistical rose diagram. Rose diagram are made using digital processes with frequency interval of 10°. The analysis is based on the Kriging and IDW interpolation methods results (Figure 7).

The major lineament direction trends in NE-SW. A small difference can be seen between the two rose diagrams. The diagram resulted from Kriging method shows a random lineament and almost same in all directions, whereas IDW method shows a rather random lineament and less NW-SE trends.

4 Discussion and conclusion

Several important points emerge from this research. Because the primary objective is to compare different interpolation methods, we first consider the effect of interpolation method on accuracy [as measured by log (MSE)]. The most striking result along these lines was that the Kriging method consistently and substantially outperformed the two inverse distance weighting methods over all levels of the other factors. A second point pertaining to the comparison of interpolation methods is that although the Kriging methods were consistently superior to inverse squared distance weighting over all levels of the other factors, the extent of superiority was affected by the other factors. More specifically, the disparity in performance between the two types of methods tended to be greatest at those levels of the other factors at which all four methods performed best.

Although the primary objective of this investigation was to compare interpolation methods, the effects of the other factors on overall interpolation performance were also of some interest. The significance of the main effects and the relatively small magnitude of the interactions allow us to make several points and to note some aspects that require further investigation. First, our results indicate that overall interpolation performance deteriorated consistently and significantly as the sampling pattern varied from the most regular pattern, hexagonal, to the next most regular, inhibited, to a random pattern, and finally to the most irregular pattern, clustered.

Finally, consider the effect of surface type. We found that interpolation performance was best for the plane, next best for the sombrero, and worst for Morrison's surface. That the plane yielded the best performance is not surprising in light of this surface's extreme smoothness, but it is difficult to characterize the sombrero or Morrison's surface as smoother than the other and hence difficult to explain why performance was better for the former than for the latter. Additional investigation is required to understand how surface type affects interpolation performance at both the overall level [as measured, for example, by log (MSE)] and the micro level. In particular, more work is needed to explicitly identify and parameterize those surface characteristics (e.g., peaks, troughs, or portions of the surface with large gradients) that are responsible for the greatest discrepancies in performance. At finer scales, the grid evaluation

Table 2: Parameter of lineament extraction.

Parameter	Value for Kriging and IDW raster	Parameter	Value for Kriging and IDW raster
RADI	3	FTHR	3
GTHR	5	ATHR	5
LTHR	3	DTHR	3

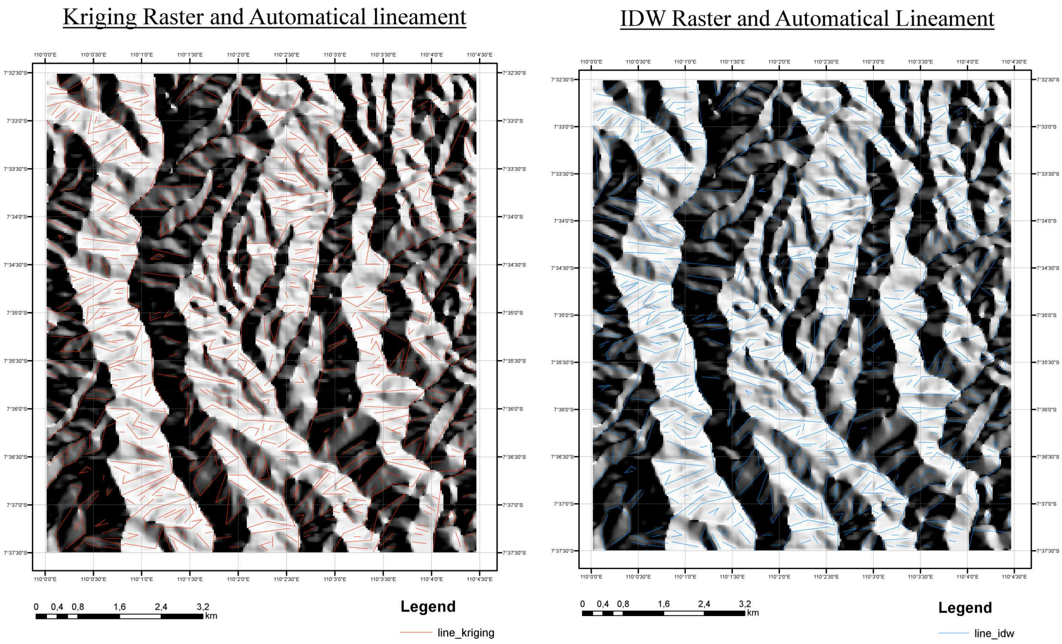

Figure 6: Comparison of lineament extraction in Kriging and IDW raster.

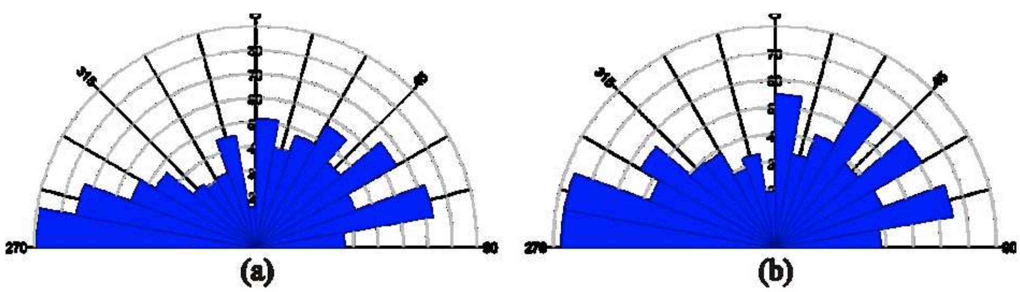

Figure 7: Rose diagram with bearing parameter (a) Kriging and (b) IDW.

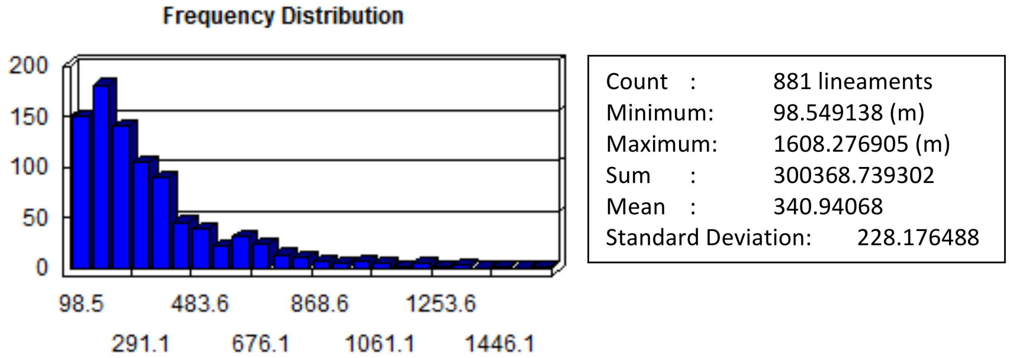

Figure 8: Frequency distribution of lineament resulted from kriging interpolation.

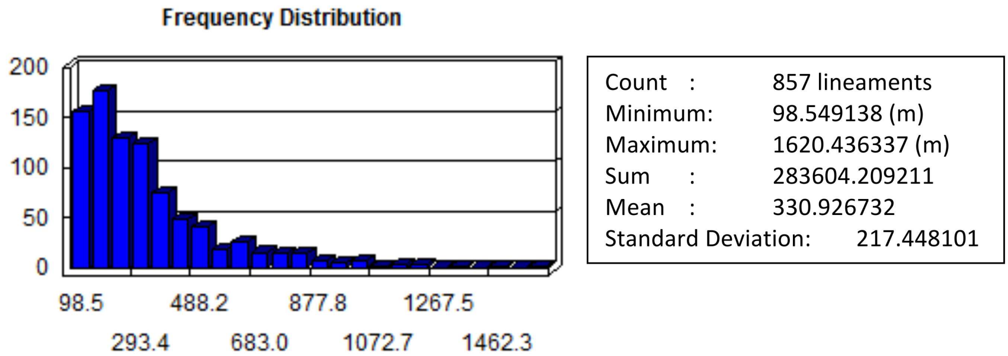

Figure 9: Frequency distribution of lineament resulted from IDW interpolation.

approach used in this paper could serve as the basis for visualizing and evaluating local performance characteristics

This study also evaluated the accuracy of two interpolation techniques for generating DEMs. Different landform types and density values of height measurement were considered. Irrespective of the surface area, landscape morphology and sampling density, few differences existed between the employed interpolation techniques if the sampling density was high. At lower sampling densities, in contrast, the performance of the techniques tended to vary. Kriging yielded better estimates if the spatial structure of altitude was strong. The spatial structure of height was weak as observed at the IDW.

These results may help GIS specialists to select the best method for the generation of DEMs. A technique should be chosen not only for its performance on a specific landform type and data density, but also for its applicability to a wide range of spatial scales. The result of the methodology used in IDW raster is lineament looks smoother and more firmly drawn than lineament from kriging raster extraction. Furthermore, lineaments analyzed by using Rose diagram show that the lineament in IDW raster is more accurate than Kriging because the presence of minor lineaments and the less display of maxima whic are useful as an interpretation of the force that form lineament. The analysis from Kriging raster shows that there are many major maxima in study area, hence making geological interpretation less accurate.

References

Bemmelen, R.W. Van (1949) The Geology of Indonesia; Vol. I.A., The Hague, Martinus Nyhoff.

Burrough, P.A., McDonnell, R.A. (1998) Creating continuous surfaces from point data. In: Burrough, P.A., Goodchild, M.F., McDonnell, R.A., Switzer, P., Worboys, M. (Eds.), Principles of Geographic Information Systems. Oxford University Press, Oxford, UK.

Chaplot, V., Walter, C., Curmi, P. (2000) Improving soil hydromorphy prediction according to DEM resolution and available pedological data. Geoderma 97, 405–422.

Lillesand, T.M., Kiefer, R.W. and Chipman, J.W. (2004) Remote Sensing and Image Interpretation, 5th edition, Singapore, John Wiley & Sons Inc.

Pulunggono, A. and Martodjojo, S. (1994) The Tectonic Changes During Paleogene-Neogene was the Most Important Tectonic Phenomenon in Java Island, Proceeding of the Seminar on Geology and Tectonics of Java Island, from the Late Mesozoic to Quaternary, pp. 1-14, Yogyakarta, Gajah Mada University.

Rahardjo, et al. (1995) Geological Map of the Yogyakarta Sheet, Jawa, Bandung, Pusat Penelitian dan Pengembangan Geologi.

Sabins JR., F.F. (1978) Remote Sensing Principles and Interpretation, Amerika Serikat, W.H. Freeman and Company.

Sudradjat, A., Syafri, I., dan Budiadi, E. (2010) The Geotectonic Configuration of Kulon Progo Area, Yogyakarta, Proceeding PIT IAGI 39th.

Wilson, J.P. and Gallant, J.C. (2000) Terrain Analysis. Principles and Applications. Wiley, New York. 479 pp.

