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ORDINARY KRIGING GEOSTATISTICAL MODEL FOR LAND VALUE ZONING: A SPATIAL STUDY IN RANTAU PULUNG, EAST KALIMANTAN

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ABSTRACT

Land is a crucial element whose use is closely tied to spatial planning and regional management. This study aims to estimate the distribution of land values in Rantau Pulung District, East Kutai Regency, using the Ordinary Kriging geostatistical method. The main problem raised is the limited information on land values in areas that lack sample points. Primary data were obtained from 343 sample points of land prices from field surveys, while secondary data in the form of administrative boundaries were used as spatial references. The analysis was carried out using ArcGIS software with a spherical variogram model, which was selected as the best approach based on cross-validation results. The mapping results show that the highest land values are around main road access and activity centers, while the lowest prices are spread across less accessible outlying areas. This finding confirms that accessibility and proximity to public service centers are dominant factors in influencing land values. This interpolation map can be used as a basis for spatial planning, zoning, and more efficient land management policies.

Keywords: Land value distribution, geographic information system, ordinary kriging.

1. BACKGROUND

Land is a resource whose use is closely tied to spatial planning and regional management. As development and settlement continue to expand, land use inevitably changes both in terms of how much undeveloped land remains and the quality of the land itself. Because these changes can affect land value at any time, monitoring land use is essential for keeping regional growth consistent with established spatial plans. Land value in a given area is generally shaped by two groups of factors: internal and external. Internal factors include the land's topography, its physical characteristics, and the condition of any structures built on it. External factors, meanwhile, cover the presence of activity centers nearby shopping areas, terminals, residential clusters, and other facilities that influence surrounding land values (Sihombing dkk., 2018).

According to Effendi (1994), land is defined in a legal sense as the surface of the earth, while land rights refer to entitlement over a specific, bounded portion of that surface, measured in length and width (Adhiani & Haryanto, 2016). The legal basis for regulating land in Indonesia is set out in the Basic Agrarian Law No. 5 of 1960, which governs applicable land law along with the associated rights and obligations. This law serves as the primary legal reference for the public and other interested parties (Agus et al., 2019). To assess land value fairly and transparently, the government applies what is known as the Land Value Zone (LVZ) system.

A Land Value Zone is an area where land values are relatively uniform, delineated either by natural boundaries or administrative markers based on land use (Amelia dkk., 2015). The value assigned to each zone is derived from a comparative analysis of market prices and associated costs (Santoso dkk., 2014). Officially, this value reflects market value as determined by the National Land Agency (*Badan Pertanahan Nasional,* BPN) through officially approved LVZ maps. In areas that do not yet have a published LVZ map, land valuation instead relies on the current year's Tax Object Sale Value (*Nilai Jual Objek Pajak*, NJOP), as listed in the Land and Building Tax notice (SPPT PBB). Determining NJOP is closely linked to property valuation more broadly, which considers both land and buildings (Mahyeda dkk., 2020). In practice, land value tends to carry more weight in this process, although building size and height are also taken into account (Haripurnomo, 2000; Adhiani & Haryanto, 2016; Fahirah dkk., 2010; Ramadhan & Sunaryo, 2014).

LVZ maps present geographic information in polygon form, with each polygon representing the actual land value observed at that location. This means LVZ data are not the product of prediction, estimation, or any mathematical formula, they come directly from records of land sale transactions that have actually taken place, so the values shown genuinely reflect the market prices buyers have paid sellers. Because of this, LVZ mapping plays a critical role: it provides land value information that is accurate, valid, and defensible, which is needed for a wide range of purposes, including determining NJOP, spatial planning, asset management, and decision-making by governments, businesses, and the public alike. Since LVZ maps are grounded in real transaction data, they also help improve transparency and fairness in land valuation and guard against unreasonable price speculation in the property market.

LVZ mapping is an important process aimed at identifying and delineating areas within a region that share relatively similar, or homogeneous, land values. This process goes beyond simply producing a map, it generates spatial information useful for a range of strategic and operational needs, such as building more structured and efficient spatial plans, setting fair land and building tax rates based on actual land values, establishing clear and legally sound land ownership boundaries, and supplying data to support decisions on property investment and infrastructure development. With a LVZ map in hand, stakeholders from government agencies and developers to the general public can gain a clearer picture of how land value is distributed across an area, reducing the risk of errors in land planning and resource management (Adhi dkk., 2015). That said, the accuracy and reliability of a LVZ map depend heavily on several factors, one of the most important being how much land value varies within a single zone.

An earlier study by Mayangsari dkk., (2015) used a Geographic Information System (GIS) to map land value based on market prices as a basis for determining NJOP. The results revealed a substantial gap between NJOP-based values and actual market prices. The study concluded that if market price data were used as the basis for valuation instead, potential regional tax revenue from land could increase by more than 500%. Even so, this earlier work had some notable limitations. Land valuation was carried out in bulk, without accounting for factors such as proximity to main roads, activity centers, or surrounding environmental conditions. Data limitations also meant that only some zones were sampled at a minimum of three points per zone which likely affected the accuracy of the resulting interpolation. In addition, the study did not apply geospatial interpolation techniques such as Kriging, which can produce more reliable land value predictions, particularly for locations lacking direct field data.

Kriging interpolation is a geostatistical method used to predict land value in unmeasured areas by drawing on spatial information from sample points where land values are already known. The method works by constructing a variogram model that captures the spatial relationship between sample points, so that predictions for other locations are based on their proximity to, and spatial relationship with, the measured points. In other words, the semi-variogram helps identify patterns in how a variable's values relate to one another across nearby locations, enabling further analysis for data estimation or interpolation within a region (Pririzki dkk., 2022). In the context of land valuation, Kriging makes it possible to estimate land prices in unsampled areas, producing a more detailed and accurate map of land value distribution. Prior findings show that Kriging can produce more detailed and accurate land value estimates, making it a strong support for fair and transparent LVZ mapping.

Building on this background, the present study aims to examine the distribution of land prices in Rantau Pulung District, East Kutai Regency. To this end, it employs the Ordinary Kriging method, a spatial analysis technique in geo-statistics capable of estimating land values at unmeasured locations based on the relationships among existing data points. This method is implemented within a Geographic Information System (GIS), allowing the results to be visualized in map form. Through this approach, the study is expected to yield land value information that is more detailed, objective, and reflective of actual field conditions.

2. METHOD

This study was conducted in Rantau Pulung District, one of the districts within East Kutai Regency, East Kalimantan Province, Indonesia, over a three-week period in March 2025. Geographically, Rantau Pulung District lies at 0° 37′ 21.52″ North Latitude and 117° 17′ 16.25″ East Longitude, placing it in the central part of East Kalimantan. Administratively, the district borders several neighboring districts:

Batu Ampar District to the west, Sangatta Utara District to the east, Bengalon District to the north, and Sangatta Utara District again to the south. The district covers an area of approximately 16,915.04 hectares and is divided into nine villages: Rantau Makmur, Mukti Jaya, Tanjung Labu, Kebon Agung, Manunggal Jaya, Tepian Makmur, Pulung Sari, and Margo Mulyo, and Masalap Raya. The administrative map of Rantau Pulung District is shown in Figure 1.

This study relied on two types of data: primary and secondary. Primary data were obtained directly through field surveys, specifically a Land Value Zone (LVZ) survey, which involved collecting valid and representative land sale transaction data across the study area. Through this process, 343 land price samples were gathered, covering both selling and purchase prices obtained from sellers, buyers, and local residents. These transaction records served as the main basis for determining land value within each designated zone. Secondary data, meanwhile, consisted of administrative boundary data for Rantau Pulung District, obtained from the Geospatial Information Agency (*Badan Informasi Geospasial*, BIG). This dataset was used purely for mapping and spatial analysis purposes, without requiring direct field measurement.

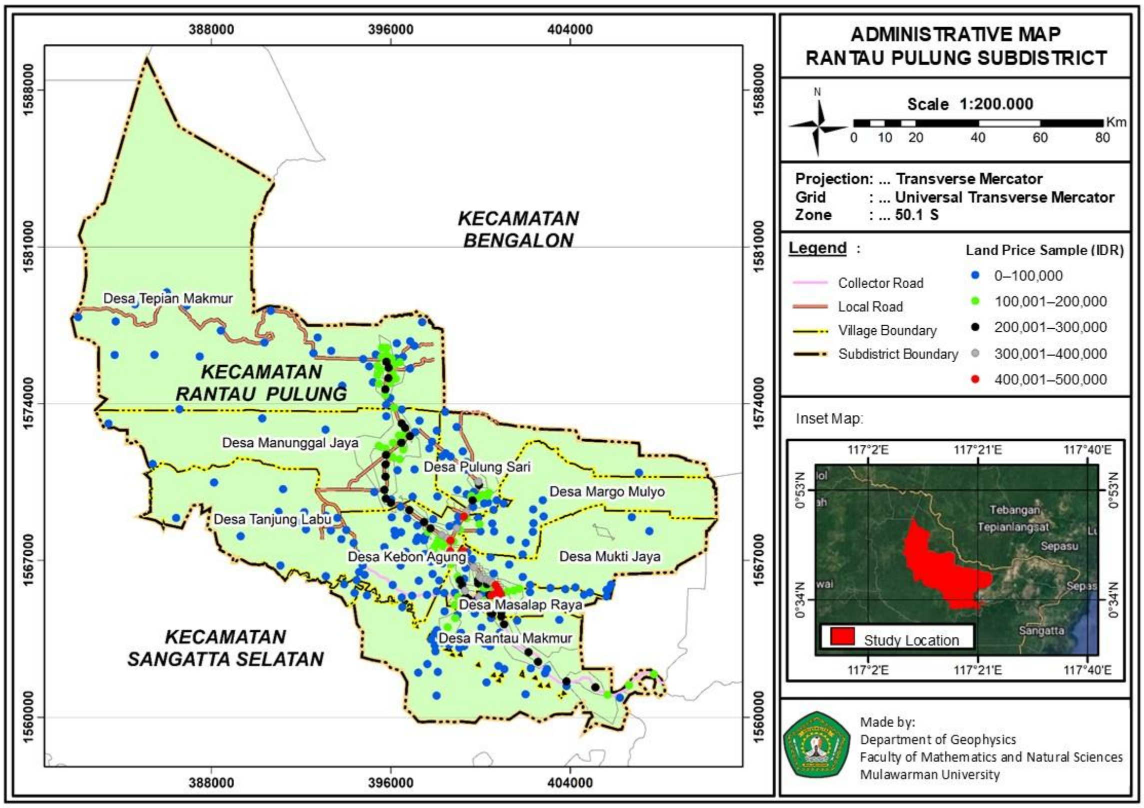

Figure 1. Administrative Map of Rantau Pulung District

Heading Data processing in this study was carried out using Geographic Information System (GIS) software, specifically ArcGIS, which offers comprehensive support for spatial analysis and enables the visualization of data as informative, easy-to-read thematic maps. Before interpolation, the land price data first underwent outlier screening and a stationarity test, steps taken to ensure that the basic assumptions required by the Kriging method were properly satisfied, so that the resulting interpolation would be both valid and accurate. In addition, the geographic coordinates of each sample point used in the analysis were converted into the Universal Transverse Mercator (UTM) Zone 50S projection system. This conversion helped maintain spatial consistency and prevent distortion in geographic position during analysis, allowing all data points to be analyzed within a uniform coordinate framework consistent with standard mapping practice.

The method used to predict land prices in this study was Ordinary Kriging, a geostatistical interpolation technique widely recognized for its reliability in estimating the value of a variable at unsampled locations based on values observed at surrounding points. Ordinary Kriging performs optimally when the underlying data are stationary that is, when the data show no clear directional trend across space, so that value fluctuations remain centered around a constant mean regardless of time or location, with the variance of those fluctuations also remaining constant (Alfiana, 2010). In other words, data are considered stationary when their mean value does not change significantly from one location to another and no dominant trend pattern is present, allowing the basic assumptions of Ordinary Kriging to be adequately met. The equation for the Ordinary Kriging method is presented below (Amalia dkk., 2022):

$$\widehat{Z}\,(x_0) = \sum_{i=1}^{n} \lambda_i Z\,(x_i) \qquad (1)$$

with:

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

$Z(x_0)$: Predicted (estimated) value at the unsampled location
$Z(x_i)$: Observed value at sample point i
λ_i : Kriging weight assigned to sample point i

In the analysis, the semivariogram model used to describe the spatial structure and the relationship between neighboring data points was the spherical model, chosen for its ability to represent the pattern of spatial variation commonly found in land price data.

Land prices can be classified according to their selling value per square meter. This classification is intended to simplify the analysis and mapping of land prices within the study area, allowing each zone to be identified by its corresponding price class. The classification of land prices in Rantau Pulung District is presented below.

Table 1. Classification of Land Prices

Zone	Land Price Range (Rp)
1	0-100,000
2	100,001-200,000
3	200,001-300,000
4	300,001-400,000
5	400,001-500,000

Table 1 divides land prices into five classes, each with its own price range. Class 1 represents the lowest price category, ranging from IDR 0 to IDR 100,000 per square meter, while Class 5 represents the highest, ranging from IDR 400,000 to IDR 500,000 per square meter. This classification makes the land price analysis more systematic and structured, thereby facilitating decision-making related to land management and utilization.

3. RESULT AND DISCUSSION

Based on the plot of land price against observation points (No. Mark), land values show very high, unstable fluctuation across the study area. Prices vary drastically, ranging from very low figures to more than IDR 400,000 per square meter, in a pattern that shows no clear regularity. This reflects substantial shifts in land value from one location to another, with no consistent or repeating trend. Such behavior indicates that the land price data are non-stationary, since they do not fluctuate steadily around a mean value and instead show strong local trends and high spatial variation.

A cross-validation test was performed on the three semi-variogram models used in the land price interpolation, yielding Root Mean Square Error (RMSE) values as an indicator of each model's predictive accuracy.

Table 2. Cross-Validation Results

Model Semivariogram	RMSE
Spherical	87,783.61
Gaussian	93,965.04
Eksponensial	92,929.82

The spherical semi-variogram model performed best, with the lowest RMSE of 87.783,61, indicating that it produced land value predictions closest to the actual values. The exponential model followed with an RMSE of 92.929,82, while the Gaussian model performed worst, with an RMSE of 93.965,04. Since a lower RMSE reflects greater predictive accuracy, the spherical model was selected as the best-performing model in this analysis, as it more efficiently captured the distribution of land prices across the study area. The resulting interpolation is visualized in the land value zone distribution map of Rantau Pulung District, shown below.

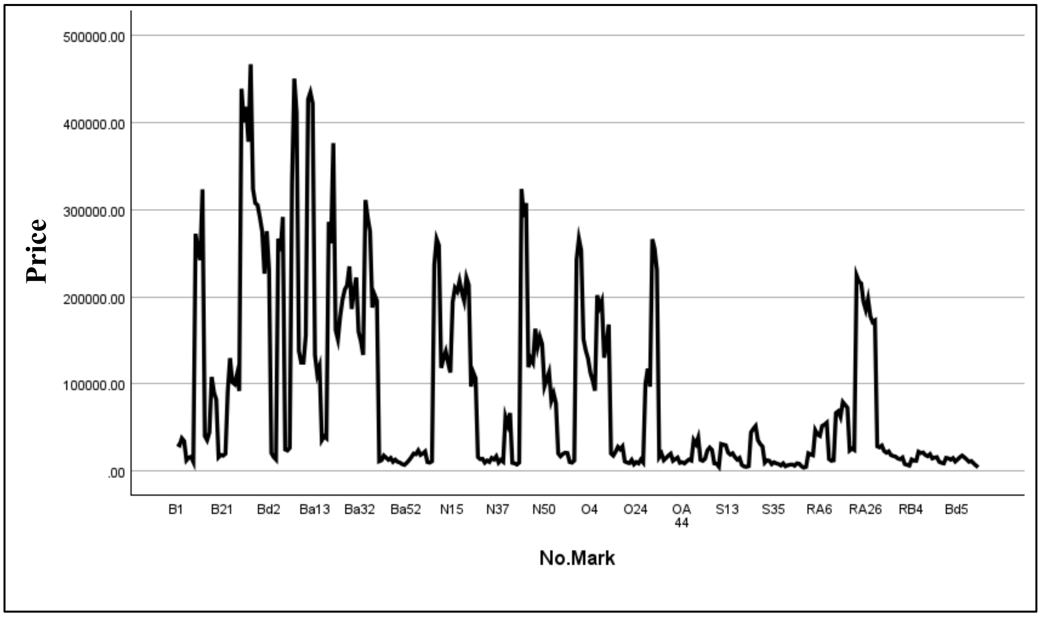

Figure 2. Stationarity Test Results for Land Price Data in Rantau Pulung District

Following the interpolation process, the percentage area occupied by each land price zone was calculated to show how the district's land area is distributed across the different price categories, as presented in the table below:

Table 3. Classification of Land Prices in Rantau Pulung District

Zone	Area (km^2)	Percentage (%)
Zone 1	325,15	91.7
Zone 2	21,48	6.1
Zone 3	6,84	1.9
Zone 4	1,07	0.3
Zone 5	0,9	0.05

The land area distribution is heavily dominated by Zone 1, which covers 325.15 km² (91.66% of the total study area), followed by Zone 2 at 21.48 km² (6.05%), Zone 3 at 6.84 km² (1.93%), Zone 4 at 1.07 km² (0.30%), and Zone 5 at 0.19 km² (0.05%). The total study area is 354.73 km². These figures show that Zone 1 alone accounts for the large majority of the land, while Zones 2–5 together make up less than 10% of the total area.

Based on the interpolation results, the area with the highest land prices ranging from IDR 400,001 to IDR 500,000 is shown in bright red. This zone is concentrated along collector roads and portions of local roads, marked on the map with magenta and purple lines. The presence of this road network raises the area's accessibility, which in turn drives land values upward. The dense cluster of data points along these roads further confirms that economic activity and population mobility are more concentrated in these areas. Zones with mid-range prices, between IDR 200,001 and IDR 400,000, appear in gradients of orange to yellow. These areas surround the high-price zones and are generally located near local roads or slightly farther from main roads, suggesting a gradual transition in land value from the main activity centers toward areas with lower economic activity. Low-price zones, ranging from IDR 0 to IDR 200,000, are shown in green to yellowish-green and dominate areas farther from main road access, typically in peripheral or less-developed parts of the district.

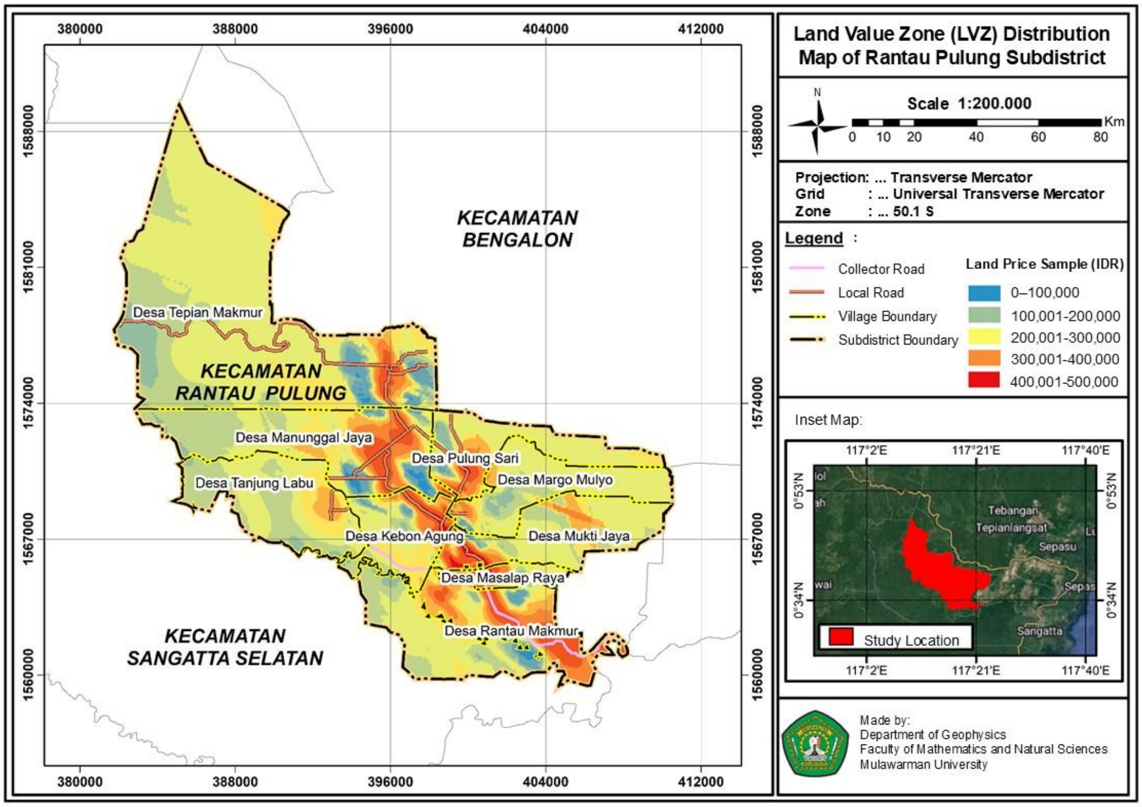

Figure 3. Land Value Zone Distribution Map of Rantau Pulung District

The sharp transitions visible between price classes on the map also suggest that urbanization and regional development in Rantau Pulung District remain uneven. Several areas show sharp shifts in land price over relatively short geographic distances, pointing to marked differences in facility development, accessibility, and market demand. For instance, in the central to southern part of the district, particularly around the collector road leading toward the district center, a concentration of high-price land (IDR 400,001–500,000) sits directly adjacent to a mid-price zone (IDR 200,001–300,000). This pattern can help identify priority areas for development, whether for expanding residential areas, developing commercial zones, or protecting agricultural land.

The distribution of land prices also points to a close relationship between land value and spatial factors such as proximity to roads and activity centers. Areas farther from major infrastructure and population centers tend to have lower land values, while areas that are strategically positioned in terms of transportation and public facilities show higher values. This relationship is consistent with the principle of spatial economics, which holds that accessibility is one of the primary determinants of land value.

These findings carry several practical implications for local land administration and spatial planning. First, the resulting land value zone map can serve as a supplementary reference for the National Land Agency (BPN) in areas that have not yet been covered by an official LVZ map, allowing local governments to estimate NJOP more equitably in data-scarce zones rather than relying on uniform, bulk-based assessments. Second, the clear price gradient observed around collector and local roads suggests that infrastructure investment, particularly road expansion and improvement in the district's peripheral areas, could be prioritized as a strategy to gradually raise land values and stimulate economic activity in less-developed zones. Third, given the sharp price transitions identified between high-value zones near activity centers and adjacent lower-value zones, local planning authorities should consider incorporating these boundaries into the Detailed Spatial Plan (RDTR) to guide the designation of commercial and residential zones and to safeguard remaining agricultural land in low-price peripheral areas from premature or speculative development. Finally, because Ordinary Kriging can generate reasonably reliable value estimates even where field samples are limited, it offers local governments a cost-effective tool for periodically updating land value assessments to support fairer property tax collection and more transparent land-based revenue planning.

Compared with other interpolation methods such as Inverse Distance Weighting (IDW) and Spline, Ordinary Kriging offers a key advantage: it accounts for the spatial relationship between data points through variogram analysis. This approach produces more accurate and representative predictions, particularly in areas with unevenly distributed data. IDW, by contrast, bases its estimates solely on distance between points giving closer points greater weight without accounting for the statistical structure of data variability. Spline interpolation, meanwhile, often produces an overly smooth surface that can generate unrealistic values between sample points. Ordinary Kriging addresses these limitations by modeling semivariance to preserve accuracy and realism in the spatial distribution, making its interpolation results more reliable in a geospatial context.

CONLUSSION

Based on the analysis using the Ordinary Kriging method with a spherical variogram model, it can be concluded that the distribution of land prices in Rantau Pulung District is significantly shaped by spatial factors, particularly proximity to major road networks and centers of economic activity. The interpolation map reveals fairly sharp variation in land price between different parts of the district: the highest-price zones are concentrated along collector and local roads, mid-range zones surround these areas, and low-price zones dominate the peripheral parts of the district that lie farther from infrastructure access. These findings confirm that accessibility and the presence of public facilities are the primary factors shaping land value. From a scientific standpoint, this demonstrates that geostatistical models such as Ordinary Kriging are effective for mapping the spatial distribution of land value. The results of this study can be applied to spatial planning and land management.

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