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GIS-based spatial autocorrelation analysis and use of aerial photos metrics for land price per plot: a case study of Tembalang sub-district

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Abstract. Tembalang sub-district is included in the suburban area of Semarang which is growing very rapidly in the housing market growth sector. Research on housing policies and existing land market value mechanisms was carried out by empirical analysis using traditional econometric models with multiple regression analysis and GIS-based spatial autocorrelation models. This research was conducted by modeling land prices based on land parcels from the interpolation of land price samples from the field survey results as well as analyzing the level of data closeness to the Tax Object Selling Value (NJOP). Land parcel data was created using the 2018 metric aerial photograph (10 cm spatial resolution). The dependent variable in the regression analysis model used data on the average value of land prices for each zone in 2018. The variables used in the first modeling, namely the geographic location, transportation accessibility, trade center and service intensity were used as independent variables. The apply Radial Basis Function (RBF), spatial autocorrelation model, in integration and comparative analysis of models with a focus on the analysis of factors affecting land prices, especially heterogeneity of spatial characters.

1. Introduction

The land is very important in human life, it is also a significant factor in the production and fundamentals of local economic development [1]. The Tembalang area is directed as the location for an educational area, especially for universities. This becomes an attraction for residents to occupy this area and results in increased space requirements. The increasing need for land for settlement, trade as well services causing land prices in Tembalang sub-district to continue to increase. In recent years, changes in land prices and land uses in Diponegoro University area & Semarang State Polytechnic in Tembalang sub-district area have shown an interesting occurence. The land previously used in the form of agriculture, open space, and vacant land, has been transformed into housing and service trade, which is considered to have greater strategic and competitive commercial value. According to [2], [3], factors that influence land value include social factors, economic factors, government policies and political factors, environmental and physical factors. This land use change provides an opportunity to increase land prices in the Tembalang sub-district area. The success of the housing project cannot be separate from the planning of laying out public and social facilities that do lead to a commercial area [4], where housing deliberately builds shopping malls, guest houses, restaurants, modern markets and apartments along the Prof. Soedarto road, K.H. Sirojudin road and Banjarsari Selatan road in the center of the sub-district. There is access to secondary arterial roads that connect transportation within the city, thus encouraging

this sub-district economy. The rapid development of Tembalang sub-district with an increasingly limited amount of land has resulted to an increase in land prices in the area. The increased land prices is certainly influenced by the facilities that have been built. However, there is no certainty about the existing facilities in Tembalang sub-district that will affect land prices in the area. This can be solved with multiple linear regression equations [5] where the variable used is the calculation of the distance between the facilities and the land area. Based on this, the authors tried to examine the relationship between facilities and land prices in Tembalang sub-district, resulting in land price predictions. As a comparison in predicting the price of land per plot of land in Tembalang village, the Radial Basis Function (RBF) method [6], [7] is used by looking at the relationship between the distance of land parcels to roads, public facilities and social facilities. This method was introduced by Hardly in 1971 and is well known for the accuracy of estimates for the smooth fitting case of scattering data in any dimension visually or analytically [8], [9]. This research is expected to help the community and government determine the appropriate land price or tax in Tembalang sub-district.

2. Methods and Material
2.1. Area Study

This study is located in the Tembalang sub-district, Semarang City, Central Java, Indonesia. Tembalang is a sub-district at the southern edge of Semarang, with an average elevation of 320 meters. It is a hilly topography. The study of this research is shown in Figure 1.
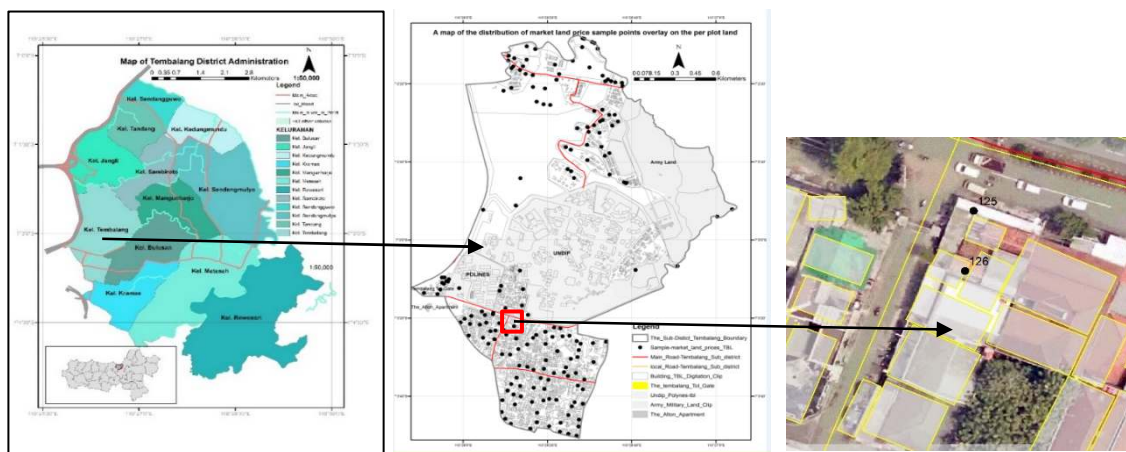

Figure 1. (a) Tembalang District's Map Administration, (b) Distribution of land market price survey sample points's map, and Example of the location of the sample point number 126 on the digitized plot of the 1: 5,000 scale aerial photograph in 2018.

2.2. Research Data

In this study includes data in a form of non-spatial and spatial data, including:
1. NJOP (Tax Object Sales Value) data obtained from the Semarang City Revenue Service.
2. The 2018 Tembalang sub-district block map obtained from the Regional Revenue Service of the city of Semarang.
3. The road network map of Tembalang sub-district obtained from the Semarang Regional Planning and Development Agency.
4. Administrative map for 2018 Tembalang sub-district obtained from the Semarang Regional Planning and Development Agency.
5. Social facilities survey data using a Mobile Topographer.
6. Aerial photo of 1: 5000 scale medium format has a spatial resolution of 10 cm from the National Land Agency used to digitize and verify land parcel maps.

7. The land price survey using a market approach was obtained through related party interviews based on land zones totaling 175 samples [15].
8. The parameters used in this study include Alton Apartment (X1), Tembalang Tol Gate (X2), Bank BRI Tembalang (X3), Bank BNI Tembalang (X4), Tembalang Post Office (X5), Pratama Mitra Clinic (X6), Bulusan Auxiliary Health Center (X7), Tembalang Sub-District Police Office (X8), Tembalang Sub-District Office (X9), Tembalang Village Office (X10), Diponegoro National Hospital (X11), Diponegoro University & Semarang State Polytechnic (X12), Indomaret Sirojudin (X13), Indoprinting Tembalang (X14), Indomaret Tembalang (X15) and Prof. Soedarto Road (X16).

2.3. Multiple Linear Regression Analysis

Multiple linear regression will discuss three things, namely multiple linear regression modeling, model testing, and model quality testing.

1. Linear Regression Modeling
   Regression analysis was performed to determine the influence of the independent variables on the dependent variable. If there is one independent variable and one dependent variable in the regression, it's namely simple linear regression. However, if there are multiple or more than one independent variables in the regression, it's namely multiple linear regression [10].

2. Radial Basis Function (RBF)
   The radial basis function method of multivariate estimation is an approach that is often used in modern forecasting theory when the task is to estimate data that is spread over several dimensions. The RBF approximation method has an approximate function s which is always a finite linear combination of the symmetrical basis function having a diagonal ($\|\cdot\|$), where ($\|\cdot\|$) is the Euclidean norm. Radial symmetry means that the function's value depends only on the Euclidean distance from the argument point and the center point, and rotation does not make a difference to the value of the function [11], [12].

3. Model Testing
   Model testing is conducted to determine how much influence the independent variable has on the dependent variable.

4. Model Quality Testing
   a. A model can be seen from the CoV (Coefficient of Variation) value. If the CoV value is between 7% and 10%, the model chosen is suitable. The CoV value representing a very good model is less than 5%, but in some principle cases this assessment is rarely found [16].
   b. Testing whether the model's estimation results are uniform or not, we can see the PRD (Price Related Differential). PRD requirement is $0.98 \leq PRD \geq 1.03$. If PRD < 0.98, it can be said that the predicted price has progression, which means that the value is above the actual value. If PRD > 1.03, then regressivity occurs, the estimated value of the model is below the actual value [17].

2.4. Research Implementation

The research was carried out to obtain a prediction of land prices per plot in Tembalang sub-district with the following stages of work:

1. Preparation of Textual Data and Determination of Samples
   Textual or attribute data consists of NJOP data obtained from BAPENDA and fair market prices acquired from surveys. Method of sampling used was stratified random sampling where we had to make a class stratum first.

2. Distance Calculation

The distance calculation is done by measuring the distance between the center point of the plot and the centroid's analyzed factors. So we need to know the centroid of the field and the factor first, then the distance will be calculated using the Generate near Table function in ArcTools in ArcGIS.

3. Model Calculation, Statistical Test and Classical Assumption Test

   Statistical tests and classical assumption tests are needed to find out how useful the data we have. The test is processed using the SPSS program.

4. Model Testing

   Model testing uses the COV test whether the model is good or not. In contrast, testing whether land prices are appropriate or experiencing progressivity and even regressiveness, can be calculated with PRD. Model calculations using Microsoft Excel and Minitab software.

5. The influence of road accessibility factors, public facilities and social facilities on the price of land parcels will be analyzed starting from the fair market price data, NJOP land prices, the Land Value Zone (ZNT) price to find out how much influence these factors use radial basis function (RBF).

3. Results and Discussion

3.1. Result

The following is the coefficient for each model. The resulting coefficient has a positive or negative value, which means it shows the correlation of these variables.

Table 1. Coefficient parameters of NJOP model and sample model.

Parameters	NJOP RBF Coefficient (Rp)	NJOP Regression Coefficient (Rp)	Sample RBF Coefficient (Rp)	Sample Regression Coefficient (Rp)
X1	-4,810,804,603	2,379,812	-6,375,376,698	-7,950,483
X2	6,337,117,533	-3,041,000	-2,973,361	9,848,824
X3	1,013,763,394	1,011,989	1,839,216,850	-127,658
X4	-2,576,084,753	2,307,236	5,964,961,267	182,455
X5	-4,877,262,486	806,520	5,529,084,751	2,603,954
X6	-7,747,267,881	1,183,004	5,813,523,890	6,858,961
X7	3,133,456,485	2,671,655	-4,043,136,551	-5,155,538
X8	162,224,982,410	-3,520,887	-74,253,696,767	902,391
X9	-164,609,566,927		73,752,787,394	
X10	6,079,617,238	-2,088,300	-2,793,193,049	-3,485,283
X11	5,044,930,021	-3,121,210	3,825,830,532	2,474,033
X12	59,052,873	1,861,730	-3,533,486,301	-695,525
X13	1,561,623,884	-955,880	1,678,009,181	166,294
X14	-70,406,505	-1,209,397	-3,214,551,595	-507,496
X15	-4,902,405,848	3,919,762	-1,241,467,787	496,870
X16	2,833,829,375	-3,900,722	1,200,190,409	-2,185,853

Statistical tests were carried out on all models to find out how accurate the model. The statistical test results are shown in Table 2.

Table 2. Quality of NJOP model and sample model.

	NJOP RBF Model	NJOP Regression Model	Sample RBF Model	Sample Regression Model
SEE	Rp 2,278,105,222	Rp 2,291,795,051	Rp 4,177,106,343	Rp 3,427,272,813
CoV	0.073	0.073	3.580	1.095
PRD	3.258	3.400	4.341	4.871
Data used	2629	2629	179	179

3.2. Discussion

In Table 1, it can be seen that the coefficients Tembalang Sub-District Police Office (X8) and Tembalang Sub-District Office (X9) have the highest value compared to others in the RBF model for NJOP and Sample. This shows Tembalang Sub-District Police Office and Tembalang Sub-District Office are the most influential parameters for the two models. A positive or negative sign explains the directional relationship between the independent variables and dependent variables [13][14]. In the NJOP RBF model, X8 has a positive sign, which means that the land price will increase if it approaches Tembalang Sub-District Police Office. Whereas in the Sample RBF model, X8 has a negative sign, which means that land prices tend to fall if moves away from Tembalang Sub-District Police Office. Tembalang Sub-District Police Office and Tembalang Sub-District Office influence land prices because they are public services.

The most influential factors in the NJOP regression model are Indomaret Tembalang (X15) and Prof. Soedarto Road (X16). Whereas in the Sample regression model, the most influential factors are Alton Apartment (X1) and Tembalang Tol Gate (X2). In actuality, Prof. Soedarto Road has a higher land value due to central accessibility. Moreover, there are supporting infrastructures such as trade, Alton Apartment and Tembalang Tol Gate. The difference in the most influential factors between the regression models can be caused by differences in the RBF and regression methods in determining the coefficient. In the RBF method, basis function data is used as input for processing, while in regression, distance data is used as input for processing.

Based on Table 2, the model with a fairly good accuracy is NJOP RBF and NJOP Regression because both models have a CoV value below 10% [16]. Sample RBF and Sample Regression have a bad CoV value. This can be due to one of which is the amount of data used in the processing. Also, each model's PRD value has a value greater than 1.03, which means that the predicted land prices obtained are generally below the actual land price [17].

4. Conclusion

According to the research results, the following conclusions can be drawn:

1. According to the coefficient, Tembalang Sub-District Office and Tembalang Sub-District Police Office affect NJOP price in RBF Model while in Regression Model, Indomaret Tembalang UNDIP and Prof. Soedarto Road affect NJOP price. Based on the coefficient, Tembalang Sub-District Office and Tembalang Sub-District Police Office affect Sample price in RBF Model while in Regression Model, Tembalang Tol Gate and Alton Apartment affect Sample price.

2. Based on the table, NJOP models have a good quality because CoV value less than 10%. Then, both models are regressiveness which means that the predicted value lower than the actual value. Based on the table, Sample models have bad quality because CoV value more than 10%. Then, both models are regressiveness which means that the predicted value lower than the actual value.

Acknowledgement

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