



Statistical models for generation of generic values plants in urban areas

Modelos estatísticos para geração de plantas de valores genéricos em áreas urbanas

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Abstract: The calculation of the Tax on Land and Urban Property (IPTU) is based on property market value, usually established in the city plant of general values (PVG). However, there are municipalities, especially small ones that do not collect IPTU taxes. This is due to outdated real state register, in addition to the lack of qualified personnel, financial resources and robust and easy methodology to determine real state market value. Therefore, this work aims to combine the spatial regression model and location factor modeling to determine the market value of each property in a small city for the generation of the table of general values (PVG). The study was conducted in the city of São Gotardo/MG. One hundred and eighty-four samples of residential real state assessments made by Caixa Econômica Federal in 2012 and 2013 were used. Aiming to analyze the application of spatial models, four multiple regression models were generated based on the logarithm dependent variables on the total and unit values, and the independent variables related to the construction characteristics of the constructions, according to previous studies. Additional variables related to the land characteristics were also tested. For the models with spatial error dependence, a spatial error model was generated to determine a new homogenized variable encompassing the location factor (VH), which was used as an independent variable on a new linear regression model. The best regression model was selected based on the compliance of assumptions of the linear regression model and the analysis of the lowest Dispersion Coefficient. The model with the logarithm dependent variable on the unit values and the homogenized variable as independent, showed the best results and observed all the assumptions. Thus, it was demonstrated that the homogenized variable improves the performance of the linear regression model, since it includes the property location factor in the independent variables.

Keywords: Property market value; Small towns; Spatial model; IPTU; Table of general values.

Resumo: O cálculo do Imposto sobre a Propriedade Predial e Territorial Urbana (IPTU) tem como base o valor venal do imóvel, geralmente estabelecido na planta de valores genéricos (PVG) dos municípios. No entanto, existem municípios, principalmente os de pequeno porte, que não realizam a cobrança do IPTU. Esse fato se deve à desatualização do cadastro imobiliário e à falta de metodologia robusta e fácil para determinação do valor venal, de pessoal capacitado e de recursos financeiros. Nesse sentido, o objetivo deste trabalho foi aplicar a combinação do modelo de regressão espacial e a modelagem dos fatores de localização para determinar o valor venal de cada imóvel de um município de pequeno porte para a geração da planta de valores genéricos. O estudo foi desenvolvido na cidade de São Gotardo/MG. Foram utilizadas 184 amostras de avaliações de imóveis residenciais realizadas pela Caixa Econômica Federal no período de 2012 a 2013. A fim de analisar a aplicação dos modelos espaciais, foram gerados quatro modelos de regressão múltipla a partir das variáveis dependentes logaritmo do valor total e logaritmo do valor unitário e das variáveis independentes relativas às características construtivas das edificações, conforme estudos anteriores, bem como foram testadas variáveis adicionais referentes às características do terreno. Para os modelos que apresentaram dependência espacial no erro, foi gerado o modelo espacial do erro para determinar uma nova variável homogeneizada que englobasse o fator localização, (VH), a qual foi utilizada como variável independente de um novo modelo de regressão linear. A escolha do melhor modelo de regressão se deu a partir da análise do menor Coeficiente de Dispersão, bem como pelo atendimento aos pressupostos do modelo de regressão linear. O modelo com a variável dependente logaritmo do valor unitário e a variável homogeneizada como

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independente foi o que apresentou melhor resultado, atendendo a todos pressupostos. Dessa forma, foi possível verificar que a variável homogeneizada melhora a performance do modelo de regressão linear; visto que insere o fator localização dos imóveis nas variáveis independentes.

Palavras-chave: Valor venal do imóvel; Município de pequeno porte; Modelo espacial; IPTU; Planta de valores genéricos.

1 Introduction

The growing social demands from the urban development, and the lack of tax resources have demanded from public administrations a big effort to keep financial balance between expenditure and revenues of Brazilian municipalities (Freire et al., 2006).

The tax revenues of the municipalities are taxes, duty and contribution for improvement, whose competency is constitutionally attributed to the local sphere of government. The integral collection for municipalities which institute them are: Services Tax (ISS), Tax on the Emission of Immobile Goods (ITBI), and The Urban Building and Land Tax (IPTU) (Brasil, 2013).

Each municipality organizes its own collection system with a tax code itself, but respecting the rules presented in the Constitution and in the National Tax Code (CTN). The ISS incurs on provision of services to third parties; the ITBI, on transactions involving transfer on the ownership to real state; and the IPTU, on the property owners located in urban area of the city (Brasil, 2013).

The Federal Constitution of 1988 determines IPTU has to be of municipal competence. The calculation of this tax is based on the nominal value of the property, which has to correspond to the sales cash value, being determined by sum of value of the land and construction (Afonso et al., 2010). According to Florencio (2010), the criteria for determining the nominal value of each property of the municipality are established by Plants of Generic Values (PVG).

From 2000, the municipalities had to start an adaptation process which refers to the way of charging IPTU. For several years, this tax was neglected by some public administrators. However, from the Law Fiscal Responsibility, mayors felt it was their obligation to update urban real state registers as well as charge IPTU correctly, under penalty of foregoing income, according to Supplementary Law number 101, of 05/04/2000 (Brasil, 2000).

Mainly small municipalities – population under 50.000 inhabitants (IBGE, 2014a), faced difficulties to charge IPTU due to out-of-date real state cadastre, and lack of solid methodology and easy use of determining the nominal value of urban properties, as well as qualified people and financial resource.

As the calculation basis of IPTU is the nominal value of the properties, the municipal administration

must always determine it as the most realistic possible way, making this value the closest to the market. However, due to the complexity for determining it, as well as high number of properties to be assessed, it becomes a very hard task (Carvalho, 2011).

According to Afonso et al. (2010), most of Brazilian real state valuations are based on old parameters, and do not take into consideration dynamics impacts that cause impact on valorizing the properties, threatening the collection of IPTU. Besides this, it is the fact of the valuations be highly conditioned to issues of political nature. According to Carvalho (2006, p. 23), “[...] many municipalities use the same land to determine area of the city or even for urban perimeter, generating significant distortions in the level of the valuations”.

For Florencio (2010), most part of the plants of generic value in the Brazilian municipalities are outdated or updated based on inflation indices, which is correct, because the city has no appreciation or devaluation the same way everywhere. This author reports some aspects that explain the distortions in the calculation of Plants of Generic Values (PVG):

- The difficulty of quantifying and qualifying the several attributes (physical, locational and economical characteristics) that define the value of the property.
- The use of Linear Regression models, which need to take into consideration some basic presumptions as true, which are not always work for the property market.

Another factor to be highlighted is that in many cases, the estimates of property values have as level of accuracy the verification of prompt type, which is an assessment done subjectively, not using any mathematical-statistical procedure (Braulio, 2005); many of these estimates are realized from personal experience or opinion.

According to information from IBGE (2014b), in 2012, the collection of IPTU in Brazil was around R\$ 107.40 per inhabitant. The highest collections of IPTU per inhabitant were of R\$ 251.60, R\$ 154.90 and R\$ 126.60, in the states of São Paulo, Rio de Janeiro and Mato Grosso do Sul, respectively. On the other hand, the lowest value was in the state of Maranhão, with only R\$ 9.80 per inhabitant. Therefore, it is clear the discrepancy of collection in the Brazilian states.

An alternative for better determining PVG is the use of a mass evaluation, once in the calculation of a property value, the constructive values might be taken into consideration, being the valuation of property as a result of its location, accessibility, infra-structure (garbage collection, sewage, pavementation, public lighting, etc.), proximity of hospitals, parks, shopping centers among others (Medvedchikoff, 2009). Silva & Verdinelli (2000) define mass evaluation consists of “determining values for all properties located in a certain perimeter, by using assessment procedures that should be legally supported”.

Methodologically, what highlights to determine the commercial value of the properties to generate PVG is a mass assessment through the use of techniques that apply spatial econometrics. Trivelloni (2005), using spatial econometrics with analysis and modeling of the factors for location of the properties, obtained the value of average m² of each square aspect of the study area, generating PVG.

There is no consense in the literature in relation to the best methodology for determining the commercial value of the property in a mass assessment, mainly for small counties, once works related to small counties were not found in the literature.

These small municipalities are the ones that need information and techniques the most, which get adjusted to the reality in relation to the assessment of properties, since it is sometimes on them IPTU is not even charged, missing out resources that could be used for the society in a better way of provision of services.

Thus, this study aimed to apply the combination of spatial regression model and modeling of the location factors to determine the commercial value of each property in an urban town for generating of the plant of generic values.

2 Areas, materials and methods

2.1 Study area

The study was carried out in the city of São Gotardo/MG, which is located in the mesoregion of the Triangle Mineiro/Alto Paranaíba. The municipality has an area of approximately 866.087 km², demographic density of 36.74 hab./km², and has as surrounding municipalities Matutina, Campos Altos, Quartel Geral, Rio Paranaíba, Tiros, Santa Rosa da Serra, Serra da Saudade and Estrela do Indaiá. The urban area of São Gotardo has approximately 5.35 km², and perimeter of 16.208 m. In Figure 1, the location map of the municipality of São Gotardo is shown.

The growth of the population in the last decades was significant, once the population in 1991 was of 19.697 inhabitants, going up to 31.807 inhabitants in 2010. In relation to the urban population, there

were 16.520 inhabitants in 1991, and in 2010 there were 30.050 inhabitants (IBGE, 2014a).

The main activity of the county is the agricultural production, which was leveraged from 1970 with the implementation of Directed Settlement Program of Alto Paranaíba (PADAP). In relation to technology, the crops (wheat, carrots, potato and garlic) of São Gotardo are among the most developed ones in the country.

The collection of IPTU in São Gotardo, in 2012, was of R\$ 562.383.32 (FINBRA, 2014). Thus, in 2012 the collection of IPTU per person in this municipality was of R\$ 17.68.

2.2 Materials and methods

Below, the methodology developed in this work will be described in details. A summary can be seen in the flow chart shown in Figure 2.

2.2.1 Database

The cartographic basis of the city was obtained in the City Hall of São Gotardo. This basis has the road, division per district and some lots.

The assessment of properties was used by Caixa Econômica Federal from 2012 and 2013, in the city of São Gotardo/MG. All loan processes were made available for consultation in this period. One of the contents of these processes are the valuation reports, which were scanned for use in this research. After tabulating all information in an Excel sheet and verifying its inconsistency, 184 assessed properties remained, which were used for the development of this work. All information refers to residential properties.

Having the address of the properties assessed, the situation of each one was registered with the recipient GPS Garmin GPSMAP 78s. Each point referring to assessed properties was inserted (from UTM coordinates) in the cartographic basis available by the City Hall of São Gotardo.

2.2.2 Available variables

The available variables in the valuation report provided by Caixa were divided into four categories: price of the property; characteristics of the land; constructive characteristics of the construction; and characteristics of valuation. In Table 1 a summary of the characteristics for all available variables is presented. The acronyms, descriptions and units of each unit are also inserted in it.

From the variable age of the propriety, a new independent variable was created: the age of the propriety squared. This variable aims to identify some improvement or remodeling made in the propriety throughout the time (Bourassa et al., 1999;

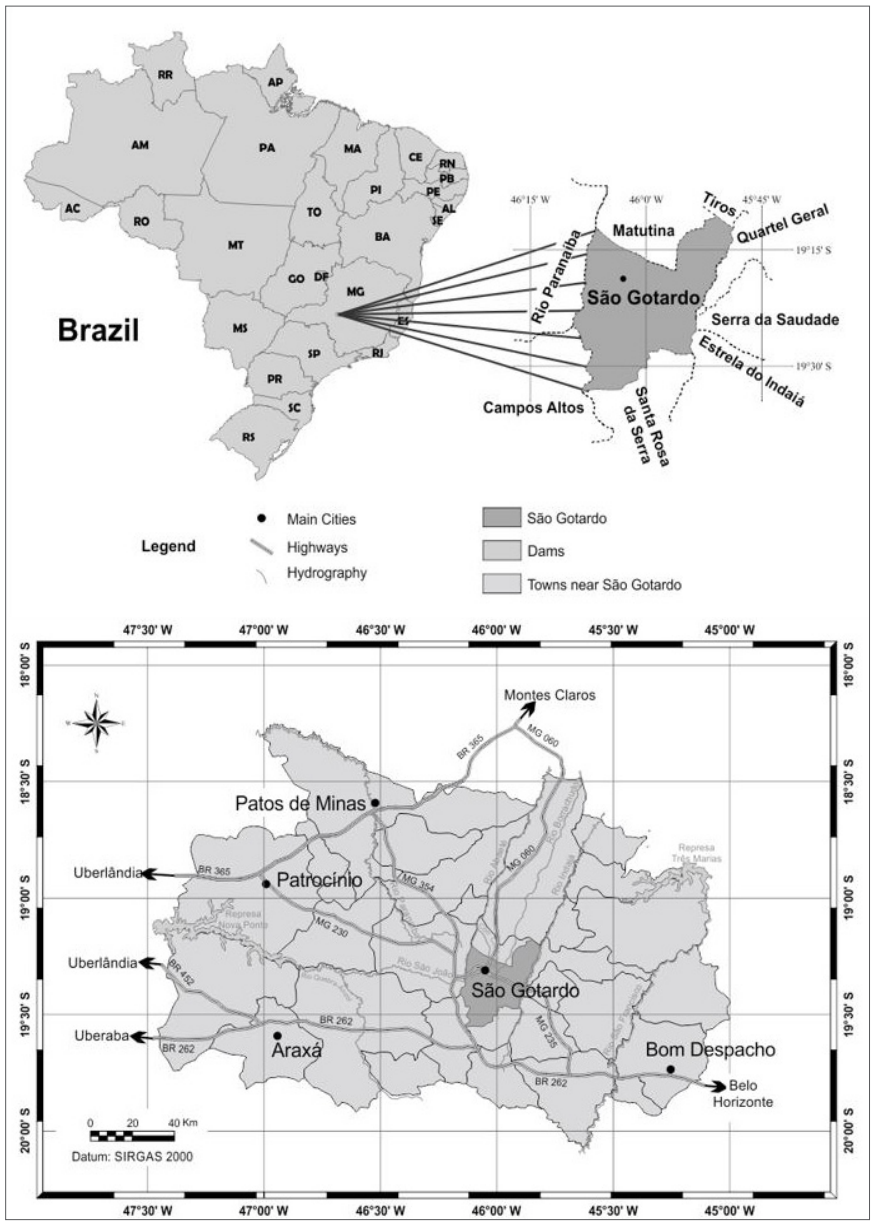


Figure 1. County of São Gotardo.

Beron et al., 2004). Thus, an older propriety would get a compensation for this possible remodeling made.

2.2.3 Selection of samples for quality analysis of regression models

For realizing the quality analysis of prediction for the value of the property, 10% of 184 assessed properties was approximately selected by Caixa from 2012/2013. Initially the standardization of all variables was done by its standard-deviation, in other words: $[(\text{variable value} - \text{average}) / \text{standard-deviation}]$. Later, the nonhierarchical grouping analysis was carried out (*K-means*), through the module Spatial Statistics

Tools of ArcGIS software, in which no 184 properties were divided into five groups.

From the grouping result, it was possible to identify which samples were similar. After that, a selection of approximately 10% of the samples of each group was randomly done through the module Geostatistical Analyst Tools of ArcGIS software.

Therefore, all analyses done during the work were based on the 166 samples of the properties. In Figure 3, a location map with each sampling point and the points selected for the quality analysis of the regression models generated is shown. It is possible to observe the 18 samples selected for quality analysis of the models are randomly displaced in the area studied.

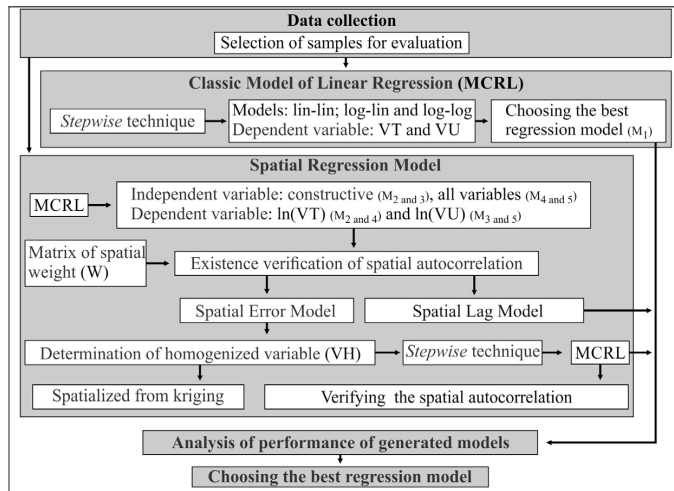


Figure 2. Flow chart with the procedures adopted in the work. Note: M_1, M_2, M_3, \dots are the regression models generated.

Table 1. Available variables in the assessment of properties of Caixa.

Category	Variable	Acronym	Description/definition of the variable	Unit
Price of the property	Total value of the property	VT	Total value of the property assessed	Real
	Unit value of the property	VU	Total value of the property assessed / built-up area	Real/m ²
Characteristics of the land	Form of the land	FO	Irregular or Triangular = 0 Rectangular or Trapezoidal = 1	-
	Share/Greide of the land	CT1, CT2	If CT1 = 0; CT2 = 0: Under the street level If CT1 = 1; CT2 = 0: Above the street level If CT1 = 0; CT2 = 1: In the street level	-
	Inclination of the land	IT1, IT2	If IT1 = 0; IT2 = 0: Bumpy If IT1 = 1; IT2 = 0: Uphill/Slope > 10% If IT1 = 0; IT2 = 1: Flat/semiflat	-
	Area of the land	AT	Total area of the land of the valuated land	(m ²)
	Front of the land	FT	Measurement of the front land	(m)
	Situation of the land	ST	Placement of the land in relation to the square: mid block = 0 corner = 1	-
	Number of floor	NP	Number of floor of the construction 1 floor = 0 2 or 3 floors = 1	-
	Age	ID	Age of the construction	(years)
	Age ²	ID2	Age of the construction squared	(year) ²
	Constructive characteristics of construction	Standard of finishing	PA1, PA2, PA3	If PA1, PA2, PA3 = 0: Minimum or between low and minimum If PA1 = 1; PA2, PA3 = 0: Low or Between normal and low If PA2 = 1; PA1, PA3 = 0: Normal or Between normal and high If PA3 = 1; PA1, PA2 = 0: High
State of conservation of the property		EC1, EC2	If EC1 = 0; EC2 = 0: Bad If EC1 = 1; EC2 = 0: Regular If EC1 = 0; EC2 = 1: Good	-
Garage		GA	There is no garage = 0 There is a garage = 1	-
Constructed area		AC	Total constructed area of the assessed property	(m ²)
Characteristics of assessment	Number of Rooms/Suites	NQ	Total number of rooms and/or suites of the assessed property	-
	Number of Bathrooms	NB	Total number of bathrooms in the assessed property	-
	Assessment Date	DA	Year of assessment of the property 2012 = 0 2013 = 1	-

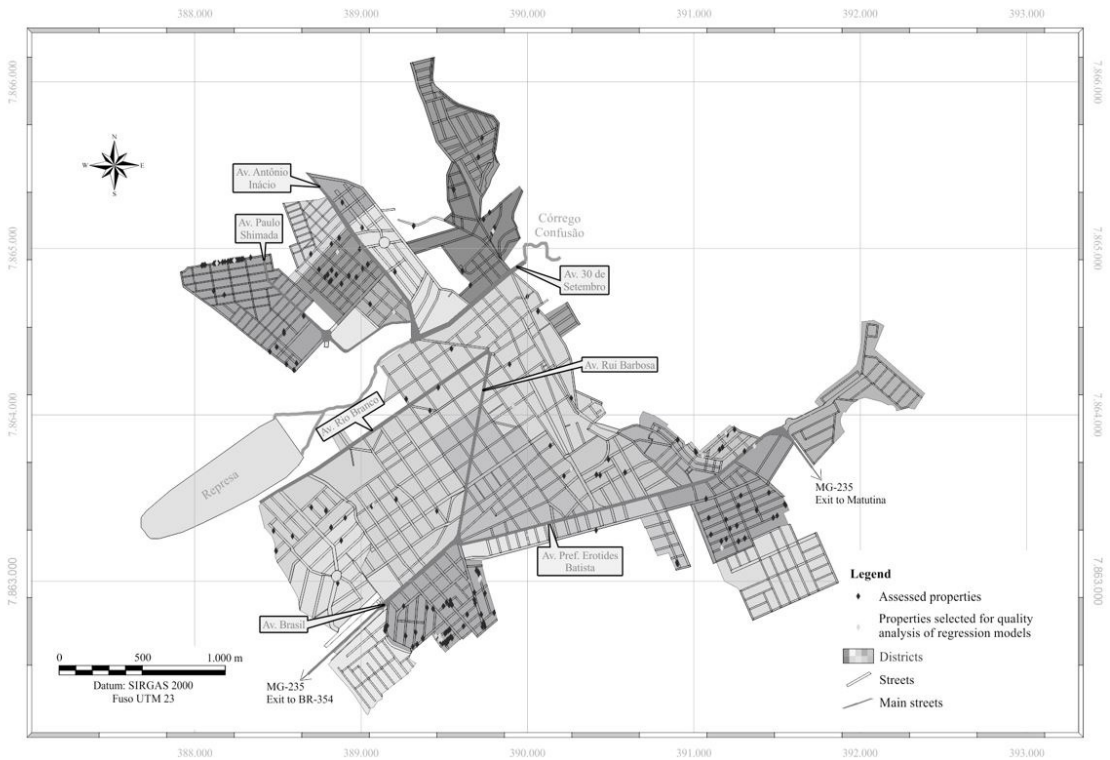


Figure 3. Map of São Gotardo with the location of each property assessed and the properties selected for quality analysis of regression models generated.

2.2.4 Classic Model of Linear Regression (MCRL)

For Gujarati (2000, p. 185), the equation of MCRL “[...] provides the average or the expected value of conditional Y to the fixed values (in repeated sampling) of X_1, X_2, \dots, X_k ”. In general, MCRL can be written as shown in the Equation 1:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} + \mu_i \quad i = 1, 2, 3, \dots, n \quad (1)$$

in which: Y_i : dependent variable; $X_{1i} \dots X_{ki}$: k-1 explanatory variables; β_0 : intercept; $\beta_1 \dots \beta_k$: partial coefficient of inclination; μ : error; i : i-ith observation; and n : size of the sample.

The *stepwise* technique was applied, which aims to group the independent variables that represent the best way of regression model. For this, the SPSS software was used in order to obtain a regression model only with relevant variables automatically. As parameters for this method, the probability of test F lower than 5%, and the exclusion higher than 10% of significance was used for inclusion of a variable.

To verify the best arrangement between dependent and independent variables, the following regression models were used: linear (lin-lin), semilog (log-lin) and logarithmic (log-log). For this, the total value

(VT) and unit value (VU) of the properties were used as dependent variables.

The use of VT and VU variables as dependent is justified due to the fact there is no unanimity in the literature consulted. Of the 33 consulted works, referring to the generation of some econometric model related to the value of the property, 10 of them used the unit value as dependent variable, in other words, the total value of the property divided by the constructed area (Brondino, 1999; Carvalho, 2011; Florencio, 2010; Gomes et al., 2012; Hochheim & Uberti, 2001; Michael, 2004; Pelli, 2006; Ribeiro, 2011; Trivelloni, 2005; Vazquez, 2011); 19 works used the total value of the property as dependent variable (Araújo et al., 2012; Avila, 2010; Braulio, 2005; Coelho, 2007; Dalaqua, 2007; Dantas, 2003; Dubin, 1992; Furtado, 2011; Gazola, 2002; Koschinsky et al., 2012; Matta, 2007; McCluskey et al., 1997; Monteiro & Leite, 2011; Moura & Carneiro, 2004; Paixão, 2010; Sander & Haight, 2012; Schiavo & Azevedo, 2003; Sousa & Arraes, 2005; Vieira, 2005); and four works used the total and unit values, separately, as dependent variables (Anselin & Lozano-Gracia, 2008; Catalão, 2010; González, 2002; Marques et al., 2009).

Finally, the normality tests, heterocedasticity and multicollinearity of all regression models generated were done.

2.2.5 Spatial Regression Model

Four models of multiple regression were generated from the dependent variables Ln(VT) and Ln(VU). For this, initially, only the constructive characteristics of the constructions, and after that, all available variables were used as independent variables. Thus, four combinations of linear regression models were generated to know: M₂ (Ln(VT) as dependent variables and constructive variables as independent ones), M₃ (Ln(VU) as dependent variable and constructive variables as independent ones), M₄ (Ln(VT) as dependent variable and all available variables as independent ones) and M₅ (Ln(VU) as dependent variable and all available variables as independent ones).

After that, the matrix of spatial weights (W) was generated through GeoDaSpace software. The definition for the value of maximum distance so that two properties were considered neighbors was realized from the achievement value semivariogram of the homogenized variable (which represents the factor of location). This value was of approximately 1.350 m, which is not the reality for the studied area. Thus, this value was being reduced up to getting to 800 m, which represents in a more accurate way the property reality of São Gotardo. Therefore, the matrix of spatial weight was determined using the geographic distance, in which the properties up to the cutting distance (800 m) are considered neighbors and receive the unit value (1), and from the cutting distance are not considered neighbors, receiving value zero. This matrix was standardized by sum of the line.

Using the models M₂, M₃, M₄, M₅ and the spatial matrix of weights, the existence verification of spatial autocorrelation through Robust Lagrange Multiplier test (LM) of spatial lag and error. In order to analyze the application of all possible models, when LM test indicated significance in the spatial lag and in the error, two models were generated, differently from the one that is usual in the studied literature, which uses only what is significant.

Anselin (1988) developed the methodology that uses econometric techniques for studying the existence of spatial dependence. This dependence occurs when the observations of an *i* local depend on other observations located in other places *j*, given that *i* ≠ *j*, can be modeled in two ways:

- **Spatial Lag Model or SAR (Spatial Autoregressive Model):** in case of value of properties, this occurs when the value of a property is influenced by the value of transactions realized in the neighborhood. The Equation 2 presents the spatial lag model:

$$Y = X\beta + \rho WY + \varepsilon \tag{2}$$

in which: Y: dependent variable; X: independent variables; β: parameters of the model; ρ: coefficient of spatial autocorrelation that represents the average

influence of the neighboring unit; W: spatial matrix of weights that links the variables in different locals; and ε: residues of the model.

- **Spatial Error Model or SEM (Spatial Error Model):** occurs when the error term of a local is correlated with the error values of other neighboring places. In the Equation 3, the spatial error model is presented:

$$Y = X\beta + \lambda W\varepsilon + u \tag{3}$$

in which: Y: dependent variable; X: independent variables; β: parameters of the model; λ: coefficient of spatial autocorrelation; W: spatial matrix of weights that links the variables in different locals; ε: residues of the model; and u: non-correlated residues.

When generating the spatial error model, it was aimed to determine a new homogenized model that involved the location factor. For this, the methodology recommended by Trivelloni (2005) was used, in which the new homogenized value (VH) of each sample was determined from the division of VT or VU by the spatial error model without its constant and λ (lambda).

This new homogenized variable, which represents the location factor, was used as independent variable of a new linear regression model (MQO). This model was generated using the *stepwise* technique. Later on, a new verification of spatial autocorrelation existence through Robust Lagrange Multiplier tests (LM) of spatial lag and error.

In relation to the determination of homogenized variable (VH), for any property present in the studied area, an interpolation of this one was done using kriging.

2.2.6 Analysis of performance of generated models

To analyze the performance of regression models generated, the methodology recommended was applied by the International Association of Assessing Officers (IAAO). This association says the measurement of variability or uniformity of an assessment has to be carried out through the Coefficient of Dispersion (COD) (IAAO, 2013). Thus, the determination of COD was done as described in Equation 4:

$$COD = \left[\frac{\text{average} \left(\frac{P_c}{P_o} \right) - \text{median} \left(\frac{P_c}{P_o} \right)}{\text{median} \left(\frac{P_c}{P_o} \right)} \right] * 100 \tag{4}$$

in which: COD: coefficient of dispersion; P_c: estimated value by regression equation; and P_o: observed value.

In this work, the assessed properties are single-family residential, located in heterogenic areas. Therefore,

according to IAAO (2013), the value of acceptable COD goes up to 15.

2.2.7 Practical analysis of final regression model

For Gazola (2002), the fact of the model meet the assumptions is not guarantee of quality for predictions, being a practical assessment necessary, which shows if in fact there is quality of adjustment and predictive capacity. Thus, the percentage of error can be determined by (Equation 5):

$$\text{Error}(\%) = \frac{\text{abs}(\text{MappedValueObserved} - \text{MapedValueEstimated})}{\text{MappedValueObserved}} * 100 \quad (5)$$

Values of error up to 5% are considered an excellent result; between 5 and 10%, very good result between 10 and 15%, good result; and between 15 and 20%, acceptable result (Gazola, 2002).

To realize a spatial error analysis of prediction in m² values of constructed area of São Gotardo, two maps were generated through the application of kriging as: the map of m² values of assessed construction by CEF; and m² values of construction estimated by M₁ regression model for the 184 properties used in this study.

After that, the algebra of these two maps was done, aiming to determine the locals with higher and lower successes through Equation 6:

$$\text{Error}(\%) = \frac{\text{abs}(\text{MappedValueObserved} - \text{MapedValueEstimated})}{\text{MappedValueObserved}} * 100 \quad (6)$$

3 Results and Discussion

3.1 Classic Model of Linear Regression (MCRL)

Three regression models were generated for the dependent variable VT (lin-lin, log-lin and log-log), using the *stepwise* technique and SPSS software.

In Table 2, the model with better result in relation to parameters R² is shown, adjusted and statistics of Akaike and Schwarz. This model, here called M₁, showed higher value of R² adjusted (0.87), and lower value of Akaike and Schwarz, in comparison to the other models tested.

M₁ model has as dependent variable the logarithm of total value of properties and logarithm of independent variables, except the dichotomous ones. In Table 2, it is possible to observe the variables inclination of the flat land/semi-flat (IT2), and logarithm of the land area (Ln(AT)) were significant at 5%, while the logarithm of constructed area (Ln(AC)), the high finishing standard (PA3), the validation date (DA) and the regular finishing standard or between regular and high (PA2) were significant at 1%.

In relation to MCRL assumptions, M₁ model did not meet the assumptions of normality and homocedasticity, once the tests of Jarque-Bera, Breusch-Pagan and Koenker-Bassett were significant. According to Gujarati (2000), the values of Factor of Variance Inflation (FIV) lower than 10, have an acceptable level of correlation and do not cause damage to the model. Thus, for M₁ model, it is verified the effect of multicollinearity is not significant.

Three other regression models were generated with dependent variable unit value (VU); however, R² adjusted varied from 0.25 to 0.21. Thus, due to its low performance, these models are not shown in this work.

3.2 Spatial regression model

The models that used spatial regression techniques were generated independently of the models estimated by MCRL, permitting to analyze the differences and/or similarities between the methods.

Four MCRL were generated, having as dependent variables the total and unit values of the properties,

Table 2. Regression Model (M₁) log-log referring to the dependent variable logarithm of the total value of the properties (VT).

Variable	Coefficient	Error-Standard	Statistics t	Value-p	FIV
Constant	6.4907	0.28	22.91	0.00	
Ln(AC)	0.9095	0.04	22.66	0.00	1.61
PA3	0.4983	0.10	5.05	0.00	1.19
DA	0.1287	0.03	4.40	0.00	1.06
PA2	0.0985	0.03	3.26	0.00	1.14
Ln(AT)	0.1648	0.06	2.81	0.01	1.39
IT2	0.0602	0.03	2.06	0.04	1.03

R² adjusted: 0.87
 F: 185.42 P-value: 0.00
 Heterocedasticity test
 Breusch-Pagan: 87.64 P-value: 0.00
 Koenker-Bassett: 35.19 P-value: 0.00
 Normality test
 Jarque-Bera: 72.18 P-value: 0.00
 Akaike: -93.41
 Schwarz: -71.62

The variables Ln(AT) and Ln(AC) are the logarithmic change of the variables land area, front of the land and constructed area, respectively.

and as independent ones, only the constructive variables (following the methodology suggested by Trivelloni, 2005), and with all variables available as independent ones to analyze if the model improves the quality when there are more variables involved.

After that, the matrix of spatial weights was generated, using as cutting distance, so that the two properties were considered neighbors the value of 800 m. In order to verify the existence of spatial autocorrelation, Robust Lagrange Multiplier tests of error and spatial lag were realized, using the matrix of spatial weights generated. The results of these tests are presented in Table 3.

From this table, it is possible to verify that (M₂) model generated with dependent variable logarithm of total value Ln(VT) of the properties and with constructive variables as independent significant effect at 1% only in the spatial lag. For (M₃) model, in which the independent variables of M₂ were maintained (constructive variables), and using as independent variable the logarithm of unit value Ln(VU), the existence of autocorrelations in spatial lag and error was verified, being these significant at 5%.

Yet, from Table 3, it is observed (M₄) model, which has as dependent variable the logarithm total value of the properties and with all independent available variables, was identified significant effect at 1% only in spatial lag. Finally, for (M₅) model with dependent variable logarithm of unit value of properties and as independent variables all the available ones, it was possible to observe the existence of autocorrelation in spatial lag and in error, being significant at 1 and 5%, respectively.

When confirmed the autocorrelation in spatial lag and/or error, the following models of spatial lag and/or error model were generated. Due to high number of models generated, two models that presented the best result will be shown in the following topics. The two best models (M₃ and M₅) were generated with dependent variable logarithm of unit value of the properties. Both models presented significant effect in spatial lag; however, when generated the model of spatial lag, the results were not good, once they did not show the variable constructed area (AC) as significant, and yet, the value of R² adjusted was low.

3.2.1 Model with dependent variable Ln(VU) and constructive variables of constructions as independent (M₃)

As M₃ model showed the spatial autocorrelation in the residues, the suggested methodology was applied by Trivelloni (2005), in which a homogenized variable referring to the property location. Thus, initially the spatial error model was generated through GeoDaSpace software. The result of this model is shown in Equation 7:

$$\begin{aligned} \text{Ln(VU)} = & 6.9512 - 7.24\text{E-}05 * \text{AC} + 0.2098 * \\ & \text{EC1} + 0.2071 * \text{EC2} - 0.0536 * \text{GA} - 0.0102 * \\ & \text{ID} + 0.0004 * \text{ID2} + 0.0291 * \text{NB} - 0.0533 * \\ & \text{NP} - 0.0381 * \text{NQ} + 0.0603 * \text{PA1} + 0.1351 * \\ & \text{PA2} + 0.4799 * \text{PA3} + 0.3524 * \text{LAMBDA} \end{aligned} \tag{7}$$

The homogenized unit value (VH_U) for each property was determined by (Equation 8):

$$\begin{aligned} \text{VH}_U = & \text{VU} / \exp(- 7.24\text{E-}05 * \text{AC} + 0.2098 * \\ & \text{EC1} + 0.2071 * \text{EC2} - 0.0536 * \text{GA} - 0.0102 * \\ & \text{ID} + 0.0004 * \text{ID2} + 0.0291 * \text{NB} - 0.0533 * \\ & \text{NP} - 0.0381 * \text{NQ} + 0.0603 * \text{PA1} + 0.1351 * \\ & \text{PA2} + 0.4799 * \text{PA3}) \end{aligned} \tag{8}$$

With the value of VH_U calculated for each property, it was possible to generate a new model MQO with this variable. This model guarantees the spatial effects that influenced the M₃ model negatively, and are not present anymore because the effects are inserted in the variable VH_U. Thus, M₆ model with independent variable VH_U is presented in Table 4. It is highlighted the dependent variable used was Ln(VU), and the *stepwise* technique was applied by SPSS software. It is also observed in Table 4 that all variables presented were significant at 1%, except the standard variable of low finishing or between regular or low (PA1), which was significant at 5%. The value of R² adjusted was of 98%.

In relation to MCRL assumptions, M₆ model did not meet normality (test of Jarque-Bera) and homocedasticity for the test of Breusch-Pagan, although it was presented non-significant at 1% for heterocedasticity for the test of Koenker-Basset. In relation to the FIV of multicollinearity, the variables EC2, PA1 and PA2 presented values higher than 10, which demonstrates the multicollinearity in them. Thus, the removal of these variables of model, but the effect of this removal on the significance of other variables was negative, in other words,

Table 3. Tests of spatial autocorrelation.

Test	M ₂		M ₃		M ₄		M ₅	
	Statistics	Value-p	Statistics	Value-p	Statistics	Value-p	Statistics	Value-p
LM robust (lag)	11.8050	0.0006	6.1260	0.0133	11.3380	0.0008	9.4160	0.0022
LM robust (error)	0.1650	0.6847	3.9310	0.0474	0.1570	0.6919	6.3920	0.0115

Table 4. MQO model (M_6) with the variable VH_U location.

Variable	Coefficient	Error-Standard	Statistics t	Value-p	FIV
Constant	6.0180	0.03	199.01	0.00	
AC	-2.16E-04	0.00	-2.71	0.01	3.49
EC1	0.2003	0.02	8.18	0.00	9.46
EC2	0.1932	0.03	7.57	0.00	11.33
GA	-0.0494	0.01	-6.76	0.00	1.21
ID	-0.0148	0.00	-11.04	0.00	8.87
ID2	5.56E-04	0.00	11.93	0.00	6.23
NB	0.0301	0.00	8.38	0.00	1.94
NP	-0.0750	0.01	-7.78	0.00	1.31
NQ	-0.0444	0.00	-9.20	0.00	1.48
PA1	0.0391	0.02	2.19	0.03	13.55
PA2	0.1195	0.02	6.37	0.00	14.47
PA3	0.5063	0.03	19.39	0.00	2.75
VHU	9.41E-04	0.00	74.71	0.00	1.02

R ² adjusted: 0.98	Normality test
F: 530.89 P-value: 0.00	Jarque-Bera: 2381.98 P-value: 0.00
Eterocedasticity tests	Akaike: -667.83
Breusch-Pagan: 169.68 P-value: 0.00	Schwarz: -624.26
Koenker-Bassett: 17.48 P-value: 0.18	

important variables that were significant were not anymore. Therefore, it was chosen to keep all resulting variables of application of *stepwise* technique in M_6 model.

The test LM robust (lag) presented value-p of 0.8960, and LM robust (error), of 0.2395. Thus, it is possible to verify that there is no spatial autocorrelation in M_6 model, which demonstrates the independent variable VH_U covers the characteristics of location in the regression model calculated by MQO.

3.2.2 Model with dependent variable $\ln(VU)$ and all available variables as independent (M_7)

From the confirmation of the existence of spatial autocorrelation in the residues, although lower the autocorrelation of spatial lag, it was decided to generate the spatial model of error through GeoDaSpace software. The result of this model is shown in Equation 9:

$$\begin{aligned} \ln(VU) = & 6.9471 - 4.01E-04 * AC + 8.48E-04 * \\ & AT + 0.0066 * CT1 - 0.0103 * CT2 + 0.1503 * \\ & DA + 0.0930 * EC1 + 0.0513 * EC2 + 0.0177 * \\ & FO - 0.0059 * FT - 0.0781 * GA - 0.0199 * \\ & ID + 7.91E-04 * ID2 - 0.0241 * IT1 + 0.0292 * \\ & IT2 + 0.0326 * NB - 0.0457 * NP - 0.0467 * \\ & NQ + 0.0599 * PA1 + 0.1545 * PA2 + 0.5684 * \\ & PA3 + 0.0585 * ST + 0.1671 * LAMBDA \end{aligned} \tag{9}$$

After that, the homogenized unit value (VH_{U1}) was generated for each property through the Equation 10:

$$\begin{aligned} VH_{U1} = & VU / \exp(- 4.01E-04 * AC + 8.48E-04 * \\ & AT + 0.0066 * CT1 - 0.0103 * CT2 + 0.1503 * \\ & DA + 0.0930 * EC1 + 0.0513 * EC2 + 0.0177 * \\ & FO - 0.0059 * FT - 0.0781 * GA - 0.0199 * \\ & ID + 7.91E-04 * ID2 - 0.0241 * IT1 + 0.0292 * \\ & IT2 + 0.0326 * NB - 0.0457 * NP - 0.0467 * \\ & NQ + 0.0599 * PA1 + 0.1545 * PA2 + 0.5684 * \\ & PA3 + 0.0585 * ST) \end{aligned} \tag{10}$$

The variable VH_{U1} was used as independent variable in a new multiple regression model generated by MQO. Thus, the guarantee of all location effects not considered in model M_5 was aimed, and will be represented by this variable in M_7 model. The model (M_7) resulting from the application of *stepwise* technique is presented in Table 5.

It is observed in model M_7 all variables were significant at 1%. R^2 adjusted was of 0.81, and the normality assumptions (test of Jarque-Bera), homocedasticity (Breusch-Pagan, Koenker-Bassett) and multicollinearity were met.

The test LM robust (lag) showed value-p of 0.1473, and LM robust (error), of 0.5172. Thus, it was verified there is no spatial autocorrelation in the model M_7 , which demonstrates the independent variable VH_{U1} involves characteristics of location in the regression model calculated by MQO.

3.3 Choosing the best regression model

In Table 6, the values of COD are presented and a summary of all assumptions of the models $M_{1,6}$ and M_7 . The coefficient of dispersion (COD) of all models met the recommendation of IAAOof a lower value

Table 5. MQO model (M_7) with the variable of VH_{U1} location.

Variable	Coefficient	Error-Standard	Statistics t	Value-p	FIV
Constant	5.9697	0.05	122.58	0.00	
AC	-1.01E-03	0.00	-4.95	0.00	2.86
AT	6.60E-04	0.00	5.76	0.00	1.61
ID	-0.0205	0.00	-5.96	0.00	7.20
ID2	7.57E-04	0.00	5.69	0.00	6.32
IT2	0.0514	0.01	3.56	0.00	1.03
NB	0.0310	0.01	3.07	0.00	1.90
PA2	0.0785	0.02	5.19	0.00	1.17
PA3	0.4563	0.05	8.93	0.00	1.31
VH_{U1}	9.46E-04	0.00	23.35	0.00	1.01
R ² adjusted: 0.81			Normality test		
F: 79.89 P-value: 0.00			Jarque-Bera: 0.51 P-value: 0.77		
Heterocedasticity tests			Akaike: -325.06		
Breusch-Pagan: 7.41 P-value: 0.59			Schwarz: -293.94		
Koenker-Bassett: 8.56 P-value: 0.48					

Table 6. Values of COD and assumptions of each model generated.

Models	COD		R ² adjusted	Attendance for assumptions			
	All samples (166)	Validation samples (18)		Normality	Heterocedasticity		Multicollinearity
				Jarque-Bera	Breusch-Pagan	Koenker-Bassett	
M_1	12.65	13.14	0.87	no	no	no	yes
M_6	1.98	11.23	0.98	no	no	yes	no
M_7	7.07	9.99	0.81	yes	yes	yes	yes

than 15.0. M_6 is highlighted, which presented value of 1.98 for the 166 samples used to generate the regression models. On the other hand, it was observed discrepancy in relation to the value of COD of the 18 samples not used for generating the models, which can indicate some kind of incoherence in this model. Thus, M_7 seems to be more trustworthy, once the value of COD for validation samples was the lowest among all the other models.

In relation to R² adjusted, M_6 present the best result (0.98), and M_7 , the worst one (0.81). Finally, it was verified that only model M_7 met all the assumptions; therefore, the final model to be used for determining the values of properties with the objective of generating the plant of generic values for the urban area of São Gotardo.

3.4 Determination of homogenized variable VH_{U1} for São Gotardo

The most recommended model for generating the plant of generic values is (Equation 11):

$$\begin{aligned}
 VU = & \exp(5.9697 - 1.01E-03 * \text{Constructed area} + \\
 & 6.60E-04 * \text{Area of the land} - 0.0205 * \\
 & \text{Age of the property} + 7.57E-04 * \\
 & \text{Age of the property}^2 + 0.0514 * \\
 & \text{Inclination of the land} + 0.0310 * \\
 & \text{Number of Bathrooms} + 0.0785 * \\
 & \text{Standard of finishing} + 0.4563 * \\
 & \text{Standard of finishing} + 9.46E-04 * \\
 & \text{Homogenized Variable}_{U1})
 \end{aligned}
 \tag{11}$$

Therefore, to evaluate a property in any urban area of São Gotardo using the model M_7 , it is necessary to obtain the value of the location variable, VH_{U1} . For this, a map of the variable VH_{U1} , was generated, estimated by kriging.

According to Trivelloni (2005), kriging is the most recommended technique to generate the spatialized map of homogenized variable. Thus, initially, four semivariograms of the variable VH_{U1} were generated, through GS+ software in the directions 0°, 45°, 90° and 135°, in which the negligible difference in the value was noted in the reaching value and level in these directions, proving the isotropy. In Figure 4a,

isotropic semivariogram is presented with its all main characteristics.

In Figure 4b map of spatialized VH_{U1} is presented from kriging. It is observed in this map the highest values of homogenized values VH_{U1} are located in the urban center area of São Gotardo, followed by the districts Mansões dos Lagos, Jardins das Flores, Campestre and Nossa Senhora de Fátima. This result indicates in these locals the local variable, which takes the influence of the neighborhood has more impact on the unit value of the property.

3.5 Practical assessment of M_7 model

In Table 7 the values of error calculated for this work are presented. It is possible to observe in it that when the 184 samples were used, 94.6% of the points presented values of error lower than 15%, while for the 18 validation samples, this value was of 77.8%. Therefore, taking into consideration the parameter, it is possible to say the result of the model was good and can be used for the calculation of property values in the urban area of São Gotardo. Gazola (2002) verified

that 70.6% of the validation samples (17 samples) of the predicted values were lower than 15% of error. This study presented 88.9% of the validation samples below the range of acceptable error with the limit up to 20%, which reinforces the quality of its prediction.

For spatial error analysis, two maps were generated through the application of kriging. Figure 5a shows the map of unit values of the assessed properties by CEF, and Figure 5b, the unit values of the properties estimated by M_7 . It is possible to verify in the range that goes from Centro to the district Jardim das Flores are the most valorized locals. It is also observed the amplitude of the unit value was higher in the estimated map.

The visual analysis of the two maps does not permit to infer major differences between the observed and estimated values Thus, the algebra of the maps was done according to Equation 6.

The observed result in Figure 6 shows the districts Nossa Senhora de Fátima and Novo Mundo presented a higher error, demonstrating model M_7 should be applied with caution in these districts. This fact was expected because they are areas with lower number of

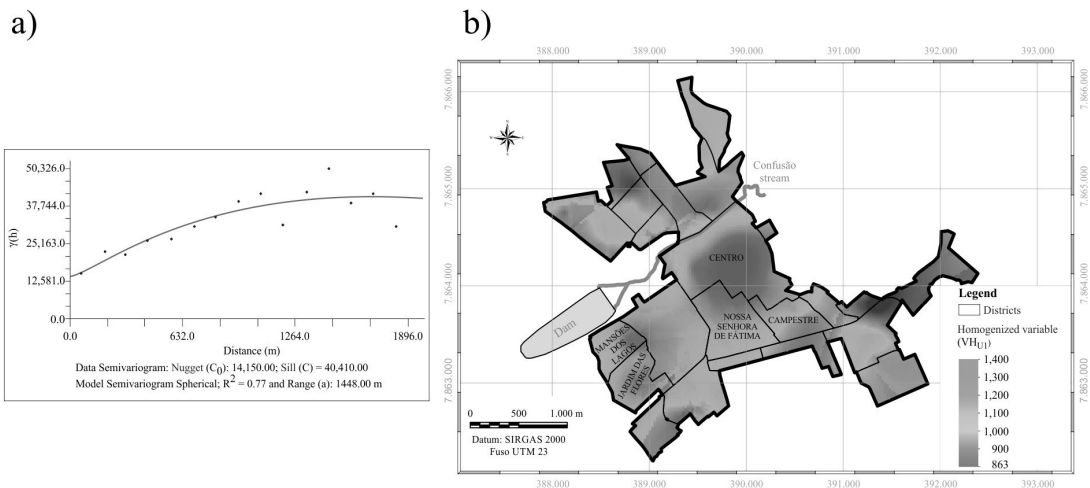


Figure 4. (a) Isotropic semivariogram of the homogenized variable VH_{U1} ; (b) map of VH_{U1} spatialized from kriging.

Table 7. Error for all samples and only for validation samples.

Error Range	Number of favorite values		% of favorite values		% accumulated of favorite values	
	All Samples	Validation Samples	All Samples	Validation Samples	All Samples	Validation Samples
0-5%	63	5	34.2	27.8	34.2	27.8
5-10%	81	3	44.0	16.7	78.3	44.4
10-15%	30	6	16.3	33.3	94.6	77.8
15-20%	6	2	3.3	11.1	97.8	88.9
20-30%	4	2	2.2	11.1	100.0	100.0
Total	184	18	100.0	100.0		

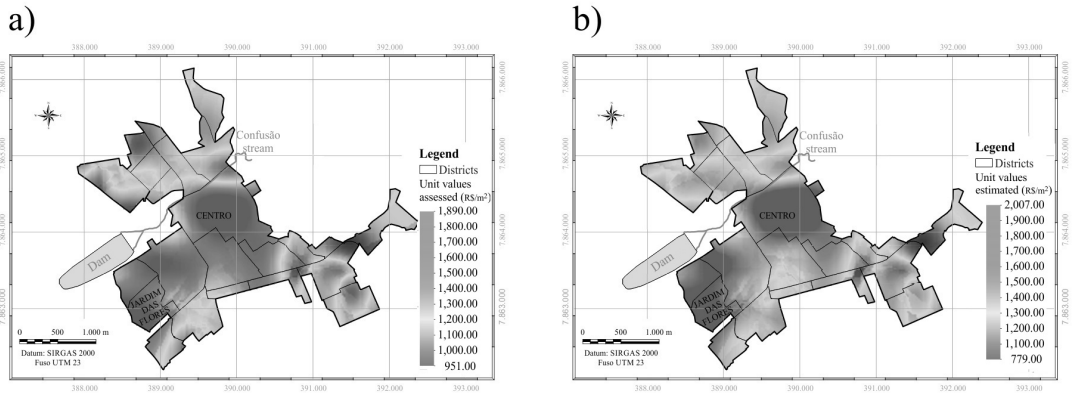


Figure 5. (a) Map of unit values assessed by CEF; (b) map of unit values estimated by M_1 regression model.

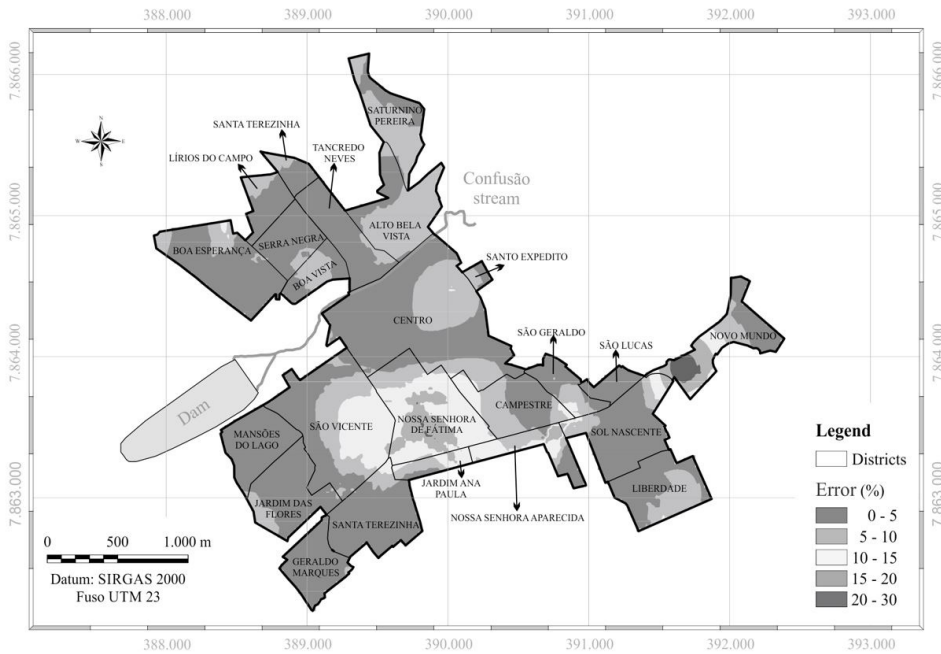


Figure 6. Map of the error (in percentage) of the unit value of properties.

samples, once the district Nossa Senhora de Fátima is old with residential properties that do not go through changes frequently. On the other hand, the district Novo Mundo is new, having no construction. The other districts showed error values lower than 20%, which is considered acceptable according to Gazola (2002).

A counting of pixels was realized for each error range, in which 60.5% of the pixels presented error values lower than 5%; 86.0%, below 10%; 96.1%, below 15%; and 99.3%, below 20%. According to the classification of Gazola (2002), this result makes it possible to say the model can be used in the calculation of property values in the urban area of São Gotardo

because 99.3% of the pixels presented acceptable error, in other words, the error value lower than 20%.

4 Conclusion

In view of the results, it was possible to conclude that:

- The final model can be applied individually for each property in the municipality studied, being necessary to obtain the variables constructed area, area of the land, age of the property, inclination of the land, number of bathrooms, standard of finishing and the homogenized variable for

each property belonging to the urban area of the county.

- The inclusion of characteristics of the land improved the estimate of the variable referring to location.
- It was evident the indiscriminate use of classic model of linear regression in this work without considering the location variable can take to wrong estimates of the market value of the properties.
- The dependent variable Total Value showed better results when the classic model of regression was used; on the other hand, when the variable referring to location is inserted, the dependent variable Unit Value became more relevant.

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