

# Determination and prediction of agricultural land prices using hedonic prices model: an application

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## Abstract

This article aims specific markets agricultural land prices determination and forecast using hedonic prices methodology. The absence of official or trustworthy information on land prices makes this very important in Brazil. This multiple regression model has as dependent variable the price per hectare and the next explanatory variables: physical attributes (soil, relief), production (systems of production, localization, access), and infrastructure of the property and expectations (regional situation, local investments). The application to a Homogeneous Zone of Maranhão, Brazil generated a parsimonious model, where five independent variables explained 70% of the variance of the price of agricultural land.

**Key word:** land market; hedonic prices, multiple regression analysis, land politics.

## 1. INTRODUCTION

In Brazil, previously to the economical stabilization of 1995, the issue of the determination of agricultural land prices was frequently left aside for two reasons: be considered a restricted concerning to landowner and difficulties to its calculations set by the high inflation. However, the lack of records of prices added to the results of Brazilian land policies, the clashes in the courts among others, evidences the high relevance of having adequate estimates and projections of agricultural and urban land prices in Brazil's reality.

The dynamics of the land markets and in consequence of the evolution of its prices have had a crucial role on the aims and goals of the land policies and on the land administration. For instance

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the high reduction of agricultural land prices, after the PLANO REAL in 1995, has favored significantly the goals reached in the land reform in the first term of president FHC. On the side of the democratization of land through the market, from 1997 on, the programs Cédula da Terra (Land **Cédula**), Banco da Terra (Bank of Land) and Crédito Fundiário (Land Credit) had, because of the acquaintance of the markets and the construction of suitable policies very differentiated impacts. While the Cédula da Terra (Land Cédula) because of subsidies for the agreements made with prices lower than the market ones reduced market prices, the Banco da Terra (Bank of Land) without subsidy and supervision on prices broadened the demand for land increasing significantly its prices.

In the legal brunt's, in the expropriation of land for land reform and in the land purchases for the programs called "access to land through market" the agreements are done using the market prices. But how is the market price established? How to unravel the variables that determine the dynamics of the land price in a specific geographical place or local market? What kind of model should be used to forecast this price? This article contributes with a methodology to predict the land price in specific markets with the purpose of giving subsidies, among others, to the agricultural policy makers in charge of democratizing the access to rural land in Brazil.

In the specialized international literature in agricultural economics, empirical papers like Peters(1966), Lloyd, Rayner and Orme (1991), Lloyd (1994) and Hallan, Machado and Rapsomanikis (1992), concentrate their explanation of the agricultural land prices dynamics on a macroeconomic perspective. These writers recognize that the agricultural land is an asset and that its price is determined by the capitalization of its future incomes obtained with its productive and speculative uses. The productive incomes are derived from the agricultural products and the speculative incomes, from its characteristics as an asset that maintains value along the time. For the Brazilian case, because of the experience of high inflation the speculative use has had a large impact as can be seen by studies like Pinheiro (1980), Reydon (1984), Brandão (1986) Brandão and Rezende (1992), Bacha (1989), Reydon (1992), Reydon and Romeiro (1994) and Plata (2002).

Based on these studies, this article develops a methodology for determination of land price for specific markets taking in account both characteristics of land use. It starts by selecting the determinants of land prices in specific markets and after that it establishes econometric models to explain the dynamics and forecast price of land in homogenous areas.

## **2. Price Determination of Agricultural Land**

The price of agricultural land, in a specific geographical area, reflects its market structure and the political and social-economical development of the region. The market prices guide the private economic agents in the land market in the purchases and sales; they are reference for the government in its rural democratization and in land taxing programs; they are used by credit institutions for the determination of the land mortgage and as guarantee for rural credit. Land prices is consequently on one hand the relevant variable that expresses the expectations of the economical agents for this resource and also acts like a signal to be considered by the policy makers when intend to define an efficient economic and social land use and distribution.

But how to estimate and describe the dynamics or rural price in imperfect land markets like the Brazilian, in which the land has a fixed, immovable and concentrated offer? On the one hand,

land can be used as a productive factor in the production of rural goods and, on the other hand, as a speculative asset as it maintains value from one period to the other. There are also rules for its usage (for instance, the preserved forest) and taxes on properties, besides the cultural and socio-political characteristics that affect the market. In this context, the rural land price synthesizes the effect of all the factors that interact in its market. So, in this paper are discussed, in theoretical and empirical ways, the determinant variables and the dynamics of these market prices.

Theoretically it is assumed that these land markets are established in capitalistic economies in which the economical agents have expectations and make decisions to obtain maximum monetary gain<sup>6</sup>. In this scenery of enterprise and market economies, the owners of wealth obtain different kinds of assets<sup>7</sup>, with different levels of liquidity to get monetary gains and protection of the capitalistic economy uncertainty, and try to predict the psychology of the markets and decide to buy the assets that, according to their expectations, will provide higher liquid return (Reydon,1992; Reydon, Plata,1995; Plata,2002).

Rural land is an asset because of the three important characteristics: a) scarcity; b) immobility; and c) durability. The scarcity of land is not only a consequence of its physical scanty, but also because of the scarcity of the products from it. However, land being an immobile factor, that can't be reproduced, has its economical scarcity originated by its low production and substitution elasticity's that can be privately appropriated by some agents. But the development of technologies that increases its productivity as well as administrative measures like, for instance, land reform can modify substantially the level of land scarcity in a region.

It is also assumed that a land market is created when the ownership of the region is accepted in general terms, independently of the way and the guaranties for its maintenance<sup>8</sup>. Therefore any changes in legislation or on the guarantees that property has<sup>9</sup>, its condition of an asset becomes more relative, increasing the risk associated to its acquisition and decreasing the liquidity, its capitalization rate and its price. The reference has always been the property independently of its form, because in some areas or countries where the property is not formally established but socially accepted and trade with land happens the land market exists.

Land prices are the result of the business between purchaser and seller in the land markets. But the trade is only done when a purchaser has higher expectations about the future gains of that land than the seller. Consequently, the movements of expectations about the future gains from the land and, therefore, its prices, are the most important variables to understand the dynamic of land market.

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<sup>6</sup> There are in some less developed Brazilian regions places where only the subsistence is achieved and not the maximum monetary gains. Mostly in these regions extra economical factors are the dynamic factor of the land markets, for instance: tradition, family's blood, status and others. Certainly these regions when developed, with production for the markets, demand for industrial products and with the growing of employment and income will also became aimed on maximum monetary gains.

<sup>7</sup> Any good acquired with the purpose of producing profits or that generates expectancy of changing its value is considered an asset. This is why all the goods can be treated as assets.

<sup>8</sup> The level of guarantee and/or acceptance of the legal rules for the establishment of the private property (legally, enforced and political) are the determinants of the liquidity and of the dynamics of its secondary markets. In Brazil the Land Law of 1850 established generally these rules, but because it did not have a Cadastre System and it has always been possible to regularize possession this market still needs an important intervention from the State.

<sup>9</sup> As everything is based on expectations there is no need for a change in the rules, if the agents think that the changes might happen, the asset price will suffer these changes.

Summarizing, rural land can be characterized as being simultaneously a capital and a liquid asset, negotiated with flex price – established by the capacity of the owners to stock the asset. The main reason is that the supply of land is fixed<sup>10</sup>, and the market price will be determined by the dynamics of the demand.

The expectations of the owners can set the quantity of land to be negotiated, but the expectations of the purchasers about the future gains with the use of land that will establish the price. In this context, according to Reydon (1992), similar to all the assets, the rural land price is the expression of the expectative gains for the three capitalized attributes:

$$P = q - c + l$$

**q: productive quasi-rents** – the expected gains from productive uses of the property. The value of this attribute depends on the expected gains with the rural production and the possibility of other gains resulting from the property of the land, such as credits or governmental subsidies.

**c: maintenance cost** - expected costs of maintain the land in the portfolio of the agent, it means, all the not-productive costs associated to the property, such as the transaction costs, land taxes and similar.

**l: liquidity premium** – the facility of selling the land in the future. This is the least objective part of the price and is mostly formed by the expectation of the agents in relation to the land markets. It's higher when the economy grows and the demand for land as a capital asset increases or when there is an increase in the demand for liquid assets. Some times in a crises when the expectation for other liquid assets is worse than land its liquidity can also grow.

It's important to emphasize that the local specific Brazilian land markets are imperfect mainly because of: a) an expressive political and social inequality in the property distribution; b) an individual economical agent can manipulate the supply and the price of land; c) the landless need land but they don't have economical possibility to obtain it; d) land is not a smooth product, the properties have distinct size, quality, fertility and surface; e) there are spatial conditions that affect the price. But empirical evidences show that regions with dynamic land markets have also dynamic products, labor and credit markets.

It's important to emphasize that land markets have two different segments: the trade market and the rental market. On one hand, an economical agent that operates in the trade market is willing to pay for the total possible gains: the productive quasi-rents and the liquidity premium of the land. On the other hand, renters will be willing to pay a rent based just in the productive profit and so the value of the rent of the land can be considered as a proxy of its productive gain.

### 3. VARIABLES FOR LAND PRICES DETERMINATION

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<sup>10</sup> The assumption of constant supply is used because it is impossible to support theoretically the existence of a supply function for an untypical asset as land. Land cannot be produced, making the use of the production theory to establish empirical supply functions difficult.

From the tin implicit theory, it can be said, that the land price in a specific market is determined by the expected productive and speculative gains from the property. The main variables that explains the dynamic of these gains and the land prices are:

- The general demand and prices for the products from the specific farming activities. This demand is determined by the prices of the products and by the input costs as: technology, mechanization (capital) and other factors used in the production. In micro economical terms, the land use productive profit in a specific moment would be similar to the expected value of the land's marginal product<sup>11</sup>. So, the productive gain from land would depend on the conditions of the product's market and the technical conditions for production, because the land's marginal physical productivity is a consequence of a technical relation with the other factors of a specific technology. An increasing of the price of the product, due to the increasing of profit or a change in the consumers' preference, causes expectations of an increase in the productive profit. The same occurs when the production costs reduces (decreasing the price of assets, facility of access to capital, technological improvement and/or in the condition of production) which increases the production function and physical productivity of the land.

- The infrastructure of production and trading affects the expected land productive gain. The existence of irrigation infrastructure, availability of water, access, transportation, closeness to consumption centers and information affects positively land prices, besides decreasing the risks of its productive gains. These variables determine, in many cases, the different land local prices.

- The institutional restriction to the utilization of land creates negative expectations about the productive gains, making the price of the land decrease. Good examples are the Laws of Forestry Preservation that reduce land prices. On the other hand, the social benefits from the preservation of the environment can be high, and the alternative use of rural land, such as the ecological tourism, can generate optimistic expectations that will raise the gains from land.

- Another variable that affects the land price is the level of fragmentation, the smaller the properties the higher prices, mainly because of the increase in liquidity. In the case of the agricultural land, the impact on land prices of the fragmentation depends on the area required for the regional efficient agricultural exploration (Reydon att alli 2006).

- The growth of population can have an important effect on land prices through at least two different ways: an increase of demand of farming products (food) and space for urbanization and leisure. The increase in demand for lands for non-farming purposes mostly increases its prices only for a homogeneous area.

- The inflation affects land prices in two ways: first a productive gain change, caused by the increase in the prices of products and inputs<sup>12</sup>. The second and more important way is related to land's capacity of retaining value that comes from its liquidity. So there is a potential demand for land that will be determined by the expectation of its

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<sup>11</sup> The land's marginal productivity can also be interpreted as an opportunity cost, *ceteris paribus*, the functions of product market and production function. This should be the value paid for the expropriation of land for land reform.

<sup>12</sup> In inflation environment with indexation only some prices are totally indexed s which exists at total tax, it doesn't establish the same price. However it is expected that some prices increase more than others

gains in contrast with other real and financial assets. For instance, in 1986, during the Plano Cruzado, when the Brazilian financial market was under intervention, the demand for real assets increased significantly. In this moment the agricultural land reached its higher value in the last 40 years.(Plata 2001)

- The demand for land in inflationary contexts is strongly related to the effect of inflation on the rates of real interest. If the rates of real interest are negative, the financial assets aren't attractive and, therefore, the investors will search for real assets, such as real estate, houses, urban areas, agricultural land, etc. (Reydon and Plata, 1995).
- In high inflation periods, the demand for land can increase even when its agricultural use is affected. It occurs because the economical agents (farmers and not farmers) expect the real value of the land to increase or at least stay constant during these periods. In these moments other investors enter the land markets expecting that land will maintain its value or even increase creating other capital gains. Although in periods of inflation demand for land can change and affect the productive gains and its prices because the increase in the prices of the produced goods and assets. A demand of the land to productive reasons will increase or decrease according to the relative variation of these prices (Plata, 2001).
- Rural land taxes can affect its price as far as it raises its maintenance cost. A land tax has a virtue to encourage the increase of productivity of idle land or of low level of utilization (Reydon; Plata, 1995).
- The level of development of a countries financial system affects the price of rural land. The absence of liquidity in an economy is important because it increases the opportunity cost of money. In the case of agricultural business, with long-term investments, liquidity constrains are frequent. As an example in a country with an underdeveloped financial system only be agents that have portfolios with highly liquid assets<sup>13</sup> can purchase land. In consequence, purchasing land will have small and scarce demand, but the demand for rent of land will be higher.
- The transaction cost in the land markets is the combination of several costs: bureaucracy cost, cost of research, asset evaluation, management costs, etc. High transaction costs with the land market is one major cause of low incentive to deal with land.
- Finally, the socio-economical and political environment where trade with land takes place is crucial. If other investments and opportunities of investment are not so attractive and safe, land prices will increase in consequence to the high return and safety offered by this asset. If the legal system is complex or instable, if there isn't any safety in the rental of the land and if there is an instable political environment, no investment of long term will be done, which will affect land prices. If the ownership of the property is under risk, such as invasion or expropriation, land prices will be affected negatively (Reydon, 1992). The entire economical, social and political contexts of the specific land market should be taken in count when under analyze.

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<sup>13</sup> Even these agents bought land taking in account the prices of other real and financial assets.

#### **4. METHODOLOGY FOR RURAL LAND PRICES DETERMINATION IN SPECIFIC MARKETS<sup>14</sup>**

This item presents a methodology to determine rural land prices in specific markets, defined as homogeneous zones. The homogeneous zones are defined, by cluster analysis, based on the similarity of the municipalities in a set of characteristics: the land agronomical conditions, location, main stakeholders in the market, level of mobility, expected purchase prices, level of urban development.

Land prices in specific markets are determined by local variables, so markets have to be analyzed using disaggregated information. The level of State or Province is too aggregated, so these will be divided in Homogeneous zones – HZ, aggregating municipalities using clusters techniques. The variables to aggregate the municipalities to form the HZ are mostly economical, social and agronomical. After the aggregation of municipalities in HZ's for each state a questionnaire will be applied to a random sample of properties traded recently, to capture values for the main variables which should be taken in count for the prediction land price model.

The methodology used to study rural land prices in specific or local markets follows the next stages: i) formation of a secondary database to establish HZ through clusters techniques using secondary information, ii) formation of a primary database with application of a questionnaire to the purchasers of rural properties by stratified samples to find real land prices and its explanatory variables, iii) statistical analysis of the database of primary information to exclude incomplete or incorrect data such as extreme values and getting of the responses coming back equations of the market price and iv) create a computer program (off-line) and structure of database (web) to estimate land prices from information obtained from people that access the system.

##### **4.1 Primary information of HZ (fieldwork)**

The primary information to study the land price dynamics in specific markets will be obtained through a fieldwork done at a random sample of properties traded in an HZ. The sample must be distributed proportionally to the number of municipalities that form the HZ. The sample has to achieve a minimum of at least 50 deals per HZ.

The cadastre of trade by municipality used to define the random sample consists of a list of accomplished deals, with the respective areas, obtained at the notary. During the interviews the researchers use printed application forms that are filled and obtain electronic codes. Another program receives the database where it is criticized and final processing is done. These stages are of: critical routines, advanced checking the registers, extreme values besides other several logical processes like: deflation of prices, composition of data and interaction with base of external data. The result at this stage is the database which will be used for the statistic analysis.

Trained interviewers accomplished the fieldwork and applied the questionnaires. The first stage of the research was done in notary identifying all the deals accomplished in the extracts of area of the pre-defined municipalities of the HZ. The purchasers once identified were interviewed with a

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<sup>14</sup> There is a necessity to estimate land prices in Brazil because the owners at the registry offices under declare the value of their properties to pay less property transfer tax.

100 questions questionnaire that generated more than 250 variables. The variables cover the next types of characteristics of the properties: physical (soil, climate, topography), productive (system of production, localization, access), infrastructure of the property (fences, buildings) and expectations (regional situation, local investments). This information was stabled in the database to be used in the statistical analysis that defined equations for land prices determination.

## 4.2 Model to determine the land price in HZ

From a refined database using as minimum unit of analysis the deals accomplished in an HZ – comprehended by a set of municipalities – multiple regressions were estimated to establish equations to determine land prices to be used as a base for the forecast of the price for an specific property. The model has as a dependent variable the rural land price, in a specific moment of time, and as independent variables the relevant characteristics of the farms that explain the land price in the same specific market. The estimation method is the ordinary least squares (OLS), with the use of the forward stepwise technique. This technique consists in the inclusion of the variables of highest explanatory power in the regression equation, which, in statistical and theoretical terms, contribute in higher level in the explanation of the variation of the dependent variable. The stepwise technique reaches a parsimonious model, which will be used to predict prices, respecting, however, the theoretical relation between the dependent and independent variables.

Land prices are determined by two kinds of variables: productive, related to land as a production factor and speculative, related to the land as an asset that maintains value. To study the variable effects on land prices in specific markets, from the information collected in the fieldwork the following equations will be estimated:

$$\text{PRICE}_t = a_0 + a_1X_{1t} + a_2X_{2t} + \dots + a_nX_{nt} \quad I = 1, 2, \dots, k. \quad t = 1, 2, \dots, n \quad (2)$$

Where:

PRICE: Price per hectare of property negotiated. This variable can be represented by the current price (PCTE) or by the real market price (PREAL). This last one was gotten from the current price deflated by IGP-DI, according January 2004.

Xi: represents the relevant variables that explain the variation of rural land price in the specific market. These variables can change from one HZ to another.

The basic hypothesis tested in the model (2) is the existence of a significant relation between the specific market and the variables proxy's that capture the expectations of the buyers at the deciding the land price moment.

## 4.3 The updating of the model of land prices determination



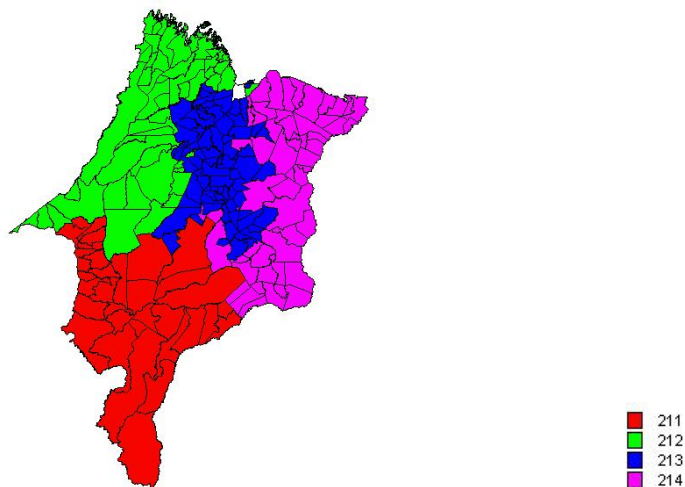
As soon as new trades of properties have been researched they can be included in the sample. It will permit the improvement of the equations with a larger sample. In the case of the Land Credit Program the loan obtained to purchase the land will permit a quick sample improvement, making easier the updating of the model. This updating will be done by the insertion of the same variable in all the new deals from the governmental programs: Consolidação da Agricultura Familiar (CAF), Credito Fundiário and Combate a Pobreza Rural (CF-CPR) and Minha Primeira Terra do Programa Nacional de Crédito Fundiário (PNCF). The data addition will be done through the integration of the collect program and analysis of data used in the routine process of PNCF coupled to a data-base in web, which receives and stocks the new information. This process of model updating requires a model maintenance team, which will monitor the entry of data and make the necessary adjustments to the equations so that they reflects the market changes and incorporates new data.

## 5. Application to the Maranhão State case

This item presents the application of the hedonic land prices model to a Homogeneous zone case of the state of Maranhão in the Northeast of Brazil. Using cluster analysis it was possible to identify 4 major homogeneous zones, such as illustrated in the Picture 1. From these 4 HZ the HZ 211 is the one for which complete analysis will be presented here.

Figure 1: Maranhão – ZH 211. Geographic distribution of sampled municipalities

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HZ 211 has 35 municipalities and, in the fieldwork, 75 questionnaires were collected in 8 sampled municipalities.

### 5.1 Refinement of the sample

In spite of the rigorous control of the data collection process, the possibility of incorrect values had to be carefully considered. Very low or high prices could be an indication of some kind of problem with the data. So, the refinement of the sample was based on the upper limit of a 95% confidence interval of price. Due to the high dispersion of the prices, the lower limit of the confidence interval was negative. Transactions with prices under R\$/ha 30.00 per hectare were eliminated based on a qualitative analysis of the market which indicated that such values would be extremely atypical. One observation had price under R\$/ha 30.00 and the prices of six cases were higher than the upper limit of the confidence interval (R\$/ha 409.70). Descriptive statistics of the sample after this refinement are presented in Table 1.

**Table 1. Maranhão – ZH 211. Descriptive statistics after sample refinement**

Number of cases	Mean	Standard deviation	Minimum	Maximum
68	147.4	79.15	30.73	376.22

Source: analysis by the authors

## 5.2 Multiple regression model

The multiple regression model to explain and predict the land price in the HZ 211, starting from a group of about 250 variables using the forward stepwise technique selected 5 explanatory variables, according to Table 2. Logarithm of land price per hectare (LNR\$/ha) was the dependent variable. Seven cases were eliminated based as outliers on Mahalanobis Distance, Cook Distance or Standardized residuals, leaving 61 observations in the final model.

Table 2 . Maranhão HZ 211. Results of the regression model

Dependent: LNR\$HAAT	Multiple R =	.83907609	F =	26.16827
	R <sup>2</sup> =	.70404868	df =	5,55
No. of cases: 61	adjusted R <sup>2</sup> =	.67714401	p =	.000000
	Standard error of estimate:	.303109987		

Source: analysis by the authors

The regression model explains approximately 70 % of the variance of the natural logarithm of land price per hectare. Above are some global indicators of the econometric model to predict the price of natural logarithm of the price of hectare of rural land in the HZ 211.

### 5.2.1. Variables of the model

In the HZ 211, the variables that best explained the land price are the ones described in the Table 3.

Table 3 Maranhão HZ 211. Description of model variables

Variable	Description	Expected signal of the estimated coefficient
Electric Power	Dummy variable which indicates the access to electric power. It takes value 1 when the farm has accessible electric power and 0 otherwise.	Positive, as besides representing benefits from electric power itself, this variable may be a proxy of other characteristics of infra-structure which usually come together with electric power.
Improvements	Dummy variable that indicates the existence of improvements in the farm, such as barns. It takes value 1 if there are improvements in the farm and 0 otherwise.	Positive, since improvements increase production alternatives.
Rock Fragments	Dummy variable which indicates the presence of rock fragments is considered good (1) soils with no restrictions due to rocks to mechanization and bad (0) the soil with rock fragments that makes mechanization impossible.	Positive, since it is expected that the property where rocks do not interfere in the use of mechanization has higher prices. Those in which the rock fragments makes mechanization impossible have lower prices.
Soil	Composite index which considers soil's physical properties, such as depth, texture. This index varies in a range from 10 to 100.	Positive, as soil with better physical properties allow greater land productivity and rent.
Subsistence	Dummy variable value 1 when the system of production of the property is agricultural and cattle rising related to subsistence and trade of surplus and 0 in the opposite situation.	The signal depends on the group of production system of HZ referred.

Source: analysis by the authors

Table 4 presents descriptive statistics of the independent variables.

Table 4 Maranhão HZ 211. Explanatory variables descriptives

	N	Mean	Minimum	Maximum	Std.Dev.
Improvements	61	0.25	0	1	0.43
Soil	61	78.3	50	96	7.89
Electric_Power	61	0.61	0	1	0.49
Rock_Fragments	61	0.74	0	1	0.44
Subsistence	61	0.28	0	1	0.45

Source: analysis by the authors

The mean, in the case of the **dummy variables**, represents the fraction of cases in which the variable assumes number 1 value (e.g. 61% of the cases present have access to Electric Power).

### 5.2.3. Estimated coefficients

Table 5 presents the standard coefficients, coefficients, standard error, value of the t test and p-value of the estimated coefficients<sup>15</sup>.

Table 5 Maranhão HZ 211. Estimated coefficients

	<b>Beta</b>	<b>Std.Err.</b>	<b>B</b>	<b>Std.Err.</b>	<b>t(55)</b>	<b>p-level</b>
Intercept			2.831	0.434	6.531	0.000
Rock_Fragments	0.374	0.087	0.450	0.104	4.317	0.000
Improvements	0.370	0.075	0.455	0.092	4.943	0.000
Subsistence	-0.216	0.076	-0.254	0.089	-2.852	0.006
Electric_Power	0.271	0.079	0.293	0.085	3.442	0.001
Soil	0.277	0.084	0.019	0.006	3.292	0.002

Source: analysis by the authors

According to Table 5, all the variables are significant at less than 1%. All the coefficients present the correct signal, as defined at Table 3.

The regression intercept indicates that, when the value of all the dependent variables is zero, the price forecasted by the model is R\$ 16.96 R\$/ha (antilog of 2.831). Because the dependent variable is the natural logarithm of rural land area, the value of B has different interpretations, which varies according to the functional forms of the explanatory variable refereed, such as described in Table 6.

Table 6. Maranhão HZ 211. Interpretation of parameters of the variables

<b>Functional form of the explanatory variables coefficient</b>	<b>Interpretation of estimated coefficient</b>
Logarithm	<i>Elasticity</i> – percentile change in the dependent variable for a one percent change in the explanatory variable
Continuous variable	<i>Logarithm of the rate of variation</i> – the predicted value is multiplied by $e^{\beta}$ for each unit change in the explanatory variable.
Dummy variable	<i>Logarithm of the price variation factor</i> – the predicted value is multiplied by $e^{\beta}$ when such a variable equals 1.

The B coefficient of the dummy variable **Rock\_Fragments** (0.450) indicates that when they do not interfere with the mechanization of the land, the predicted price of the property is multiplied by factor  $e^{0.450}$ , or that it increases in 56.8%.

<sup>15</sup> The column **Beta** would indicate the coefficients of regression if all the independent variables had been standardized with the average zero and standard deviation one, which permits the comparison of the influence of each independent variable on the price forecasted. The following column (**Std. Error**) represents the standard error of the standard coefficients. The column B indicates the estimated coefficients and the following column (Std. Error), its standard error.



Improvement	0.37	0.55	0.36	0.96	0.04	4.94	0.000
Soil	0.28	0.41	0.24	0.76	0.24	3.29	0.002
Electric_Power	0.27	0.42	0.25	0.87	0.13	3.44	0.001
Rock_Fragments	0.37	0.50	0.32	0.72	0.28	4.32	0.000
Subsistance	-0.22	-0.36	-0.21	0.94	0.06	-2.85	0.006

Source: analysis by the authors

Such as indicated in the table above, the value of Tolerance for all the explanatory variables of the models is superior to 0,1 which indicates the absence of serious problems of multicollinearity.

## Normality

Another relevant assumption of the multiple regression analysis is the normality of the residuals. The term of error of this regression model represents the aggregated effect of several variables related to the land price which weren't included as explanatory variables. By the Central Limit Theorem, the joint distribution of such variables is normal. A bias from normality could indicate an error of specification, which means, a relevant variable not included in the model. Moreover, the hypothesis tests of the linear regression model by OLS are based on a normal distribution of residuals.

**Table 8. Maranhão ZH 211. Residuals Kolmogorov-Smirnov normality test**

N		61,00
Normal Parameters(a,b)	Mean	0,00
	Std. Deviation	0,29
Most Extreme Differences	Absolute	0,12
	Positive	0,08
	Negative	-0,12
Kolmogorov-Smirnov Z		0,90
Asymp. Sig. (2-tailed)		<b>0,391</b>

Source: analysis by the authors

Table 8 indicates that the null hypothesis of residual normality in the Kolmogorov-Smirnov test can't be rejected with a significance level lower than 39%. This means residuals can be considered normal.

## Homoskedasticity

The heteroskedasticity occurs when, to the contrary to homoskedasticity, the variance of the error term is not constant, situation in which the estimates by OLS are not efficient any longer. One of the most used tests of heteroskedasticity is the White test, in which a regression is estimated in which the dependent variable consists in the residuals and the independent variables of the original model, their squares and their cross products are the dependent variables. Under the null hypothesis of homoskedasticity, the size of the sample (n), multiplied by  $R^2$  of the auxiliary

regression, follows a distribution  $\chi^2$  with degrees of freedom equal to the number of regressors, it means:  $n R^2 \sim \chi^2$  gl. A value of this statistic superior to the critical value  $\chi^2$  to a determined significance level indicates problems of heteroskedasticity (Gujarati, 2000).

Table 9. Maranhão HZ 211. Residuals homoskedasticity test (squares)

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Testing for Heteroscedastic errors (squares)  
 Chi<sup>2</sup>(6) = 2.4009 [0.8794] and F-form(6,48) = 0.32778 [0.9191]

V01=Improvement      V02=Soil      V03=Electric\_Power      V04=Rock\_Fragments  
 V05=Subsistance

Heteroscedasticity Coefficients:

	Constant	V01	V02	V03	V04	V05
Coeff.	-0.4087	-0.01496	0.0121	-0.01402	0.000613	-0.001462
t-value	-0.6812	-0.5392	0.7714	-0.5414	0.01951	-0.05431

	V02 <sup>2</sup>
Coeff.	-7.168e-005
t-value	-0.6972

RSS = 0.400508    \sigma = 0.091345

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Source: analysis by the authors

Table 9 shows the results of the regression of the residuals by the independent variables of the original model and its squares. The p-value associated to statistic  $\chi^2$  (0,8794) doesn't lead to the rejection of the null hypothesis with a significance level inferior to 88%, which indicates the absence of heteroskedasticity problems.

Table 10. Maranhão HZ 211. Residuals homoskedasticity test (squares and cross products)

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Testing for Heteroscedastic errors (squares and cross-products)  
 Chi<sup>2</sup>(16) = 9.0811 [0.9100] and F-form(16,38) = 0.41541 [0.9692]

V01=Improvement      V02=Soil      V03=Electric\_Power      V04=Rock\_Fragments  
 V05=Subsistance

Heteroscedasticity Coefficients:

	Constant	V01	V02	V03	V04	V05
Coeff.	-1.059	-0.1362	0.02595	0.4808	-0.0595	-0.2996
t-value	-1.049	-0.2981	0.9657	1.144	-0.1008	-0.8923

	V02 <sup>2</sup>	V02*V01	V03*V01	V03*V02	V04*V01	V04*V02
Coeff.	-0.0001379	0.001312	-0.02316	-0.007114	0.04147	-3.12e-006
t-value	-0.7284	0.2217	-0.3231	-1.287	0.4127	-0.0004074

	V04*V03	V05*V01	V05*V02	V05*V03	V05*V04
Coeff.	0.1081	-0.03464	0.00384	-0.005201	0.008259
t-value	1.363	-0.3967	0.8848	-0.066	0.09995

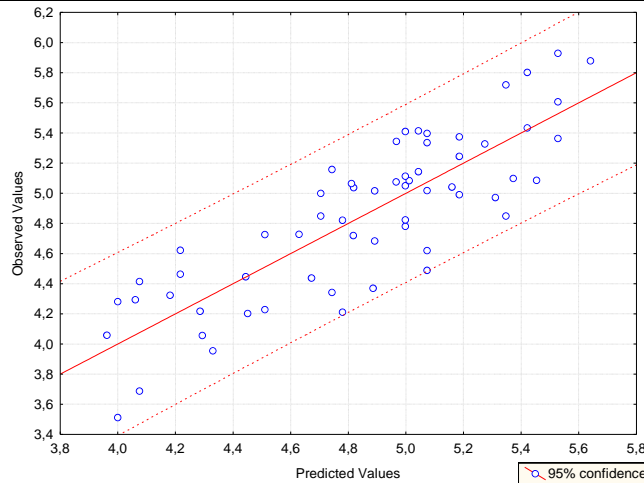
RSS = 0.354851    \sigma = 0.0966343

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Source: Analysis by the authors

Table 10 shows the results of the regression of residuals with the independent variables of the original model, its square and cross products. The p-value associated to the statistic  $\chi^2$  (0,91), doesn't lead to rejection of the null hypothesis with significance inferior to 91 % which indicates the absence of heteroskedasticity problems.

Figure 2. Maranhão. HZ 211 Predicted versus observed price of rural land hectare.



Source: analysis by the authors

Figure 2 indicates the predicted values by the model and real values of the property, ordered by the last and show the adequate adjustment of the model with all prediction lying on a 95% confidence interval.

Finally, it is important to highlight that this model can be used for prediction purposes only in the range of values of the dependent variable of the database from which was estimated.

## 6. Final considerations

This paper discussed and applied a methodology to explain and predict rural land prices per hectare in specific markets. This methodology is based on a multiple regression model, with the logarithm of the rural land price per hectare as dependent variable and, as explanatory variables, a group of variables related to the physical aspects (soil, climate, landscape), production (systems of production, localization, approach) infrastructure of the property and expectations (regional situation, local investments). The stepwise technique was used to select the variables included in the model: existence of Rock Fragments, Improvements, Subsistence as the main use of the property, access to Electric Power and Soil characteristics.

This model permitted the explanation of 70% of the variance of price per hectare of rural land. The assumptions of the multiple regression model were respected, in terms of the normality and homoskedasticity of the residuals. Multicollinearity was kept in acceptable levels. In general terms, the statistic, economical and econometric evaluation of the models showed to be satisfactory for the prediction of rural land price per hectare in the Homogeneous Zone in



question. The model has been used by the Brazilian Ministry of Agrarian Issues to establish limits for buying land through the different land credit programs all around the country.

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