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RESEARCH

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Possible effects of potential lahars from Cotopaxi volcano on housing market prices

Richard Caleb Echegaray-Aveiga[1], Fabian Rodríguez-Espinosa[1,2*], Theofilos Toulkeridis[1] and Richard Damian Echegaray-Aveiga[1]

Abstract

The recent awakening of the Cotopaxi volcano in Ecuador set the conditions to estimate and verify the possible effects of potential lahars on residential housing unit prices. About 300,000 people live in the Los Chillos valley, which is the northern natural drainage of Cotopaxi's lahars; therefore, the effects on house values can be significant. We have used housing information from 2016 of 240 properties to settle a hedonic price model within and outside of the lahar's area. The regression model has a significant R^2 value of about 0.723. The variable that determined the effects of potential lahar on the hedonic model demonstrates that the value of a residence house unit will increase its price by 41.99 USD for each meter away from the lahar path. Our study suggests that environmental disamenities generated by natural hazards will have a negative effect on residential house unit prices and we infer that consumers would be willing to pay a higher price in order to avoid such potential disamenities.

Keywords: Economic assessment, Floodplain, Integrated flood risk management, Risk assessment

Introduction

Hedonic housing models provide an intuitive analytical tool for adjusting property prices to environmental amenities and disamenities (Hulten 2003). The hedonic function relates to the supply and demand of different individual characteristics of properties and individual consumer taste preferences (Rosen 1974; Hulten 2003). Based on the mentioned aspects, the consumer reacts to environmental amenities and disamenities the same way as they do to the number of floors or bedrooms (Triplett 1983; Epple 1987; Feenstra 1995). Accordingly, environmental disamenities, such as contamination or natural hazards, will have a negative effect on housing attributes and prices and consumers would be willing to pay more in order to avoid such potential disamenities (MacDonald et al. 1987; Pryce et al. 2011). Bin et al. (2008) and Brookshire et al. (1985), who were the pioneers to consider risk factors in the context of hedonic models and housing prices, demonstrated how floods affected the coastal housing markets in North Carolina using GIS tools. Further studies of housing prices in relation and proximity to natural hazards followed (MacDonald et al. 1987, 1990; Bin and Polasky 2004; Troy and Romm 2004; Samarasinghe and Sharp 2010; Pryce et al. 2011; Egbenta et al. 2015; De Koning et al. 2016). Such studies included the analysis of the effects of flooding in communities around the USA and beyond (De Koning et al. 2016; MacDonald et al. 1990), the effects of hurricanes in coastal areas (Hallstrom and Smith 2005), the effects of erosion in rural and coastal communities (Kriesel et al. 1993; Landry et al. 2003), the effects of wildfires and forest fires (Donovan et al. 2007; Rossi 2014; Kiel and Matheson 2015) and the effects of earthquakes as well as volcanic activity (Bernknopf et al. 1990; Murdoch et al. 1993; Beron et al. 1997; Timar et al. 2014). All of these studies show that house prices decreased with increasing exposure to natural hazards.

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* Correspondence: ffrodriguez3@espe.edu.ec
[1]Universidad de las Fuerzas Armadas ESPE, Sangolquí, Ecuador
[2]Facultad de Economía, Pontificia Universidad Católica del Ecuador, Quito, Ecuador

In the current study, we have analyzed the current economic effects of potential lahars from Ecuador's Cotopaxi volcano. This volcano, which has been categorized as being one of the most dangerous volcanoes in the world (Miller et al. 1978; Barberi et al. 1995), is located in the northern volcanic Andes and is known to have had a vast history of lahar generations due to explosions reaching a Volcanic Explosivity Index of 4–5 (Barberi et al. 1995; Aguilera et al. 2004; Aguilera and Toulkeridis 2005; Pistolesi 2008; Pistolesi et al. 2013, 2014; Toulkeridis 2013; Toulkeridis et al. 2015). Past historical eruptions have had devastating impact in the areas surrounding Cotopaxi in 1534, 1742, 1768 and 1877, in which lahars destroyed important areas towards the northern and southern sides of the volcano and to a lesser extent towards its eastern area (La Condamine 1751; Sodiro 1877; Whymper 1892; Wolf 1878; Mothes 1992; Barberi et al. 1995; Aguilera et al. 2004; Garrison et al. 2011; Pistolesi et al. 2013, 2014). The aforementioned references describe in detail the trajectory and impact sites of the lahars as well as their volumes and velocities. Furthermore, studies of dated past lahar deposits indicate some 19 strong eruptive phases with concurrent lahar formations, suggesting a recurrence interval of 117 ± 70 years over the last 2200 years (Barberi et al. 1995). A lahar's travel model was developed by Padilla and Bosque (2014) based on past eruptions and lahar deposits. The model included risk vulnerabilities to assess evacuation routes and victim assistance. The Padilla and Bosque model was adopted for this study to determine critical lahar hazard areas.

Cotopaxi volcano reawakened in 2015, recording seismic unrest and hydrothermal eruptions lasting for about three months (Toulkeridis et al. 2015; Vaca et al. 2016; Toulkeridis and Zach 2017; Toulkeridis et al. 2018). Due to an unjustified alert by the underprepared volcanic monitoring staff on the 15th of August 2015, people panicked, and eight persons died due to these events (Toulkeridis et al. 2018). This resulted once again in a drop in house market prices, as house owners of buildings within the known lahar trajectory tried to sell their property and to leave this risky area. This belief is not totally unwarranted. A recent study suggest that economic losses of a potential eruption could reach 17 billion USD, while the cost estimation of mitigation structures that would prevent those potential losses was approximate 150 million USD (Rodríguez et al. 2017).

Currently, about 300 thousand people live in the Los Chillos valley, which is the northern natural drainage of Cotopaxi's lahars. Several parishes are located along Pita, El Salado, and Santa Clara rivers such as Sangolquí, San Rafael, San Pedro de Taboada, Conocoto, and Alangasí. One particular condition due to the proximity between the Pita and Santa Clara rivers (Fig. 1) is that, in the event of a volcanic eruption and the generation of far-reaching lahars, flows in the Pita river will be able to

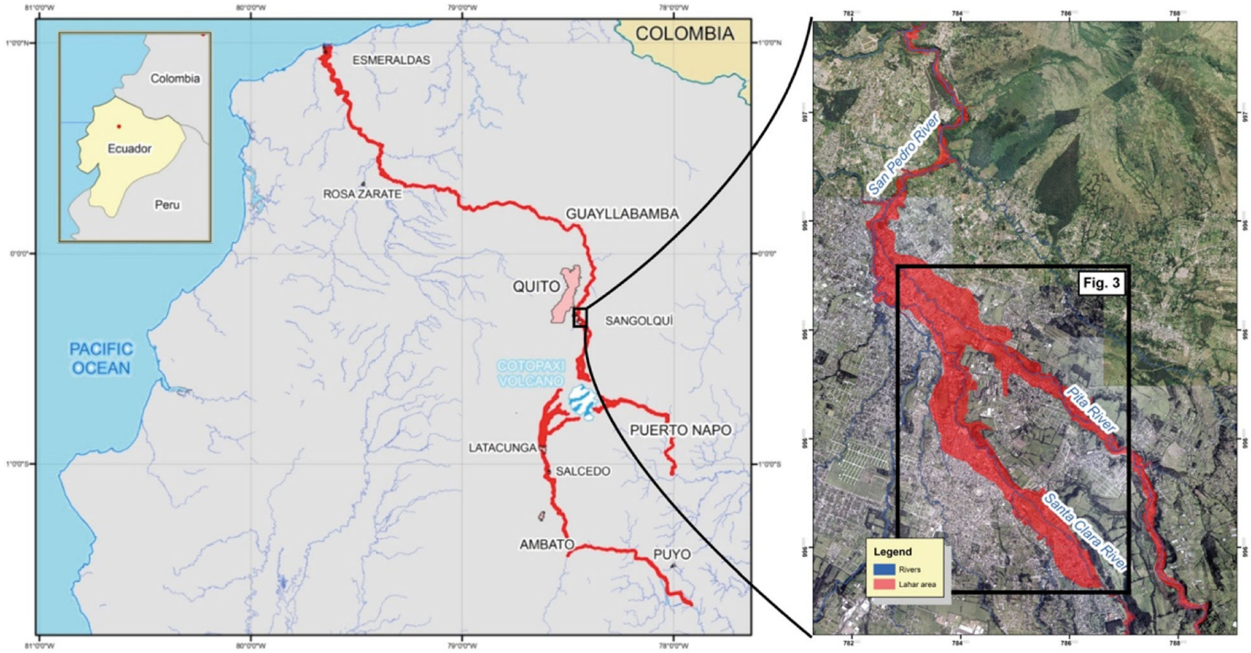


Fig. 1 Inlet upper left: Ecuador's position in northwestern South America. Left: Ecuador with the trajectory of lahars of the volcano Cotopaxi. Right: the study area (square) of the Chillos Valley within the lahars (red) of the Rivers Pita and Santa Clara (blue). Map adapted from Padilla and Bosque (2014)

overflow into Santa Clara River (Barberi et al. 1995; Aguilera et al. 2004; Aguilera and Toulkeridis 2005; Cáceres et al. 2004; Padilla and Bosque 2014). The exact overflow point is at the Cabre ravine, which is where the Santa Clara river emerges, as the closest spot between both drainages (Aguilera and Toulkeridis 2005). This current study is the first to relate potential lahar hazard effects on the housing market in Ecuador. A related study of housing market between 2010 and 2014 in the Los Chillos valley (Calderon 2015) determined what characteristics affected house prices during that period of time. Calderon (2015) obtained an average price of 167,862 US dollars per unit, but did not mention whether potential natural hazards could have an effect on the housing market.

Methodology

The methodology has been divided into an economic and a geographic part. The first part is composed of the hedonic model used, while the second part comprises the GIS tools used for spatial research. The latter is subdivided into six distinctive parts: location variables using GIS tools, the study area, the housing sample, Real Estate information, spatial information database as well as the final OLS regression model used. The combined methodology may be summarized in four different phases, namely planning, the exploratory phase and test, the implementation phase and finally analysis and interpretation (Fig. 2).

Hedonic model

We have used the hedonic price approach in order to estimate the impact of potential volcanic lahars in residential areas in five parishes of central Ecuador. These parishes are in the lahar hazard area of Cotopaxi volcano and have been historically affected by the lahars triggered by it. The hedonic model is the traditional model developed by Lancaster (1966), Rosen (1974), Quigley and Kain (1970), and Drakopoulos (1991), and it is a function of a combination of structural, neighborhood, and environmental characteristics. The general model may be expressed as:

$$P = (S, N, E, Z) \tag{1}$$

Where P is the housing sale price, S refers to structural attributes, N refers to social attributes, E environmental attributes and Z natural hazard attributes. Due to limited information on individual house market prices, mainly because this information is not freely available, and real estate companies are not willing to provide such information, we have used recent house sale prices instead. In addition, because the relationship between price and independent variables may not be linear, we considered a log-semilog function (Gujarati and Porter 2009; Taylor 2008), which may be expressed as:

$$P_i = \beta_{i1} X_i^{\beta_2} e^{u_i} \tag{2}$$

where the natural log of the price of a house P_{ith} is a function of the J characteristics assumed to influence price, $\hat{\alpha}$ and $\hat{\beta}$ are coefficients to be estimated, and ε is a normally distributed error term. One of the reasons for using the log-semilog model is to estimate partial elasticity of price housing characteristics (Gujarati and Porter 2009). According to Gujarti and Porter (2009), this elasticity represents the marginal willingness to pay for additional upgrading of housing characteristics.

We have used price as the dependable variable, representing the sale market price. Our independent variables are structural, neighborhood, environmental and natural

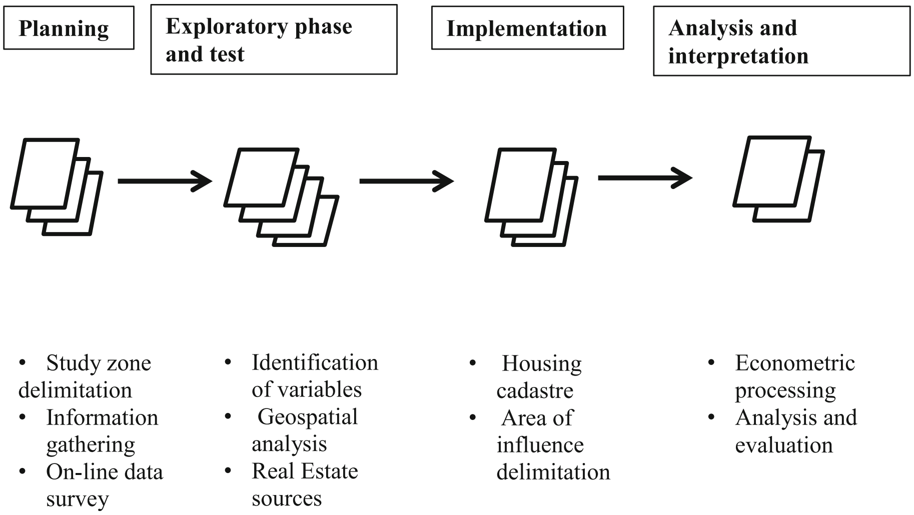


Fig. 2 Methodological diagram of the current study

hazards attributes, the latter of which is measured as the distance between selected properties and the Santa Clara River. Structural attributes are nominal variables, meaning the value assigned for each structural characteristic according to house market value. Additionally, five independent dummy variables were settled with available GIS tools, as well as location, to indicate to which parish each house belongs. The specific hedonic pricing model to estimate the effects of potential lahars from Cotopaxi volcano is best expressed with the following equation:

$$lnP_i = f(lnAC_i,\ \ln NP_i,\ \ln ND_i, \ln NB_i, MC_i, UE_i, CS_i, UPC_i, AR_i, GA_i, lnD, ZA_i, PA_i) \tag{3}$$

where:

lnP:	Natural log of market housing sale prices (sales prices in US$)
AC:	Natural log of house construction area in square meters
NP:	Natural log of the number of floors
ND:	Natural log of the number of bedrooms
NB:	Natural log of the number of bathrooms, assigning a value of 1 to each full bathroom
MC:	House' construction materials j = 1, 2, 3, 4 (Adobe bricks = 1, timberwood = 2, concrete bricks and timberwood = 3, concrete and concrete bricks = 4)
UE:	A dummy variable (1 if the house is within school area of influence, otherwise 0)
CS:	A dummy variable (1 if the house is within health center area of influence, otherwise 0)
UPC:	A dummy variable (1 unit house is within police station area of influence, otherwise 0)
AR:	A dummy variable (1 if the house is within urban recreational areas of influence, 0 otherwise - environmental variable)
GA:	A dummy variable (1 if the house has a garage. Otherwise 0)
CO:	A dummy variable (1 if the house is part of a residential housing unit, otherwise 0)
D:	Natural log of distance to Santa Clara River in m.
ZA:	Natural hazard variable. A dummy variable (1 if the house is within the Cotopaxi's lahar hazard area, otherwise 0)
PA:	Parish in which the house is located

Spatial research

Location of variables using GIS tools

Variables of education, health, and police stations were located using GIS tools and GPS data in order to be georeferenced. Regarding recreational parks and houses on sale, we performed a digital survey using a Smartphone application called 'GeoODK collect™. This digital survey has been linked to the Formhub platform developed by the Modi Research Group of Columbia University. The digital survey was carried out over 10 days inside the previously delimited study area (Figs. 1, 3 and 4).

Study area

The study area (Fig. 3) is delimited by an area of 1 km either side of the Santa Clara River. Based on the Rumiñahui canton and the Metropolitan District of Quito (DMQ) cadastre, 10,012 buildings were located and distributed in five parishes, namely San Rafael (1167), Sangolquí (7425), San Pedro de Taboada (215), Conocoto (533), and Alangasi (762).

Housing sample

We established a housing sample with Weimer's formula, which is used when the population is finite and a confidence interval is estimated, for the average of the sample (Weimer 2011).

$$n = \frac{N\sigma^2 Z^2}{(N-1)e^2 + \sigma^2 Z^2} \tag{4}$$

where;

n = is sample size.

N = Population size.

σ = Standard deviation of the population, as it is generally unknown, it takes a constant value of 0.5.

Z = Confidence value at 95% which is 1.96.

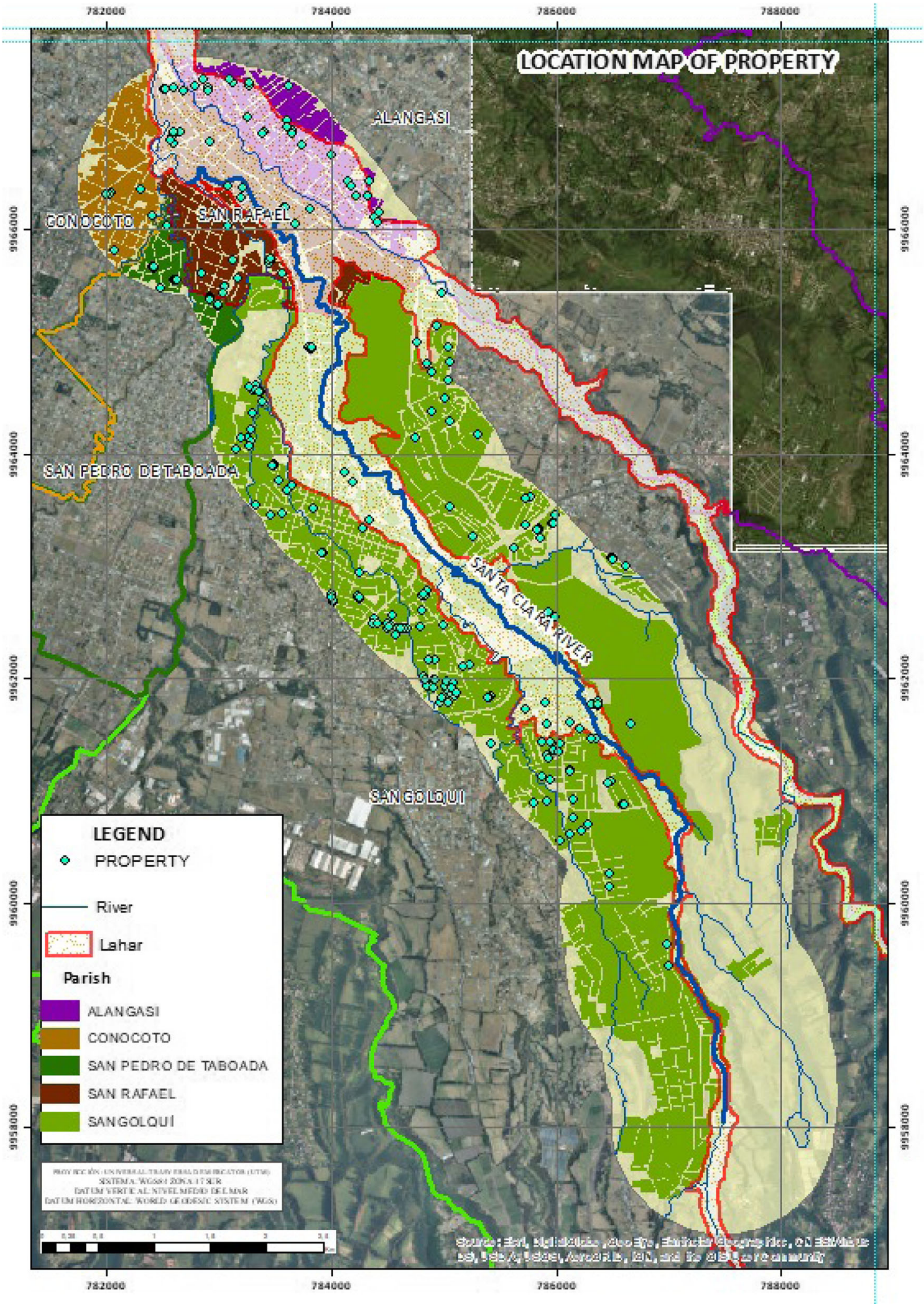
e = limit of sample error at 5%.

The housing sample yielded 371 housing units, but we have been able to obtain information only from a percentage of that number. Therefore, a total of 240 housing units were analyzed during the current study, as those units were the only ones on sale during a 6 month period in 2016, when our study was performed.

Real estate information

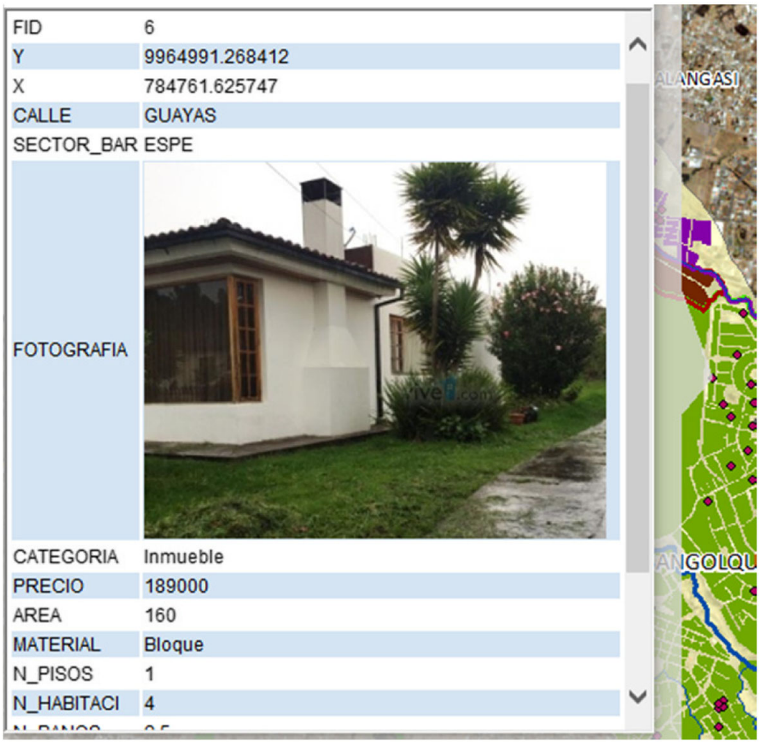
In addition to Rumiñahui canton and Quito Metropolitan Distric DMQ cadastre information, we also evaluated information from Real Estate companies, with a variety of useful sites, including Proinmobiliaria (2017), Plusvalia (2017), Provivienda (2017), E-viviendas (2017), Inmofer (2017), Kanda Inmobiliaria (2017), Nuroa (2017), Ecuador Bienes Online (2017), Inmobiliaria Excelencia (2017), Empresas and Servicios Profesionales (2017) and Vive1 (2017).

Housing information from these sites was variable, as such data depend on each Real Estate firm. However, some of the variables were available across all firms such as house price, construction area, number of floors, bedrooms and bathrooms, construction material, existence of a garage, and whether or not the house was part of a residential housing unit. This information was used to estimate the potential effects on house prices of the generation of Cotopaxi's lahars (Table 1). Furthermore, we referenced health and education centers, police stations, recreation areas, as well as zones with respect to the drainages of the lahars, using ArcGis™ tools. The zone of



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 3 Location map of housing units



FID	6
Y	9964991.268412
X	784761.625747
CALLE	GUAYAS
SECTOR_BAR	ESPE
FOTOGRAFIA	
CATEGORIA	Inmueble
PRECIO	189000
AREA	160
MATERIAL	Bloque
N_PISOS	1
N_HABITACI	4

Fig. 4 HTML Popup tool visualization

lahar reach has been spatially located based on recent mapping (Padilla and Bosque 2014).

In order to prevent data wrong interpretation from our study related to social inequality and marginalization where people in disadvantaged and marginalized situations tend to settle on river margins or unsuitable slopes. Bird et al. (2010) defined as spatial poverty traps. This study takes into consideration value and size of housing units within 100 m from the river and compares them to the national housing program of Ecuador. This national housing program is set to build units for families living under the poverty line or in inadequate housing. The Ministry of Urban Development and Housing of Ecuador (MIDUVI) housing units have approximately 60 m^2 of construction area and a cost of 24,000.00 dollars per house unit (Miduvi 2017). In this study, the value of housing units within 100 m is much higher than the national housing program.

Table 1 Descriptive statistics of the used variables

Variable	$\overline{X}$	σ
LogP:	11.831	0.511
LogAC:	5.122	0.544
LogNP:	0.662	0.310
LogND:	1.179	0.303
LogNB:	1.007	0.371
MC:	3.54	0.387
UE:	0.679	0.468
CS:	0.504	0.501
UPC:	0.296	0.457
AR:	0.387	0.387
GA:	0.975	0.156
CO:	0.800	0.401
LogD:	6.63	0.696
ZA:	0.233	0.424
PA	1.601	0.096

Spatial information database

We located and recorded all the data collected using ArcGis™ and presented them in a location map in which all 240 sample units were georeferenced (Fig. 3). In addition, we added a field in the ArcView™ software to illustrate graphic evidence of each housing unit using an HTML Popup tool (Fig. 4). Afterwards, we determined the distance of each housing sample unit to the Santa Clara River (Fig. 5). Furthermore, we also used ArcGis™ to set an area of influence of neighborhood attribute variables. Local and national regulations establish the appropriate distance for services such as hospitals and other health services, education such as schools and high schools, as well as police headquarters related to the size of the population (Senplades 2014). Based on

Fig. 5 Distances of real estate towards the Santa Clara river

these regulations, we set the area of influence that helped to define our CS, UE and UPC variables.

Final OLS regression model

Finally, when our probabilistic model had been settled, it demonstrated the relationship between our dependent variable (lnP) and the semilog independent variables. The following equation of our regression model has been expressed as follows:

$$\begin{aligned} lnP = {} & \beta_0 + \beta_1\,\mathrm{lnAC} + \beta_2\,\mathrm{MC} + \beta_3\,\mathrm{lnNP} \\ & + \beta_4\,\mathrm{lnND} + \beta_5\,\mathrm{lnNB} + \beta_6\,\mathrm{GA} + \beta_7\,\mathrm{CO} \\ & + \beta_8\,\mathrm{AR} + \beta_9\,\mathrm{CS} + \beta_{10}\,\mathrm{UPC} + \beta_{11}\,\mathrm{UE} \\ & + \beta_{12}\,\mathrm{lnD} + \beta_{13}\,\mathrm{ZA} + \upbeta_{14}\mathrm{PA}_{14} + \varepsilon \end{aligned} \tag{5}$$

Where β_0 is the variable that expresses the intercept generated on axis Y (P).

We performed the regression and determined the adjusted R^2 coefficient in order to establish the relationship between each independent variable with our dependent variable (Vivanco 2005). As some inconsistencies appeared in this first model, we did not take into consideration some of the variables due to evident collinearity. A Dublin Watson test was conducted in order to correct any autocorrelation problem. Therefore, the final hedonic price log-log model was expressed as follows:

$$\begin{aligned} lnP = {} & \alpha_0 + \alpha_1 lnAC + \alpha_2 NP + \alpha_3 NB + \alpha\beta_4 lnDis \\ & + \epsilon \end{aligned} \tag{6}$$

where,

lnP:	Natural log of market housing sale prices (housing sale prices in US$)
lnAC:	Natural log of house construction area (construction area in square meters)
lnNP:	Natural log of the number of floors (number of floors in units)
lnNB:	Natural log of the number of bathrooms, (assigning value of 1 to each full bathroom – units)
lnD	Natural log of distance to Santa Clara River (distance in m). Natural hazard variable

Results and discussion

Initially, 13 independent variables were considered in the hedonic price model (Table 1). This initial analysis yielded a 0.817 adjusted R^2 (Table 2). The results indicate that only three variables were significant at 99%: housing area (AR), number of floors per housing unit (NP) and environmental amenity variable (AR), reflecting a recreational park (Table 2). The rest of the impendent variables lacked significance, including distance to Santa Clara River, which was our natural hazard risk variable. The variable construction material MC also lacked significance, as almost all houses were built of concrete and concrete bricks. Therefore, this variable clearly did not vary. Similarly, the variable number of bedrooms NB was not significant. We attribute the latter to a lack of variability in the housing sample, as the vast majority of units had three bedrooms, while very few houses had more or less three bedrooms and none of the houses had only one bedroom.

Table 2 Results of log-semilog model

Variable	Log-Log Model
Dependent	Log (pm)
Constant	8.510 (24.448)^{c}
LnAC	0.730 (13.656)^{c}
MC	−0.013 (−0.311)
LnNP (units)	−0.113^{a} (−1.725)
LnNH (units)	0.007 (0.062)
LnNB (units)	0.132 (1.488)
GA	−0.108 (−1.040)
CO	0.003 (0.066)
AR	−0.214 (−4.665)^{c}
CS	0.043 (1.317)
UPC	−0.0004 (−0.009)
UE	0.03318 (0.416)
LnD (m)	−0.004 (− 0.156)
ZA	−0.055 (−1.178)
PA	−0.187 (−1.099)
R^2 Adjusted	0.817
Durbin-Watson	1.882
F-Stat	77.249461^{c}

Statistics t are in parentheses. ^{a}Exceeds 90% confidence level (t > │1.28│; ^{b}Exceeds 95% confidence level (t > │1.96│; ^{c}Exceeds 99% confidence level (t > │2.58│

Nonetheless, we needed to eliminate some of the variables due to the evident existing collinearity between them. We ran a Durbin-Watson test in order to correct any correlation. Within the final regression model, the Durbin-Watson test yielded a value of about 1.882. Moreover, the variable recreational park *AR* bends the variable distance *D*, which measures the natural hazard risk, i.e., the distance between housing units and the Santa Clara River, the natural path of a potential Cotopaxi lahar. The Santa Clara River is a lineal recreation park recognized by the local government of the Rumiñahui canton. In order to receive the protection status of "lineal recreation park", the recreational park of Santa Clara River needed to meet some environmental standards including being free or close to free of contamination. The water quality of Santa Clara River has high water quality (Guzmán Salazar 2011). As an environmental amenity, AR was statistically significant with a β_8 coefficient value of – 0,214 and 0.000 of significance, while for the distance D we yielded a β_{12} coefficient of – 0.004 (Table 2), lacking statistical significance. Regarding spatial poverty traps, we encountered only eleven housing units located within 100 m from Santa Clara River. The average construction areas of these units was 178.64 m^2 and the housing value reached over 115,000 US dollars per unit. Our sample units close to Santa Clara River did not fit with the national housing program housing standards; therefore, our units were not suitable to be considered as part of spatial poverty trap problem.

In order to determine whether an awareness of the Santa Clara River as a lahar hazard zone exists, and how it would influence housing values, we did not consider the variable AR in the final regression, leading to interesting results. The new hedonic price model has an adjusted R^2 of 0.791 (Table 3). All variables used in the final regression log-log model were statistically significant. The variable *D* improves considerably, with the β_4 coefficient value of 0.043 and a significance of 0.057 (Table 3).

The results demonstrate that a natural hazard such as volcano's lahar has a significant negative effect on housing values. In the particular case of Cotopaxi's lahars, house prices increase by 4.3% in value with each 1% increase in distance away from Santa Clara River (Table 5). Certainly, it does not appear to be a huge value difference at first glance, but residents of the studied valley affected by the Cotopaxi volcano have just recently become aware of any potential economic losses and may be taking this into consideration when buying a property. Yet, the results support our initial assumption that a natural hazard significantly affects property value. Sixty four houses of the sample are at direct risk impact from Cotopaxi's lahars.

As expected, the number of bathrooms has a positive impact on house prices and was statistically significant as well (Table 3). An interesting result is the number of floors, which we expected to have a positive effect on house prices, but the results suggest otherwise.

The reasons for this unexpected result is unknown, but it is possible that a local government ordinance may have played a significant role. This ordinance limits the number of floors for residential and commercial buildings. It may be also possible that a limited area for

Table 3 Results of log-log model

Variable	Log-Log Model
Dependent	Log (pm)
Constant	7.770 (33.085)^{c}
LnA (m^2)	0.724 (15.070)^{c}
LnN_P (units)	−0.208 (−3.581)^{c}
LnN_B (units)	0.218 (2.824)^{c}
LnD (m)	0.043 (1.910)^{a}
R^2	0.791
Durbin-Watson	1.694
F-Stat	227.26^{c}

Statistics t are in parentheses. ^{a}Exceeds 90% confidence level (t > │1.28│; ^{b}Exceeds 95% confidence level (t > │1.96│; ^{c}Exceeds 99% confidence level (t > │2.58│

land parcels induces local residents to build up to four floors in accordance with the Rumiñahui canton ordinance, but within an area no greater than 130 m^2. The resulting values of these houses are between 80 and 120 thousand USD.

Our hedonic price model is summarized in the following equation:

$$lnP = 7.77 + 0.724 * lnAC - 0.209 * lnN\_P + 0.218 * lnN\_B + 0.043 * lnD \quad (7)$$

Finally, we note that our study area is not exclusively a residential area, rather there are also local and national government agencies as well as commercial buildings such as malls and restaurants. However, we did not consider these buildings in our hedonic price model.

Conclusions

The Hedonic Regression Model allowed us to estimate the effect of potential lahars from the Cotopaxi volcano on housing. As a tool, the hedonic price model enabled us to determine the correlation between house characteristics and the sale price. The results illustrate that distance D has a positive β coefficient value with price, meaning that the price of a residential house property located within Cotopaxi's lahar hazard area is significantly lower than that of other residential properties located outside of the area of the lahars' influence. We determined that the price of a residential unit increases by 4.3% for each 1% in distance moving away from the Santa Clara River. The results are significant because, with an average housing price unit of 159,239 US$, the lost 6863 US$ represents a significant drop in property value. This average housing price 159,000 is 5.1% lower than the price reported by Calderon (2015) in his study.

We found 64 houses from our sample at direct risk of impact from potential lahars from Cotopaxi, and we suggest local government should consider expanding the current study in order to determine how many more properties would be directly affected. There are some limitations to our analysis since we did not compare the natural hazards insurance cost. This has been partly because there is limited information about that kind of insurance premium from the area of study. There is also an extremely limited market of natural hazards insurance programs in the residential area of Sangolquí. Therefore, we expect that any price differential, as revealed in our study, would be greater than the cost of lahar insurance premiums. For this research, we did not consider a time series study due to restricted information regarding the housing market in the area of study. Based on the information from Real Estate firms' web information of sales during 6 months in 2016, our results are site-specific. Therefore, our data analysis may not be suited to any generalization required for policy making. Nevertheless, the results highlight the need for other studies that focus on policy mitigation.

Abbreviations

DMQ: Metropolitan District of Quito; GIS: Geographic information systems; GPS: Global positioning system; HTML: HyperText markup language; MIDUVI: Ministry of urban development and housing; OLS: Ordinary least squared; TM: Trademark; USA: The United States of America; USD: United States Dollars; VEI: Volcanic explosivity index

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Authors' contributions

Contribution of each author is as follows: B.Sc. Richard Caleb Echegaray-Aveiga designed the spatial model and potential effects on housing gathered real estate information. Dr. Fabián Rodríguez-Espinosa focused on economic modeling and analysis. Dr. Theofilos Toulkeridis worked on potential damage by Cotopaxi volcano's lahar. B.Sc. Richard Damian Echegaray-Aveiga gathered real estate information and tabulated all data. The author(s) read and approved the final manuscript

Authors' information

Information about authors was included in the ADD/Edit Authors Section of the journal submissions format.

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Availability of data and materials

The data were gathered from Real Estate business companies, which are included in the paper's Reference List.

Ethics approval and consent to participate

Not applicable. The present study was designed using public information and data, as a result, it did not require consent to participate. Additionally, the econometric model has no ethical implications and did not affect any person that might require ethics approval.

Consent for publication

The main goal of authors of this research was, and still is, to get published as it is clearly included in "cover letter" where authors are declaring their consent.

Competing interests

We ensure, that our manuscript has NOT been submitted simultaneously for publication anywhere else, containing original data and a paper not presented previously at any congress as it was stated in the author's "cover letter". We do not have any material (figures, images or tables) included in the manuscript that may require to obtain permission to reproduce copyrighted material from other sources, and there is no conflict of interest with any party.

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