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Room for the Volcano?

Shaping the risk management strategies of households in areas prone to Lahar risk in Latacunga - Ecuador

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Photograph 1: View of Cotopaxi Volcano from the city of Latacunga (Tierra Zero Tours, 2019)

"Cotopaxi is beautiful, it's a beautiful monster!" Ivan, resident of Latacunga (July 2019)

Summary

As cities thrive in an urbanizing world, they face growing responsibilities and challenges. Dangerous areas once populated by a few hundred are now growing by the thousand leading to political and environmental change and socioeconomic growth rephrasing the internal dynamics of the urban. The objective of this study is to explain a section of this dynamic in an intermediate city 2800meters above sea level which resides near the most dangerous volcano in Ecuador. Cotopaxi Volcano's threat is increased by its ability to produce dangerous cement-like flows called lahars that move rapidly along rivers and can destroy all that is in their way. The research looks at the city of Latacunga from the bottom up focusing on households, how they perceive this eminent risk and what strategies they use to protect themselves from the unpredictable. The research uses a mixed method of 200 surveyed households and fourteen interviews with residents, NGOs and government officials.

Results indicate that households are aware of the risk and have learned to live with it. They rely on evacuation plans and a range of strategies to use in case of disaster. Although Cotopaxi's last major lahar eruption was in 1877, a small eruption in 2015 tested the city's preparedness but also gave the citizens valuable experience on what issues they might face in case of a bigger event. Social factors such as closeness to family and social networks keep people from leaving risky areas in addition to the financial investments they made in their property. Citizens rely on religion and personal belief putting their future in the hands of God and so they continue to live their life near Cotopaxi volcano.

Keywords

Risk management strategies, Lahars, Land use change, Risk governance, Households, Latacunga, Cotopaxi, Ecuador

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Abbreviations

IHS	Institute for Housing and Urban Development
RM	Risk Management
DRM	Disaster Risk Management
DRG	Disaster Risk Governance
DRR	Disaster Risk Reduction
INEC	National Institute for statistics and censuses - Ecuador
IG EPN	Instituto Geofísico de la Escuela Politécnica Nacional
ISTC	Instituto Superior Tecnológico Cotopaxi
COE	Comité de Operaciones de Emergencia: Committee of Emergency Operations
LUC	Land Use Change

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Chapter 1: Introduction

In a world that is rapidly urbanizing, over 600 million people live near active volcanoes (Stone, Barclay, et al., 2014). Of these, many reside in major cities within 100 kilometres of a volcano's vicinity including Tokyo, Auckland, Naples, and Seattle (Kelman and Mather, 2008). This section introduces volcanic risk as a major threat and source of opportunity for such cities around the world. It will identify the different hazards generated by volcanoes and highlight lahar risk as the focus of this study. The impacts of lahars on land governance will then be outlined followed by an introduction to the case study of Latacunga and the 2015 eruption of Mount Cotopaxi. The chapter will conclude with the main research question and the sub-questions.

1.1 Background:

"With destruction comes reward, with death, comes life" (Amongst Fire, 2017).

As cities continue to grow at unsurpassed rates around the globe, they are faced with man-made and natural hazards imposing challenges critical to their existence. Volcanoes present a source of these hazards as they presume a major threat to millions of lives, however they provide resource endowments that continue to attract agglomerations of populations to high-risk areas (Engerman and Sokoloff, 1997, Chester, Dibben, et al., 2002). In addition to creating some of the most fertile soils on earth volcanoes present a rich source of tourism and provide various minerals for mining (Stone, Barclay, et al., 2014). Evacuation and resettlement efforts from areas at high volcanic risk have hence failed as residents perceive the benefits of remaining in areas prone to volcanic disaster surpass the costs (Sagala, 2009). This is increased by the fact that volcanoes can remain dormant for long periods of time and reactivate gradually providing in most cases sufficient warning prior to devastating eruptions (Favereau, et al., 2018).

Volcanic activity can range from airborne ash and gases to magma and pyroclastic flows. Lahars are one of these hazards which take place in the physical context of land and can lead to the devastation of people and cities. Originally an Indonesian term the word "lahar" is used to describe flows of debris, transition or hyper-concentrated flows that originate at the volcano. Lahars are characterized by a high liquid percentage that makes them flow to areas far from the source. Their destructive power is increased by their speed, reach, and the rock fragments they carry (Vallance, 2000).

Lahar flows can be highly destructive causing damage to anything in their path. They can occur during a volcanic eruption due to pyroclastic flows melting the glacier top, or by volcanic debris mobilized by rain. The later occurrence is more dangerous due to its unpredictability (Pierson, Thomas, Wood, et al., 2014). One of the most devastating volcanic disasters in modern history occurred in 1985 in Colombia during the eruption of Nevado Del Ruiz volcano. Lahars flowing at a speed of up to 100km an hour resulted in the destruction of over 5000 homes and the death of 23000 people making it one of the most tragic volcanic disasters in modern history (Vallance, 2000, Pierson, Thomas, Wood, et al., 2014). Lahars reached Armero; a town in the vicinity of the volcano in about 2.5 hours after an eruption produced hot pyroclastic flows melting the snow from its summit and killing over 20,000 inhabitants of Armero alone (UN Office for Disaster Risk Reduction, 2015).

Photograph 2: "The only remaining buildings in Armero, Colombia, 72 km downstream from Nevado Del Ruiz volcano, destroyed and partially buried by lahars of the 1985 eruption (source: (UN Office for Disaster Risk Reduction, 2015).

Photograph 3: Lahars of Nevado Del Ruiz bury Armero-Colombia. Patterns of buildings and streets are visible in under the debris in the middle stream (Source: Pierson et al, 2014).

Managing lahar risk imposes a challenge to local governments as they are characterized in many cases by a low probability and extremely high impact if they occur. This is the case for the city of Latacunga in Ecuador which has been destroyed multiple times during its history by volcanic lahars (Bromley, R. D. 1979). The city is thirty-seven kilometres from one of the most dangerous volcanoes in the world and the most active in Ecuador, Mount Cotopaxi. After relatively no activity for over seventy years Mount Cotopaxi erupted in 2015 releasing ash and gas columns reaching nine kilometres over the crater (Silvana et al, 2016) and reviving the risk of volcanic lahars that had previously devastated the city of Latacunga (Vallance, 2000, Pierson, Thomas, Wood, et al., 2014). The activity continued for five months during which the president declared a state of emergency and hundreds of people were evacuated from the city (Time, 2015).

1.2 Problem Statement:

Disasters caused by natural hazards in cities are amplified in a world that is rapidly urbanizing. As cities expand, so do populations facing a risk that if not planned for well, can lead to catastrophic outcomes (Ikeda and Nagasaka, 2011). As more countries become decentralized it is up to local governments to find solutions that balance their resources with the challenges of disaster risk management (DRM).

The year 2008 market a critical milestone for risk governance in Ecuador, as the new constitution adopted for the first time a decentralized system in the country. According to Article 390 of the new constitution, disaster risk should be addressed at the local level under the principle of subsidiarity. This assigned risk management directly to municipalities and, although different levels of government can provide technical and financial support, this should not undermine local autonomy (Stone, Barclay, et al., 2014).

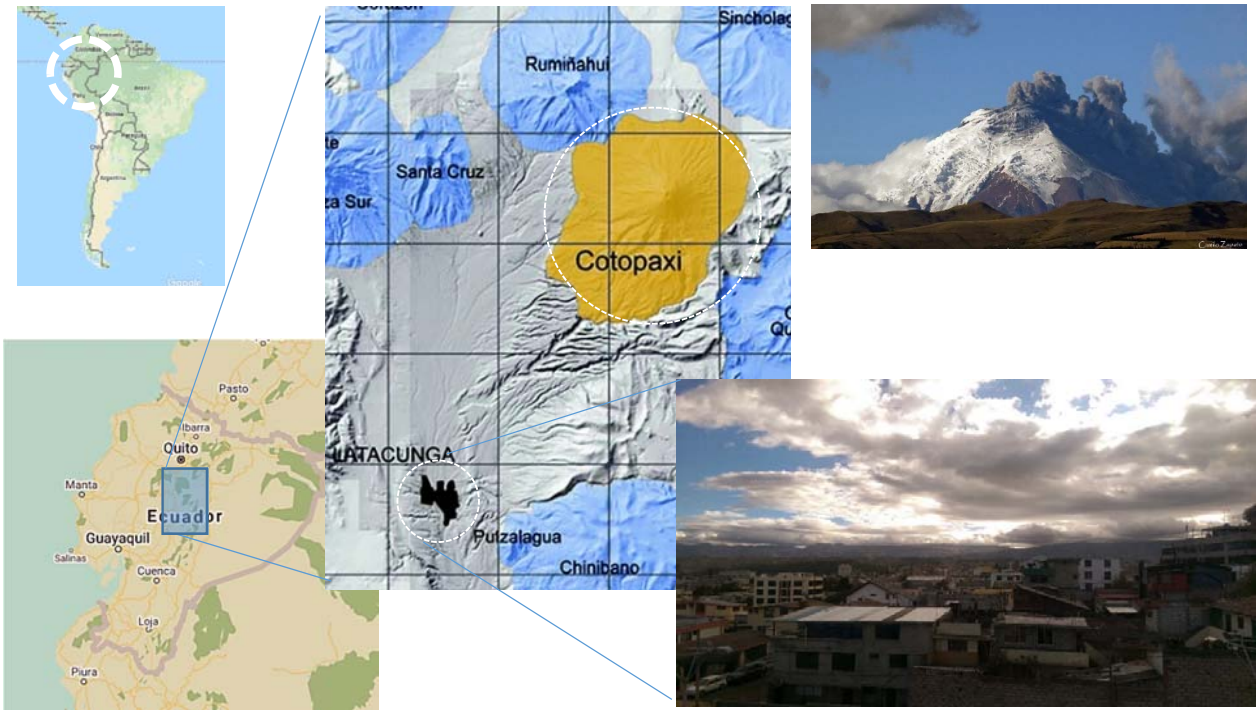

Figure 1: Location of Latacunga. (Sources: (Crafford and Venzke, 2016)**, Google earth,**(Mothes, Ruiz, et al., 2017)**)**

Following the eruption of Mount Cotopaxi in 2015, the municipality of Latacunga activated the land use and management plan which identified different risk zones and imposed regulations on the use of land in the risk area. The plan was contested by the local communities who self-organized to resist its implementation even though its objective was to protect them from volcanic risk. Local people utilized various resources including legal power, scientific knowledge, and political pressure to defend their land-use rights (La Hora, 2017).

This case is used to explain how households and communities view volcanic risk and how it is managed from a bottom-up approach. Many studies highlight how communities deal with volcanic risk when it occurs (Gaillard 2008, Sagala et al. 2009). However less research focuses on households' management of volcanic risk in the urban context of land governance. How do households make decisions to balance their knowledge of the risk with their livelihoods and what actions do they take based on this balance affect their use of land? Understanding this process is important for urban managers and local governments in order to create disaster management solutions that consider the interaction between actors and the forces driving their actions (Wilkinson, 2015).

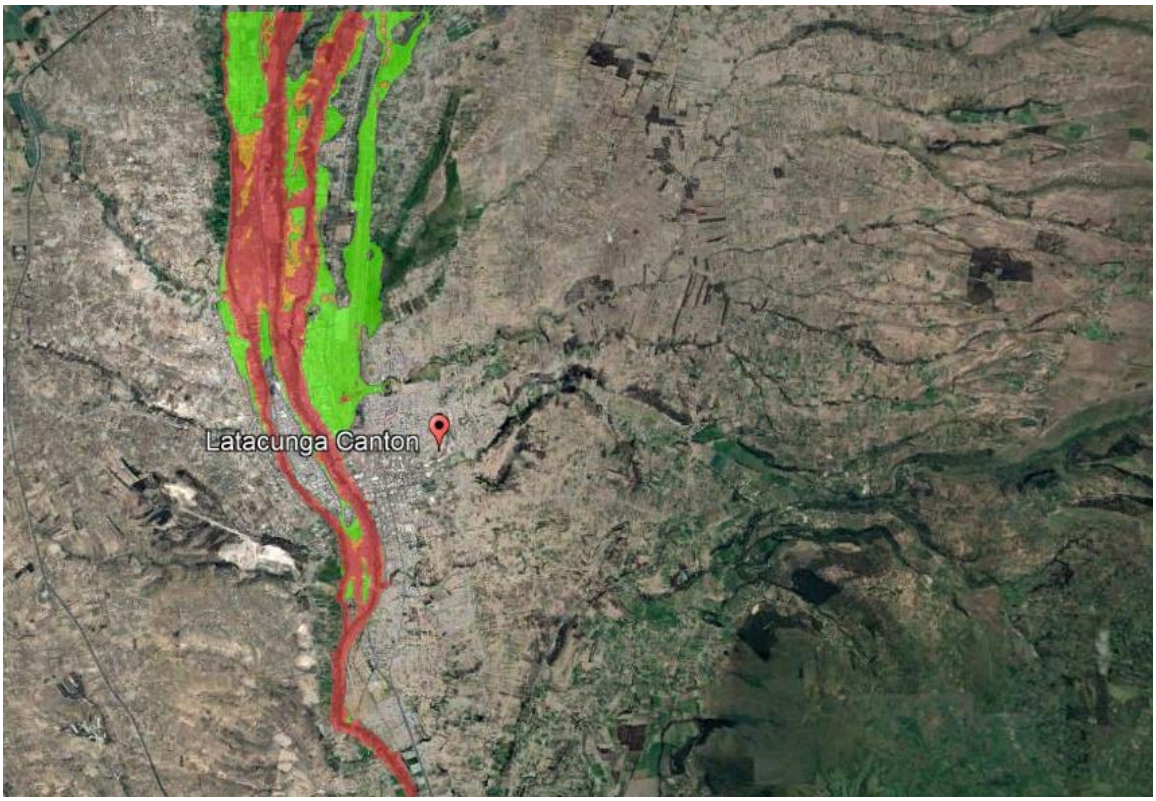

Figure 2: The Plan of land use and management created controversy amongst residents of Latacunga. It highlights the different risk zones and the permitted uses in each zone. (Directorate of citizens' safety and risk management – Latacunga Municipality,2019)

The system of Disaster Risk Governance (DRG) is formed by a complex network of actors who's interactions formulate the institutional arrangement that determine the relationships, roles and responsibilities of these actors and the coordinating mechanisms and political culture including different perceptions of risk, and result in the implementation of policies to manage disaster risk (Wilkinson, 2015). Interactions in the process of volcanic risk management include implementation of government policies, education and risk-reduction planning, and communication of hazard. Influential actors include communities at risk, different levels of government, and scientists (Pierson, Thomas C., Wood, et al., 2014). This research highlights these interactions in order to position households within the framework of risk governance and to explain how their perceptions and actions are affected by multiple factors.

1.3 Academic and practical relevance:

Within the growing body of literature that focuses on the link between risk perception and the management of risk and people's livelihoods and wellbeing, little attention has been paid to local disaster risk management systems (DRM) particularly in urban areas, and how these evolve to reduce the negative impacts of volcanic activity on lives and livelihoods of people living in close proximity to volcanoes (Armijos, Phillips, et al., 2017). There is a substantial body of knowledge written about risk perception and its impact on the decisions people make in areas of high volcanic risk. Not much however, links this perception to the shaping of land uses in urban areas. This is partly because the distribution of land uses in urban settings is

considered a top-down form of policy and is hence planned, managed and implemented by the government (for example Pierson et al. 2014).

Volcanic risk is another aspect that is less researched particularly when compared to flood or earthquake risks (Kelman and Mather, 2008). Although their eruptions occur less frequently than other dangerous natural phenomena, and have particularly in recent history taken fewer lives, volcanoes continue to presume a serious threat to cities that are highly populated and have lead previously to massive destruction demolishing whole cities and deeming others perpetually unfit for life (Sparks, Aspinall, et al., 2013).

Volcanic Lahars pose a unique impact on urban land governance due to their similarity with flood risk as they flow through main water paths and can overflow to surrounding areas (Kelman et al. 2008). The destructive nature of lahars derives from their speed, reach and composition and the difficulty in predicting (in the absence of warning systems) when they may occur (Pierson, Thomas, Wood, et al., 2014). The mitigation of lahar risk in land use plans includes special zoning regulations for high-risk areas similar to those used for flood risk. However, water in its normal state is a required asset for the city and provides numerous benefits that shape the relationship of land and the built environment with water surfaces (Rijke, Herk, et al., 2012).

Often Strategies developed for Disaster Risk Reduction (DRR) are far from the reality of the communities concerned and are so doomed to failure due to the lack of consideration of the local context. That is why establishing a multi-stakeholder dialogue combining bottom-up and top-down initiatives is essential for reaching mutually beneficial solutions that could reduce the risk of disasters.

1.4 Research objectives:

This research aims to highlight one of the land dynamics that shape land uses in areas at risk of volcanic lahars. Within a complex network of actors, the role of households and their decisions is often overlooked, particularly in top-down systems where communities are viewed as receivers of the service instead of partners in the mitigation process. "*Communities should be the centre point of engagement without which there will continue to be gaps in integrating knowledge with science viewed as far superior due to its more global nature*." (Gaillard and Mercer, 2013 p 100). The research focuses on households in order to explain how risk influences their decisions and actions leading to changes in the use of land. Specifically, the study aims to explain how risk drives the decision-making process of households in risky areas by identifying informal risk management strategies employed by households in Latacunga to manage volcanic risk and indicate how these strategies can change the use of land in areas at risk of lahars.

1.5 Provisional research question(s)

The main question this research seeks to answer is: ***To what extent does the households' perception of risk lead to changes in the land-use in Latacunga?***

Sub questions:

1- How do households in high-risk areas perceive volcanic risk?
2- What factors influence households' decisions in managing risk?
3- What are the lahar risk management strategies used by households in high-risk areas?
4- What changes in land use in Latacunga are influenced by lahar risk perception?

1.6 Scope and limitations

Cities in Japan, Indonesia, The Philippines, and many Latin American countries have a wealth of experience with lahar risk due to their locations and exposure. Access to this knowledge, however, can be limited due to the language barrier. This study is limited mainly to literature of lahar risk management in English which is relatively scarce. Also, many interacting factors lead to changes in the existing land uses which could be related to the varying effects of driving forces or the internal dynamics of the complex network of actors (Wilkinson, 2015). This research looks at a fraction of this dynamic by focusing on households and their coping strategies to explain how their decisions are formed and provide an indication of how these decisions can lead to changes in the use of land. Further research can look more deeply into the second part of this equation to understand what changes occur in land uses due to the locational decisions of households at risk that reflect on the urban land nexus (Scott, 1980).

Another limitation is that the research was conducted in a context and country foreign to the researcher which resulted in seeking assistance from research assistants and translators in the data collection. Extra measures were taken to increase validity and reliability due to the foreign context that are detailed in Chapter 3.

Image: Cutuchi River, Latacunga (Photo by author. July 2019)

"And we made from water every living thing" (Verse 21:30, The holy Quran)

Chapter 2: Literature Review

This chapter sets the theoretical framework for the research. It begins by laying out different risk governance theories to set volcanic risk management in the context of land governance by highlighting the roles of actors in managing volcanic lahar risk. It then focuses on the role of households in the DRM processes and explains how risk management and adaptation strategies are shaped by risk perception in addition to socio-political and economic factors. Finally, the link between the outcomes of these strategies and land-use change is made using the Urban Land Nexus Theory and Hersperger et al.'s theory. The chapter concludes with the conceptual framework.

2.1 Managing disaster risk in the context of land governance:

"*There is nothing more certain in disaster management business than the fact that once a disaster starts to unfold, it is too late to start looking for the information needed to manage it*" (Granger, 1999).

Disasters occur as a result of unprepared cities and in many cases, unplanned development. They are a combination of natural hazards and conditions of vulnerability and insufficient capacity or measures to reduce the negative consequences of risk. Disasters disrupt the functioning of communities causing losses in human lives and assets which exceed the affected society's capacity to adapt using their own means (Ahrens and Rudolph, 2006).
A wide range of governance measures are taken to reduce such losses, manage risks of natural hazard and strengthen the resilience of various systems (Wilkinson 2013). Of these, Mitchel et al. (2015) identify planning and control of land-use as two measures of land governance that are necessary to achieve sustainable and resilient urban development; the form of development that is key for cities to withstand disasters. Nonetheless, mainstreaming these measures in local governance can be challenging; as rapid urbanization increases conventional land-use planning becomes ineffective in controlling urban expansion extending to hazard areas (Mitchell, Enemark, et al., 2015).
A more holistic approach is hence needed to utilize the elements of land governance in order to reduce disaster risk (Mitchel et al. 2015). Current research in DRM is moving towards a risk governance approach (Ahrens and Rudolph, 2006). This emerging field draws from complexity theory (Bettencourt, 2013) and network governance in order to analyse the institutions, actors and networks involved in managing disaster risk and the formulation of policy through this complex nexus. The system of risk governance identifies the institutional arrangements that determine roles and responsibilities of these actors and their relationships, the political culture and coordinating mechanisms, and the different perceptions of risk (Wilkinson, 2013).

2.1.1 Lahar risk governance:

Governance of Lahar risks draws from an integrated water management approach and integrated volcanic risk management. This is derived by the fact that lahars share flooding characteristics such as a high saturation of liquid and their movement along water channels. Therefor strategies targeting areas around riverbanks need to manage the exposure to lahar risk while balancing water management issues (Kelman and Mather, 2008, Thouret, Enjolras, et al., 2013). Water management conversely is shifting towards more integrated approaches in order to avoid conflict between diverse uses of water through improved coordination between actors (Rijke, Herk, et al., 2012).This concept of integrated water management arose due to an increased awareness that nature is uncontrollable and new and innovative solutions are needed to manage water in cities. The room for the river project undertaken in the Netherland demonstrates this concept by creating more space for rivers to discharge flows. The project

represents the interplay between technical, societal and administrative resources and how the coordination of these aspects in an integrated manner was essential for its implementation. Such an approach transcends various temporal and governmental scales in order to balance short- and long-term objectives, anticipate future changes and work towards a unified vision (Rijke, Herk, et al., 2012).

Managing lahar risk hence needs to recognize the interacting risk and benefits of living near water and the complex actors involved in this association. This direction is supported by researchers such as Kelman and Mather (2008) who suggest the implementation and understanding of volcanic benefits within the existing risk management frameworks. This includes the maximization of benefits from volcanoes without affecting the vulnerability of the community (Kelman and Mather, 2008). Research that was undertaken by Thouret et al. (2013) in Arequipa-Peru identified the risk of Lahars and flash floods and the vulnerability of communities as the main parameters for delineating risk zones. They concluded that a multidisciplinary approach is essential in order to evaluate losses and gain a more holistic vision of the problem and solution (Thouret, Enjolras, et al., 2013).

Several attempts were made in order to categorize strategies used to mitigate lahar risk (Kelman and Mather, 2008, Pierson, Thomas C., Wood, et al., 2014). While research recognizing the role of multiple actors in risk management, and the importance of including communities and scientists for successful implementation (Eiser, Bostrom, et al., 2012, Donovan, Amy and Oppenheimer, 2014, Pierson, Thomas C., Wood, et al., 2014) the majority of Strategies found in the literature are implemented primarily as top-down approaches. Pierson, Thomas C., Wood, et al. (2014) classify these strategies into 4 categories:

1- Avoidance of hazard through land-use planning. Land use management is often promoted as essential in hazard avoidance strategies which aims to reduce potential losses in lives and assets. Its applications include:
   a. Land-use zoning regulations or development of parks and preserves that ban or limit occupation of hazard zones.
   b. Dis-incentivize occupation in hazard zones
   c. Provide education to the public about the risk and hazards

   The use of land use planning approaches has been challenged through real-life implementation as designating areas as non-inhabitable has proven to have various social, economic and political impacts not the least of which is depriving residents of the potential benefits of volcanic areas (Kelman and Mather, 2008, Donovan, Amy R., Oppenheimer, et al., 2012). Other challenges occur due to people's strong attachment to a place, their cultural belief, political push-back from business and real-estate interests, the lack of alternative locations for new development, attitudes of individuals who don't want to be told where they can or cannot live or needed access to livelihoods that exist in volcano hazard zones. A more realistic land-use planning approach may be to restrict the kind or amount of development allowed to occur in lahar hazard zones. The goal of these restrictions is to minimize population exposure and to only allow land uses in which people could be evacuated quickly (Pierson, Thomas C., Wood, et al., 2014)
2- Modification of lahar: This includes the use of engineered protection structures (Pierson et al. 2014) which can entail huge investments and are prone to failure due to the high uncertainty of lahar risk. An example of this is the channelling of lahar paths of Mount Pinatubo in the Philippines with dikes to mitigate the Lahar risk. The government undertook significant costs to build various structures including dikes, barriers, dams, drainage gutters, sand pockets, and spillways to control the flow of sediments,

nevertheless it was not able to protect the village of Cabalantian where a single lahar event killed over 100 people (Gaillard, 2008).

3- The use of warning systems to enable evacuation. These take multiple shapes and provide a point of collaboration between formal and informal institutions. An example is the *vigia*s (look-outs) in Ecuador who are the cooperation of multiple actors and institutions and exemplify an integrated system of monitoring and warning as a strategy for risk mitigation (Stone, Barclay, et al., 2014).
4- Response to recovery from lahars after they occur. This approach relies on the effectiveness of immediate response as well as the long term recovery, and although it occurs after the event of lahars, proper planning and preparation are needed to maximize its benefits (Pierson, Thomas C., Wood, et al., 2014).

2.2 Households and risk management:

The pivotal role of communities in the realization of risk management plans was highlighted by various researchers (Gaillard, 2008, Pierson et al. 2014, Scolobig 2015 to name a few). Mitchel et al (2015) who emphasize the role of sustainable and resilient urban development in managing risk, place a public that has the knowledge of the natural hazards faced, and the motivation to take risk reduction actions at the core of such development (Mitchell, Enemark, et al., 2015).

In many cases however, this role is not recognized and the divergence between authorities and communities is exacerbated leading to fatal consequences. Several researchers attribute this to the exclusion of livelihood needs in DRM plans decisions and the exclusion of households in the decision-making process. Armijos Phillips et al. (2017) for example found that volcanic activity has caused several deaths due to citizens refusing to adhere to risk zoning rules when faced with stronger imperatives of sustaining their livelihoods (Armijos, Phillips, et al., 2017a). In their extensive review of volcanic risk perception literature Favereau et al. (2018) used a study undertaken in Vesuvius to explain the role of internal trust (relating to the capability of an individual to act in dangerous situations). They indicated that people are aware of the volcanic risk but prefer to be more involved in the public discussion in order to strengthen the sense of internal trust in making decisions when facing volcanic hazard. Wilkinson (2015) points out that institutional responses to volcanic eruptions which are formed in a top-down manner can include policies and decisions in land use, and although these decisions may lead to a reduction in risk exposure and vulnerability, occupants exposed to the risk and who may face resettlement will not necessarily share these values (Wilkinson, 2015).

Nevertheless, research in DRM emphasizes the wealth of knowledge held by communities on the hazards and risks they face due to their experience and inherited knowledge. Stone et al. (2014) emphasize the need to blend scientific and indigenous knowledge to asses risk and the importance of managing risk at a local level (Stone et al. 2014). In Murray et al.'s research on interpreting volcanic risk governance through an institutional lens, they highlighted the unique knowledge in the memory of Maori people from previous eruptions which shapes their interaction with the volcano, particularly in high-risk areas. The value of such knowledge is that it transcends multiple timeframes as it is passed through generations providing a wider range of experience (Murray, McDonald, et al., 2015). A similar opinion is shared by Sheets (2012) who in his research of how communities have been shaped historically by volcanic activity, highlights the valuable knowledge shared between generations of non-literate societies

which includes recognition and response actions that reduce their vulnerability and exposure (Sheets, 2012).
Current trends in risk management are moving towards a more people-centred approach. This includes sharing part of the risk responsibility with communities and households. For example, Scolobig et al. (2015) explain how authorities in Tasmania-Australia focus on optimizing scarce resources to meet the most urgent needs while transferring part of the responsibility and risk to the people. They discuss how such solutions although resource optimizing is highly circumstantial and still face challenges when it comes to their application particularly if the public perceive natural hazard solely as the government's responsibility. In their opinion a combination of top-down and bottom-up approaches determined by the special characteristics of the system can provide a more suitable solution (Scolobig, et al., 2015b).

2.2.1 Perception and interpretation of risk, and decision making:

Understanding the decision-making process of communities is essential for the application of more people-centred approaches. Gaillard (2008) identifies the main paradigm shifts that occurred in research about the decisions undertaken by communities to face volcanic risk. The first paradigm regards the perception of risk as the main driver of actions undertaken to manage it. This paradigm identifies actions as voluntary or optional. The second paradigm argues that different forces constrain people's behaviour increasing their vulnerability and requiring them to live in hazard-prone areas (Gaillard, 2008). This paradigm is supported by Haynes et al who argues that communities do not accept risk but tolerate it to secure certain benefits (Haynes et al. 2008), and more recent research by Usamah and Haynes (2011). They found in their study of resettlement centres in the Philippines that most households did not resettle completely due to stronger imperatives of secure livelihoods and social networks (Usamah and Haynes, 2012).

Wachinger (2013) et al denote the term risk perception as "the process of collecting, selecting, and interpreting signals about uncertain impacts of events, activities or technologies" (Wachinger, Renn, et al., 2013). Understanding how different actors perceive and accept risk helps to explain the decisions made and the actions taken by them (Favereau et al. 2018). There is a multitude of research that supports this paradigm regarding risk perception as a driver of people's actions in risk-prone areas. This is usually motivated by risk experience, as demonstrated by Wachinger et al. (2013). They undertook an extensive review of papers linking risk perception to individual willingness and preparedness actions from a broad range of disciplines focusing on a range of natural hazards. The results concluded that of the different intervening factors that shape individual risk perception of natural hazards, experience of the hazard and trust in authorities and experts (or lack of it) are the main factors in complex causal arrangement (Wachinger et al. 2013). Research by Lujala et al. show that merely living in an area more exposed to risk without having a personal experience of damage does not affect households' concern towards risk (Lujala, Lein, et al., 2014).
Experience, nevertheless, does not necessarily impact everyone in the same way. A study of people who have been directly affected by flooding compared to others who have not while living in the same high-risk area concluded that people not affected by the floods underestimate flood risk (Favereau, et al., 2018). Being exposed to risk can also have varying impacts on different actors and their interactions. Institutional responses such as policies and regulations differ from public responses and can in many cases lead to conflict and passive outcomes (Wilkinson, 2015). This is partly attributed to occupants perceiving and measuring risks in terms of the probability of their occurrence, and the implications on livelihoods (Sagala, 2009). The perception of risk can also vary based on the consequences of volcanic activity. This should be considered when studying the relationship between previous risk experience and decision making (Favereau, et al., 2018).

An extensive review of the literature on the perception of flood risk was undertaken by Kellens et al. (2013) covering 57 articles. Within their research, they identified two main theoretical frameworks used to analyse risk perception: The Psychometric paradigm and heuristics. The psychometric paradigm aims to quantify people's perceptions of and attitudes towards risk using questionnaires and quantitative measures. The heuristics paradigm is used by people in order to simplify complex problems and use less of their cognitive ability to make decisions. Favereau et al. (2018) undertook a similar review of research in volcanic risk areas and highlighted experience and trust in authorities as factors that impact people's perception of risk (Favereau, et al., 2018).

2.2.2 The impact of livelihoods on decision making:

The paradigm challenging the idea that risk perception is the principal motivator for risk mitigation actions emerged in the late 1970s. Critics challenged the notion that households have a range of choices in adapting to risk and that choosing to act upon risk is made on a voluntary basis. Instead it was argued that social, economic and political forces constrain people's behaviour increasing their vulnerability and compelling them to live in hazard-prone areas (Gaillard, 2008).

Within this paradigm, numerous researchers highlighted livelihoods as a key factor that grounds communities to risk areas (Mula. 1999, Kelman and Mather, 2008, Sina et al. 2019, to name a few). Armijos et al. (2017) found that people continue to place themselves at risk by violating risk zoning regulations due to the stronger imperative of maintaining their livelihood. Stone et al. (2014) undertook research that focused on the development of informal networks between multiple stakeholders including community member and scientists in order to monitor the activity of Tungurahua volcano in Ecuador. While relocation and zoning strategies in risk areas failed due to continuous violations by citizens, the networks succeeded as a risk management strategy because they allowed people to maintain their livelihoods during changing volcanic activity (Stone et al. 2014).

Morse and Mcnamara (2013) define a Livelihood as the capabilities, assets (including both material and social resources) and activities required for a means of living. The sustainable livelihood approach SLA grew within the international development context with the objective to help explore people's livelihood needs in order to identify the most effective intervention methods (Morse and Mcnamara, 2013). The approach identifies 5 types of assets that constrain or enhance household livelihood opportunities: human capital, natural capital, financial capital, physical capital and social capital (Serrat, 2017). Viewing disaster risk reduction strategies through the lens of sustainable livelihoods can help understand household's decision making in balancing benefits and costs of living in the vicinity of active volcanoes (Kelman and Mather, 2008).

Land has a unique position within this framework; it is considered a natural asset and is at the centre of lahar risk management where the integration of water, risk and communities occurs (Kelman and Mather, 2008, Mitchel et al. 2015).Nonetheless, this dynamic has gained less attention particularly in terms of managing land prone to lahar risk in cities as the vast majority of literature focuses on land and livelihoods in rural settlements (Donovan, Amy R., Oppenheimer, et al., 2012, Scolobig, et al., 2015a, Armijos, Phillips, et al., 2017b).

2.3 Household strategies to manage disaster risk:

Households undertake different actions as a result of being exposed to risk. A spectrum of these actions is found in the literature, demonstrating a balance of safety and sense towards the risk, with livelihoods, available resources, and the benefits provided from the risk (Kelman and Mather, 2008, (Gaillard, 2008). These include passive strategies such as complete relocation from the area, and proactive strategies that not only accept volcanic risk but embrace it as a part of the daily life (Kelman and Mather, 2008, Pierson et al. 2014, Sina et al. 2019). Kelman and Mather (2008) categorized the strategies used by households to manage disaster into four types:

1- Protect households from volcanic hazard: This strategy includes technical and non-technical adjustments to protect assets from the hazard. For example, despite the high level of lahar risk, people in Bacolor village in the Philippines chose to return to their homes after being evacuated. They used several strategies to protect their assets including lifting houses on concrete posts and using sandbags to protect from flooding. Non-technical adjustments include seasonal relocation during the rainy season where lahars are most expected to occur (Kelman and Mather, 2008).
2- Avoid volcanic hazard: The avoidance of risk includes a complete relocation from the hazard areas. Households residing near Tungurahua volcano sold their property for much less than the market value in order to relocate after the eruption that took place in 1999 (Armijos, Phillips, et al., 2017).
3- Live with volcanic risk: this includes accepting the volcanic hazard as an "environmental event" or as part of the daily life. This is the case when communities accept a hazard as a reoccurring event and integrate the volcanic threat with livelihood opportunities. Kelman and Mather (2008) explain the example of farmers in the African Sahel who plant seeds in floodplains and benefit from moisture in the soil due to annual floodwaters. Acceptance can also include the establishment of informal networks to promote adaptation and learning from the risk, co-produce knowledge and collaborate in risk communication (Kelman and Mather, 2008).
4- Accept the risk and do nothing. Communities can choose to remain in or move back to high-risk areas and resume their life with no risk adaptation strategies. This can be directly related to livelihood assets, for example in the case of Pinatubo volcano in the Philippines people who did not apply any mitigation strategies attributed this to financial constraints (Gaillard, 2008). Risk acceptance could be appropriate for certain timeframes depending on the type of volcanic activity where for example volcanoes remain dormant for centuries (Kelman and Mather, 2008, Murray et al.2014).

Figure 3 is the result of combining the mentioned strategies in addition to others found in literature (Kelman and Mather, 2008, Eiser, Bostrom, et al., 2012, Murray et al.2014, Donovan, Amy and Oppenheimer, 2014a, Pierson, Thomas C., Wood, et al., 2014). According to the previous discussion two main strategies can be identified; households either avoid the risk by leaving the risk areas or they accept it and remain in the risky areas, sub-strategies are developed under these to main strategies.

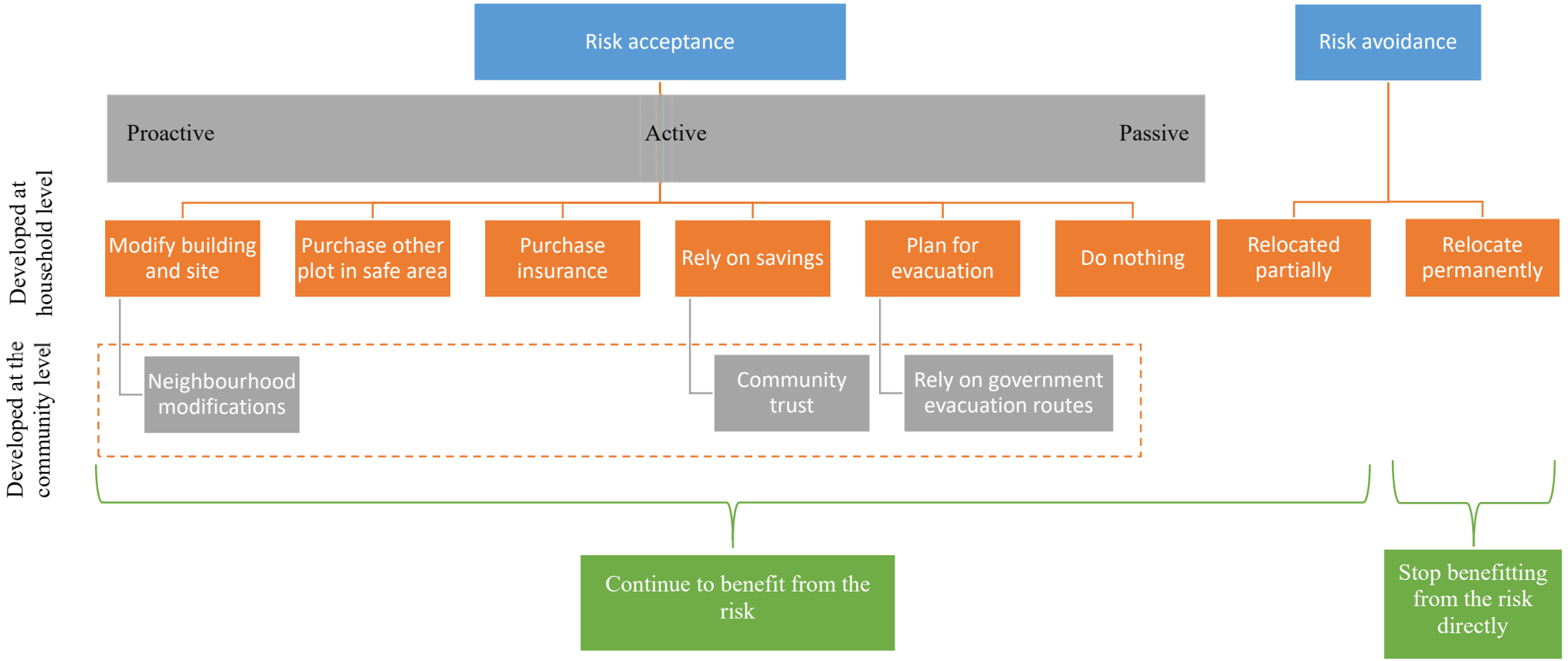

Figure 3: A spectrum of strategies used by households in areas at risk of volcanic lahars. Authors diagram adapted from several literature: Kelman and Mather, 2008, Eiser, Bostrom, et al., 2012, Murray et al.2014, Donovan, Amy and Oppenheimer, 2014a, Pierson, Thomas C., Wood, et al., 2014

2.4 Risk management and land-use change:

Various theories attempt to explain the conversion of land uses within cities and the configuration that is the outcome of this process (Zhou, Li, et al., 2016). One of prevalent theories explaining the location of land is the bid-rent theory. It is based on the principles of Ricardo's rent theory and suggests that rents diminish moving further from the centre to the outskirts as an offset of lower revenues and higher operating and transport costs. While the theory explains locational decisions within cities and the patterns of land uses (Zhou et al. 2016), it faces a fair amount of criticism as it has been argued that varying levels of information between stakeholders result in an imperfect market. Furthermore, the theory fails to account for the distinctive nature of building types and uses, and the difficulty of converting or adapting them to other uses (Balchin et al. 2000). It could be concluded here that the bid-rent theory attributes the spatial location of different users and the resulting changes in urban land use to the ability to pay.

Another theory developed in the late 1970s is the urban land nexus theory which could be defined as "an interacting set of land uses expressing the ways in which the social and economic activities of the city condense out into a differentiated polarized locational mosaic"(Scott and Storper, 2016,p.8). The urban land nexus is subject to numerous dysfunctionalities including environmental pollution, infrastructure breakdowns, and locational conflicts. This particularly seems to be the case in high-risk areas where it is the manifestation of the locational logics of different actors in the urban space (Scott, 1980). The urban land nexus is the outcome of interactions of three factors of human action and social development:

- The spontaneous decision making of private firms and households in the urban space where the decision-making calculus is structured by the social and property relations of capitalist society.
- The rationality of collective political decision-making. This rationality reflects the global orientations, biases, and imperatives of the capitalist state as it finds itself inextricably involved in the tasks of managing and attempting to resolve the urban land use problem set in motion by private decision-makers.
- The interaction of the private and public gives rise to a field of evolving but problematical land-use relationships in urban space.

Land-uses within cities are the outcome of spontaneous bottom-up urban change on one hand and top-down public policy and planning on the other (Scott, 1980). Households and firms (owners and users of land) select locations based on the proximity to each other while avoiding effects that could damage their activities (Scott and Storper, 2014). Urban planning in general and risk-sensitive land use planning particularly is used by governments as an instrument to regulate land tenure, identify risk zones and provide safer location (Sudmeier-Rieux, Fra Paleo, et al., 2015). The interaction and outcome of these processes form the nexus of urban uses and locations.

A third approach is defined by Hersperger et al. (2010) as: "The result of proximate causes (direct actions) and underlying driving forces (indirectly affecting land change)" (Hersperger, Gennaio, et al., 2010). This approach identifies 3 main components of the change process: actors, land change and driving forces. Driving forces form a complex system of interactions and affect a range of temporal and spatial levels. These forces can be divided into 5 groups:

political, economic, cultural, technological and natural forces. Population is sometimes considered a cultural force and sometimes added as an additional group (Hersperger, Gennaio, et al., 2010).

Actors make decisions and act accordingly and influence other actors and the environment with their actions. The theory distinguishes two types of actors: actors affecting the driving forces and actors that directly change land. Actors could be one or both types together.

In the case of land-use change in the context of risk governance the Hersperger theory has several advantages that can assist in explaining the land-use change process; first the theory identifies several driving forces including volcanic risk as a component of natural forces, and livelihoods as a component of economic forces, and identifies a clear relationship between them through the actors and the change in land-use. Secondly, the theory identifies multiple actors that influence this change providing a basis for a network governance approach to analyse the relationship between the actors and understand formal and informal institutions that impact the change (Stone, Barclay, et al., 2014). Thirdly, the theory recognizes the direct impact of actors on the change of land-use but also the dynamics of driving forces which can be influenced by the actors leading to indirect land-use change. This emphasizes the dynamic nature of the land-use change process and its various components that change not only the use of land but the decisions of actors and the impact of the driving forces. Figure 4 shows the outcome of these theories and how volcanic risk, livelihoods, households, and urban land-use change interact in the context of lahar risk governance.

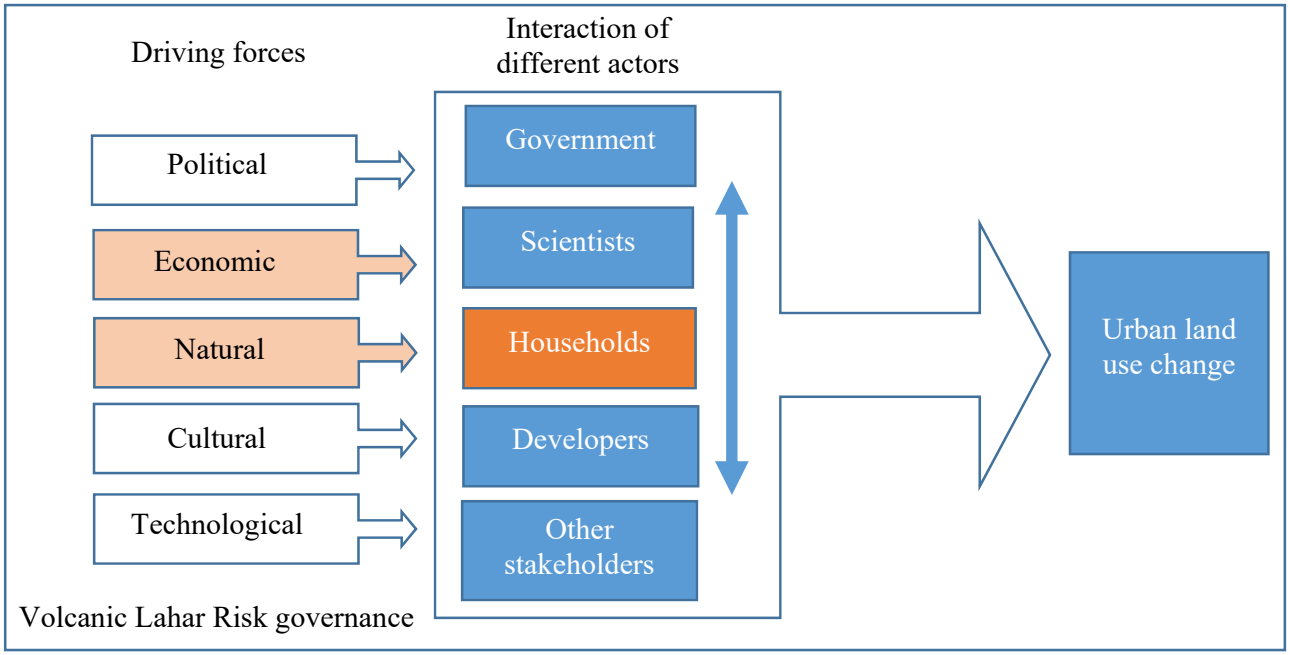

Figure 4: Forces and actors driving land use change in the context of lahar risk governance. Adapted from (Hersperger, Gennaio, et al., 2010).

2.5. Conceptual Framework:

Based on the previous discussions the following conceptual framework was developed:

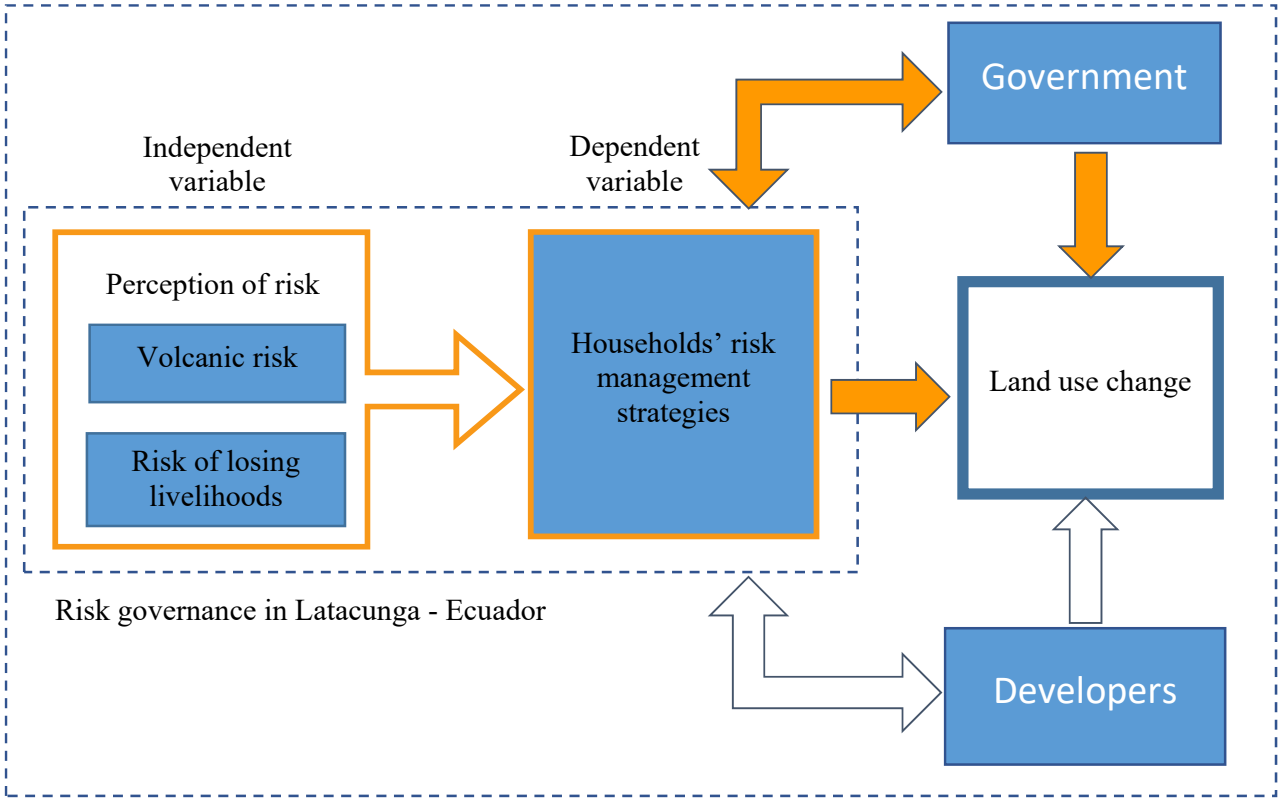

Figure 5: Conceptual framework

Chapter 3: Research Design and Methods:

This chapter begins with the updated research questions and objectives and presents the operationalization of the research questions. The concepts are then explained in more detail followed by the research strategy and data collection methods. Validity and reliability methods follow, and data analysis methods and limitations conclude.

3.1 Revised research objectives and questions:

A major part of volcanic risk management literature focuses on top-down lahar risk management strategies. In contrast, a gap exists in research highlighting in detail how households plan and act in protection of lahar risk in a bottom-up way, specifically in urban settings. This dynamic is important to understand changes that occur in land uses, it was hence decided to focus on the risk management strategies of households and the factors shaping these strategies within the larger framework of land-use change (LUC). The research objectives were revised to have a more focused scope within the bigger context of LUC. The final research objectives are to:

1- Explain how the perception of different types of risk drive the decision-making process of households in risky areas
2- Identify informal risk management strategies employed by households in Latacunga
3- Explain how households select and prioritize between different risk management strategies.
4- Provide indications of how such strategies can lead to changes in the land use

The revised main research question is as follows: ***What factors drive the use of risk management strategies of households in Latacunga – Ecuador in the context of land governance?***

Revised sub-questions:

1- How do households in Latacunga perceive different types of risk?
2- What strategies do households undertake to protect themselves and their assets from lahar risk?
3- How do different types of risk impact households' choice and use of risk management strategies?

3.2 Operationalization:

Concepts	Variables	Sub Variable	Indicators	Indicator source	Data collection method	Data type
Q.1: How do households in Latacunga perceive different types of risk?						
Risk perception	Perception of volcanic risk	**knowledge of characteristics and implications of lahar risk:**	-Knowledge type: scientific or general -Knowledge source: direct through experience or indirect through media or training	Kellen et al. 2013, Eiser et al, 2012	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
		personal ability to cope with lahar risk:	- Sense of exposure - Confidence and protection	Eiser et al, 2012,	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
		Attitudes towards risk management:	-Trust in authorities -Responsibility towards risk	Kellen et al. 2013,	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
	Perception of loss of livelihood risk	**Social Assets**	-Social support between the community members -Proximity to family	Morse et al. 2013, cutter at al. 2008	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
		Financial Assets	-Proximity to work -Income from location	Sina et al. 2019	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
		Natural & physical assets	-Multi functional land - Proximity to services - Tenure security	Sina et al. 2019, Mitchel et al. 2017	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)

		Human assets	- Age - level of education	Xu et al. 2015	survey	primary + quantitative (main) Primary + qualitative (triangulation)
Q2. What strategies do households undertake to protect themselves and their assets from lahar risk?						
Risk management strategies	Risk acceptance: acting by protecting different types of assets	**Personal strategy**	- Modification to building (strong structure, extra floors) -Evacuation plan -Purchase insurance -Purchase land in safe area -Personal savings	Gaillard et al. 2008, Eiser et al. 2012	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
		Community strategy:	-Evacuation routes -Neighbourhood physical modifications (river protection) - Active involvement in community initiatives to protect from risk (collective action) -Neighbourhood emergency fund	Gaillard et al. 2008	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
	Risk acceptance: no action taken		Choose to do nothing	Kelman et al. 2008	survey + interviews	primary + quantitative (main) Primary + qualitative (triangulation)
	Risk Avoidance		Relocate from city	Gaillard et al. 2008, Eiser et al. 2012	Interviews + Newspapers	Secondary + qualitative (main)

3.2 Concepts:

The perception of volcanic risk refers to the level of comprehension of the exposure to lahar risk and its direct impacts developed by households in high-risk areas after the 2015 Cotopaxi volcano eruption. Based on the theoretical framework people in risky areas tend to differentiate between two types of risk: volcanic risk and the risk of livelihood loss. Various frameworks are found in the literature to measure perception of risk from natural hazard. The literature review undertaken by Kellens et al. (2013) provides a framework for flood risk perception that incorporates the indicators found in numerous volcanic risk perception studies. Three main indicators are used in the framework to measure risk perception: The knowledge of the characteristics of the risk, people's perception of their personal ability to cope with the risk and what their attitudes are towards risk management (Kellen et al. 2013, Eiser et al, 2012).

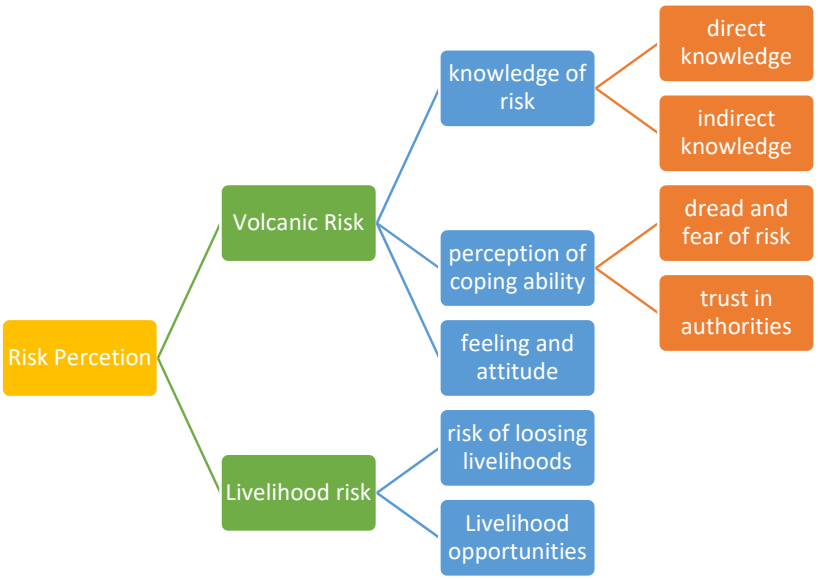

Figure 6: Types of risk perception which impact households decision making (author's diagram).

The Land use and management plan for Latacunga Canton (2019) was used to identify the extent of risk to which residents are exposed to. The plan outlines the zoning and land-use regulations of the Canton and categorizes residential areas according to risk as follows:

- Residential 1 (R1): Areas of consolidated residential use or in the process of consolidation that present affectations by volcanic threat in which the limited presence of economic activities and equipment of neighbourhood level, urban plot and built morphology are maintained.

- Residential 2 (R2): Areas of residential use in the process of consolidation and new development in which economic activities and equipment of neighbourhood and zonal level are allowed. In turn, densification is promoted with the assignment of higher indices of height and occupation ground.

This study will focus on households residing in Residential area 1 (R1). This area is further classified into 3 zones according to the exposure to lahar threat:

- Zones of high threat: Land in these areas is susceptible to transfer of ownership (expropriation) and should not be used for human settlements.
- Zones of medium threat: Single-family homes are authorized, complying with the contingency and evacuation plans and the presentation of property insurance. Fractionation of properties will be approved in application of the present regulations according to specific regulatory zones (polygons).

- Zones of low threat: two-family housing is allowed in this zone fulfilling the contingency and evacuation plans and the presentation of property insurance with respect to specific regulations of each of the polygons.

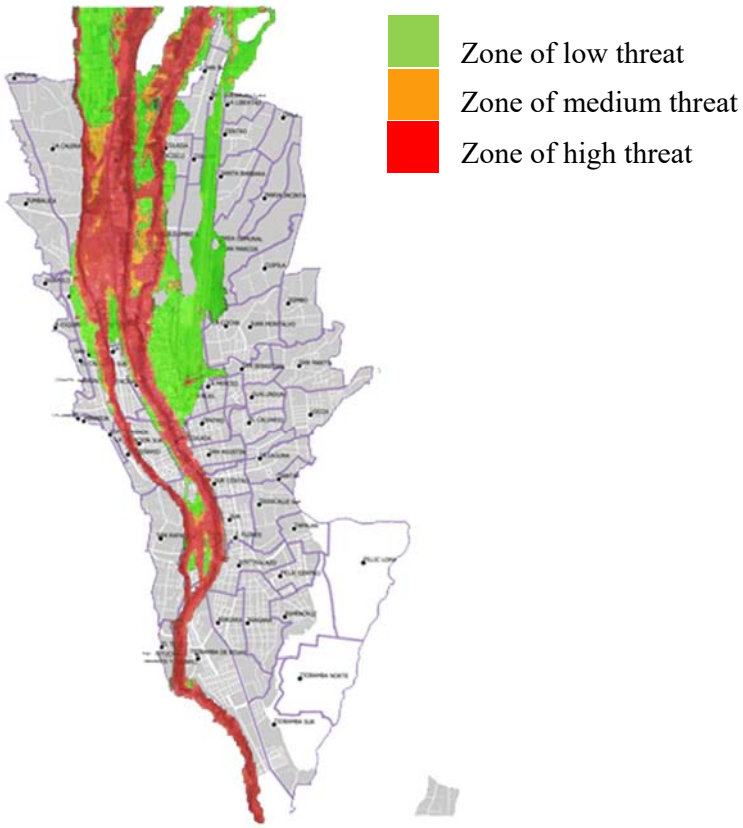

Figure 7: Latacunga risk zones based on the ordinance of land use and management. Adapted from Latacunga municipality risk zoning maps (Latacunga Municipality, 2019) and neighbourhood diagram from Grupo Faro (2019)

Livelihoods are defined as the way in which households make their living in order to fulfil their economic requirements or respond to economic prospects (Sina et al. 2019). Livelihood risk is hence the risk of losing the prospects derived from the location of the risk area; this includes financial, natural, social and physical assets which households associate with the land.

Risk management strategies are defined in this context as the plans and activities which directly affect land use, and which are carried out to enhance the ability of households to prepare for disaster or response when it occurs (sagala et al.2009). Households were grouped based on the strategies they use into households who accepted the lahar risk and those who chose to avoid it. Households who accept the risk are those who remained within the risk areas and either take some type of preventive action or preparation or do nothing. The survey mainly targeted these households as they remained within the risk areas and accepted the risk. Households who chose to avoid the risk are subdivided into those who relocated partially but continue to work and generate income in Latacunga and a second group who relocated permanently out of the city.

Figure 8: The risk management strategies used by household in Latacunga. Author's diagram

Information about households who chose to avoid the risk was more difficult to obtain as no secondary data was found about the numbers of people who left the city. Some information was extracted from the interviews about this group that was used to gain some indication of the impact of risk avoidance on land-use in the city.

3.4 Research Strategy and methodology:

This research aimed to explain the use and prioritization of household coping strategies with lahar risk in Latacunga and how they are influenced by risk perception and livelihoods. A survey was selected as the main research strategy in order to gain generalizable results by gathering information about the different risk areas and comparing perceptions, livelihoods, and strategies between households. The survey was also used due to the large number of variables needed to assess (Van Theil, 2014). Secondary data was used to evaluate and analyse

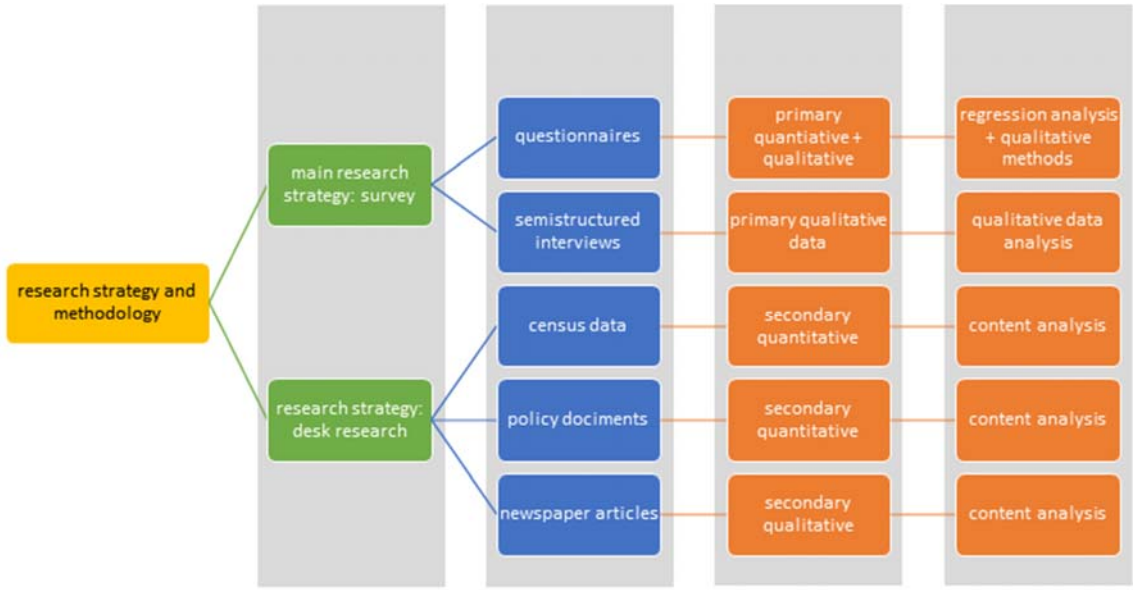

Figure 9: Research strategy and methodology. Author's diagram

official documents including the land use and evacuation plans to highlight the points of conversion and diversion between them and the strategies of households.

3.5 Data collection method:

Primary qualitative and quantitative data was collected through a written questionnaire distributed amongst households around the city. This method while timely and financially consuming helped gain a high response rate and reduced bias from using the phone or internet which are limited to people who have these services. In addition, it ensured distributing the questionnaire in different neighbourhoods with multiple risk levels. Within the questionnaire, five types of questions were used: Classification, behavioural, knowledge, perception, and feeling (Bird 2009).

Semi-structured interviews were used to gain more in-depth insights about the findings. Interviews were undertaken with purposely selected households which included three families in different risk zones in addition to one community leader. Other interviews were also made with local NGOs working with communities, government officials and scientists from Instituto Geofisico IG EPN: The Institute responsible for monitoring seismic activity in Ecuador.

Households	classification	Date of interview	description
Community leader from Nueva Vida - Colaisa	Male – head of household	10/07/2019	The leader of the group La Zona Muerta (the death zones) who lives within the high-risk area. He was told during the construction of his house that the building regulation has changed, and he is not allowed to build.
Household from Rumipamba	Female – married with 2 children	15/07/2019	Lives in the high-risk zone and has another house in a safe zone
Household from El Rosario	Male – married with 1 child	7/07/2019, 15/08/2019	A resident living in a high-risk area near his parents. The interview was conducted with him but described the situation for both families.
Household from El Rosario	Female	10/07/2019	A short interview was held with an older lady from Elrosario neighbourhood.
Group	mixed	28/06/2019	A group of teachers at the ISTC living in different risk zones. The Institute is also within the risk area.

Latacunga Municipality Planning Division	Government	16/07/2019	
Citizen safety and risk office	Government	03/07/2017	
Latacunga Cadastre Office	Government	05/07/2019	
National risk service and emergency management	Government – risk management	10/07/2019	Risk management agency at municipality level
Risk COE (Group of 6)	Government	04/07/2019	Interview with an emergency committee including representatives from 6 institutions: ministry of education, ministry of higher education, ministry of health, police, CCTV and the municipality at the Zone 3 level
Grupo Faro	NGO	19/07/2019	Local NGO working in public policy and urban development in Latacunga
Plan International	NGO	10/07/2019	International NGO working with urban and peri urban communities in Latacunga
Instituto Geofisico IG EPN	Scientists	10/07/2019	The institute responsible for monitoring the volcano
Insurance Company	Insurance Company	10/07/2019	An insurance company within Latacunga and one of the major companies in Ecuador
Total			14

Table 1: Interviews list. Author's work

Secondary qualitative data was obtained from Latacunga Municipality, the National Service for Risk and Emergency Management and other governmental agencies directly or through their official online portals in addition to several online articles.

3.6 Validity and Reliability:

One bias of questionnaires is their inability of producing in-depth results. To overcome this bias the questionnaire included several open-ended questions to gain some spontaneous answers and free form responses (Bird 2009). The first section was related to risk perception,

the second was related to livelihoods and how households relate to the risky locations, and the third section asked about risk management strategies applied by households.

The questionnaire was tested with a pilot distributed digitally to the students of the Instituto Superior Cotopaxi and the translation was revised by several people in order to validate the clarity of the questions. Students from the Instituto Superior Tecnológico Cotopaxi ISTC also assisted in distributing the survey within the city to cover a wider area and were given maps and directions on how to interview respondents. A training workshop was held to explain the questionnaire and distribution method. During the distribution students sent their locations and photos of the interviews. A feedback session was held after the survey ended for to clarify any obstacles and challenges that occurred during the distribution. Interviews were used for triangulation in addition to gathering extra data.

3.7 Data source (primary or secondary):

3.7.1 Secondary data resources:

No.	Document title	Date of publication	Data source
1	Decentralized autonomous municipal government of Cantón Latacunga, urban planning instruments containing: The Land Use and Management Plan for Latacunga Canton	2019	Latacunga Municipality
2	Community Empowerment and Preparation: Eruptive process of Cotopaxi volcano	2019	National service of risk and emergency management
3	Guide for inclusion of disaster risk management in territorial planning and management	-	National service of risk and emergency management
4	Maps of land prices in Latacunga (GIS)	2019	Latacunga Cadastre office
5	Latacunga municipality risk maps of Latacunga Canton (Google earth)	2019	Latacunga citizen safety and risk office
6	News article: Concern in Latacunga for empty houses	9/2015	Ecomercio.com
7	News article: Ordinance that prohibits building in risk areas generates debate	12/ 2015	Elcomercio.com
8	News article: Life under an active volcano in Ecuador.	3/2016	Aljazeera.net
9	News article: Land use ordinance in Latacunga creates discontent	12/2017	lahora.com.ec

3.8 Sample size and selection:

Random non-probability sampling was used to ensure the sample is representative and findings can be generalized, and to reduce the bias by having a higher representation of the population (Fricker 2008). The original plan was to distribute the questionnaires equally among the three main risk zones (low, medium and high risk). The students were given maps highlighting each zone and a table with the number of respondents needed per zone depending on the area of each risk zone per neighbourhood. However, this proved difficult due to the difficulty in demarcating the zones. The sample was instead distributed according to neighbourhood and five neighbourhoods were selected because they covered the populated residential areas within the risk zones: Colaisa, La Fae & Sigsicalle, San Felipe and Rumipamba.

Colaisa

A residential neighbourhood at the north edge of the city. It includes some of the oldest neighbourhoods in the Latacunga and some of the newest.

San Felipe

A residential neighbourhood with a high number of light industries and commercial activities.

La Fae & Sigsicalle

Two high density neighbourhoods near the airport with multiple risk zones but mostly low risk.

Rumipamba

A neighbourhood at the southern edge of the city. Its increased risk comes from it falling between the two rivers that descend from Cotopaxi Volcano.

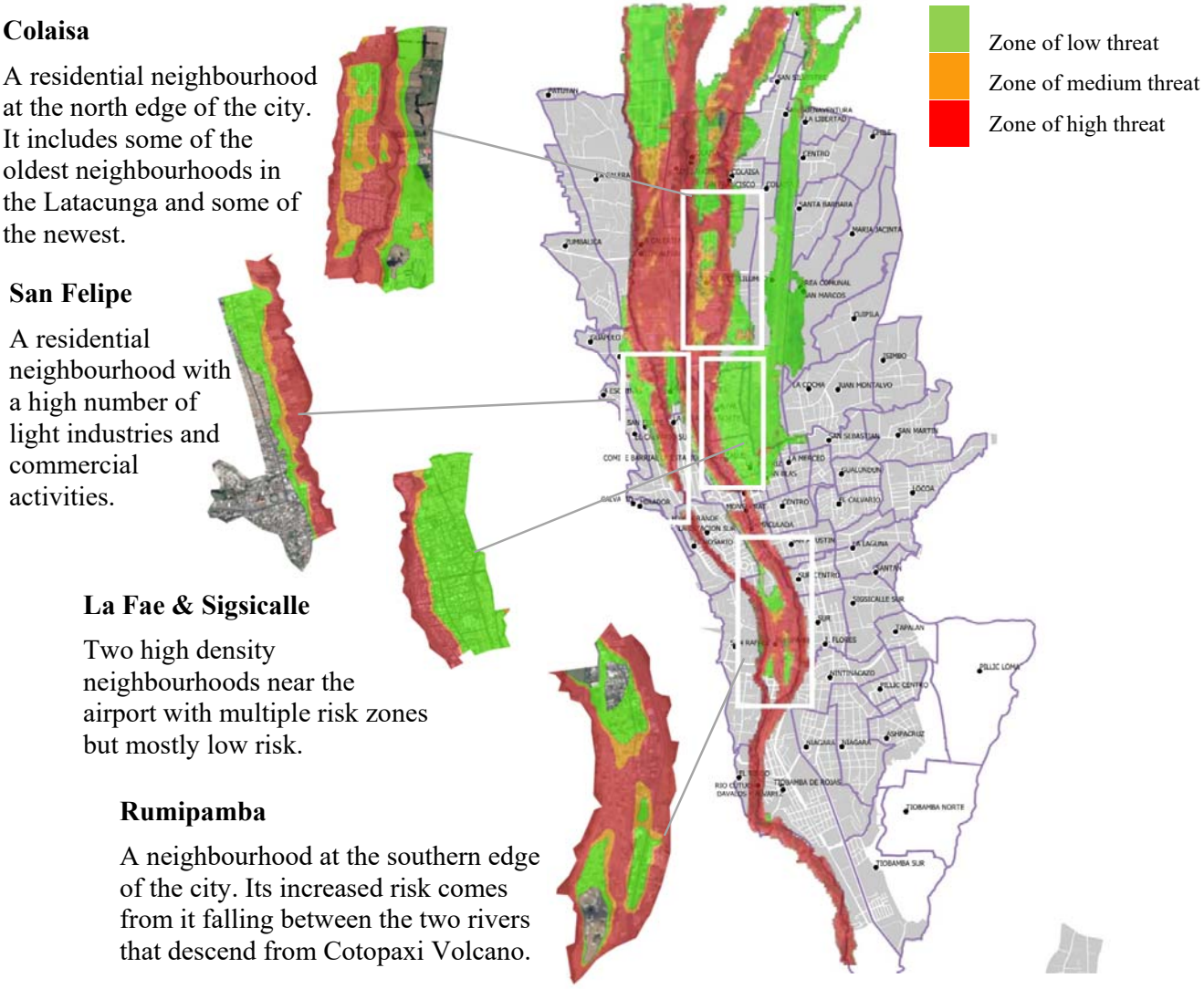

Figure 10: Sample selection and the distribution among neighbourhoods and risk zone. Author's work Adapted from Latacunga municipality risk zoning maps (Latacunga Municipality, 2019) and neighbourhood diagram from Grupo Faro (2019)

The sample size is calculated using Yamane formula (Israel, 1992) as follows:

$$N = \frac{n}{1+n(e)^2}$$

Where N is the sample size, n is the population size, and e is the margin of error. The number of households in Latacunga was estimated at 15,200 (total population is 63,842 and the average household size is 4.2). A 7percent margin of error was used making the standard confidence level 93percent. While the standard margin is 5percent, a higher margin was used due to the limitation of time and resources:

$$N = \frac{15200}{1+15200(.07)^2} = 201$$

Interviews with households and government officials were purposefully selected using snowballing and were recommended by the local NGO and the ISTC.

3.9 Data analysis methods and limitations:

A mixed data analysis method was used to analyse the various types of data. Quantitative data was collected by distributing written questionnaires in the designated neighbourhoods and then uploading them online to Qualtrics. The data was then analysed quantitatively using SPSS. The interviews were transcribed and coded using Microsoft Word and Excel and the secondary data using content analysis.

The statistical analysis focused on four main steps based on the sub-research questions: The first step aimed to explain how households in Latacunga perceive different types of risk. The second highlighted the strategies used by household to protect themselves from volcanic lahar risk. The third step explained how the perception of different risks impacted the selection of risk management strategies. The final step was to identify indication that could lead to land-use change based on the available data.

Descriptive statistics were made for all the indicators to understand the distribution of indicators across the sampled zones using frequency tests and cross tabs. The analysis then followed the conceptual framework, the indicators were analysed for each variable and then the differences between the neighbourhoods were highlighted. Secondary data was used to show the laws and existing patterns in the city and the qualitative data from the interviews was used to support and sometimes contrast with the statistical findings.

While the survey provided an understanding of how different household perceived volcanic and loss of livelihood risks, and what strategies they tended to prefer, several interviews were undertaken to gain more in-depth information. This included understanding more about why people are attached to Latacunga and the high-risk areas, how their perception changed after the 2015 eruption and how they viewed their future in these areas. Qualitative information was also needed to identify other strategies people use to protect themselves from the risk and to understand how they prioritize them. Interviews with local and provincial government officials were undertaken to understand how the strategies used by households converge and diverge from the governments' strategies to manage lahar risk.

In total 14 semi-structured interviews were undertaken with households, government officials at municipal and province levels, risk management officials, NGOs and scientists that helped understand how risk was perceived and managed in Latacunga. In addition, one focus group was held with university staff living in different risk areas.

Although both methods were complementary to each other, the main barriers to having more interviews with households were the safety issue and the language. It was difficult to move around the city unescorted because of the warnings of safety issues. Many of the high-risk areas were abandoned increasing insecurity. Translation also added to the limitations of the researcher as translators were not always available.

Another issue that restrained data analysis was the scarcity of data due to the limited research about Latacunga. Higher education is relatively young in Ecuador, and Latacunga is a medium size city with just over 60,000 inhabitants. Local NGOs and the university there said that all research in the canton focused on the rural areas.

Language and communication also complicated the data collection to some extent making modifications to the survey time consuming as it needed to be translated back and forth between English and Spanish and the reliability checked each time. The topic of volcanic risk is a sensitive one specially when asking people about their fear and dread of the volcano. Some of the questions were changed or adapted to avoid intimidating participants or making them feel

uncomfortable. Livelihoods cover more components and indicators than those mentioned here. The research focused mainly on the aspects that are directly related to land as it is the central part of relocational decisions which and brings together the different concepts.

Chapter 4: Research Findings

The research findings are discussed based on the research questions. The chapter begins by clarifying the context of risk governance in Latacunga and the relationship of city with Cotopaxi volcano. It then explains how households perceive different types of risk and follows with the strategies they use for protection and adaptation. The chapter concludes with a discussion that highlights the main outcomes of the analysis.

4.1 Cotopaxi volcano and Latacunga:

Latacunga is an intermediate city 107km south of Quito the capital of Ecuador that lies within the Andes region at a height of 2800m above sea level. A research looking at urban change in the central Highland in Ecuador between 1698 – 1940 emphasized Latacunga's importance as a town in the region particularly in the 18th century. Apart from its role as the administrative centre of a larger rural area, it contained Augustinian, Franciscan and Dominican monasteries, a house for the Mercedarians, and a Jesuit college reflecting its importance. The town also had a thriving industry compared to others in the region and included gunpowder and textile industries (Bromely, 1979). Multiple natural disasters coupled with economic changes in the region led to economic and demographic deterioration that had an adverse effect on urban development, and although the 1877 volcanic eruption is a milestone in Latacunga's social and natural history it was predeceased by several lahars and earthquake in the preceding 700 years. These disasters led to a decrease in the town's population not least because of the ruined state it was left in, causing the relocation of Jesuits and many residents to other areas. The 1877 eruption is the most famous because it is the best-documented when the lahars wiped out the only major urban factory speeding economic and demographic deterioration (Bromley, 1979).

Latacunga's neighbour, Mount Cotopaxi is one of the most dangerous volcanoes in the region. Its threat emanates from its ability to produce deadly volcanic debris flows called lahars (Mothes et al, 2017). These can be primary lahars triggered by volcanic activity, or secondary lahars which occur post-eruption due to the mobilization of debris mainly by rain. Cotopaxi has the three main factors essential for lahar generation: An adequate source of water that is rapidly available when triggered (in this case the glassier at its summit), steep slopes, and the availability of volcanic debris (Pistolesi, Cioni, et al., 2014).

Photographs 1: The Chilintosa rock is a famous site near Latacunga of a rock carriied by the 1877 lahars. (Author's photographs)

Photograph 4: Remnanants of Latacunga's famous textile factory buried by the 1877 lahars. (Author's photographs)

In 2015 there was an increase in the volcano's activity as deformation, ash plumes and ashfall, SO2 emissions, fumarolic activity, and lahars were all observed by geoscientists of IG EPN (Crafford, A.E., and Venzke, E. 2016). Although ash and gas were dispersed, it was considered a minor eruption as no magma or lahars were produced (IG EPN, 2015).

At six in the morning of the 15th of August, the local radio station in Latacunga announced that the alert level for the volcano was raised to red and that people need to evacuate:

> "*They said we are talking right now with a volcanologist and we want to alert you that at this moment there was a huge explosion, we can see lahars coming down! So please everyone evacuate because something terrible is going to happen so please leave!*"
>
> El Rosario interviewee describing his experience with the 2015 event (July,2019)

The event caused major havoc, fear and confusion throughout the city (Toulkeridis, Jacome, et al., 2018). Interviews and news articles indicated that some residents left the city (El Comercio, 2015), and while interviews showed some residents returned there is no official data do illustrate how many actually left or came back. Although the volcano did not produce lahars the event was a milestone for Latacunga as it reawakened the fact that Cotopaxi is still an active threat.

While this study focuses mainly on the urban area of Latacunga, it is important to understand the governance structure the city is part of. The governmental structure in Ecuador is made of the National government, the Provincial government, and the Cantonal government. Latacunga canton is the capital of the Cotopaxi province and includes 11 parishes with 62.6percent of its population in the rural area and 37.4percent urban. The canton relies mainly on agriculture as its source of income (INEC, 2011). Latacunga city is the only urban settlement within the canton, today. It is a city of medium rise concrete buildings with a population of about 63,767 according to the last census in 2011 (INEC, 2011).

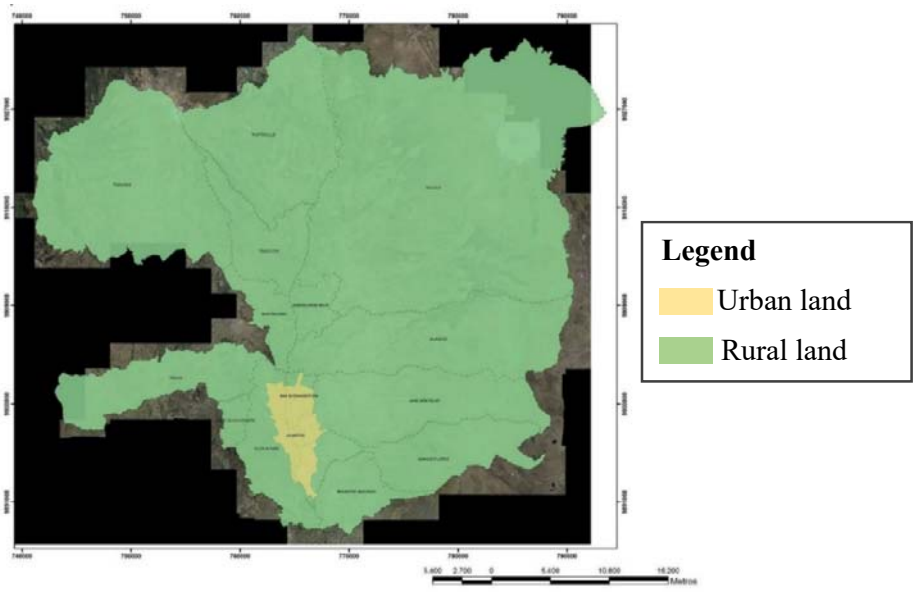

Figure 11: Latacunga canton urban and rural land areas (Latacunga Canton Plan of land use and management, 2019)

4.2 Data Analysis:

The primary quantitative data analysis was done using IBM SPSS statistics 25 while the qualitative interviews were coded and analysed using Microsoft Excel. Maps were created with a combination of software including ArcGIS Pro, Photoshop SC6 and Google Earth Pro.

In order to analyse the quantitative data from the survey descriptive statistics were first produced for all indicators (Table 2). The Chi-square test and Cramer's V test were then used to identify associations between the nominal and categorical indicators within each variable. Cross tab charts were produced to visualize distribution of indicators across groups; for example, risk knowledge across neighbourhoods. Several significant associations were found between the livelihood variables, so they were combined into a variable (Livelihood_Construct) after testing the reliability. The causality between the dependent and independent variables was determined using a Binary Logistic Regression as most indicators are ordinal and categorical. Several combinations of variables were tested to find the strongest combination of factors that included independent and control variables.

	Name of Indicator	N		Mean	Median	Mode
		Valid	Missing			
C1	Neighbourhood code	207	2	2,47	2,00	2
C2	Tenure type	205	4	4,40	5,00	6
C3	Q22.Age_new	167	42	38,99	36,00	30
C4	Gender	200	9	1,45	1,00	1
C5	Education level	206	3	2,48	2,00	2
C6	Civil status	207	2	1,91	2,00	2
C7	Ethnicity	207	2	5,96	6,00	6
C8	Income range	161	48	2,8944	2,0000	2,00
C9	Age range	167	42	2,5389	2,0000	2,00
C10	Duration_of _Residency small_intervals	202	7	6,9158	7,0000	7,00
L1	Importance of central location	209	0	5,26	6,00	6
L2	Importance of proximity to work	205	4	5,40	6,00	6
L3	Importance of proximity to family	203	6	5,75	6,00	6
L4	importance of proximity to services	204	5	5,58	6,00	6
L5	importance of connection with community	200	9	5,53	6,00	6
L6	Livelihood_construct	209	0	5,4982	5,6000	6,00
L7	Does the property provide extra income	208	1	2,57	3,00	3
V1	Eruption experience	208	1	0,18	0,00	0
V2	Evacuation experience	39	170	2,18	2,00	1
V3	Lahars defined as mudflows	209	0	0,36	0,00	0
V4	lahars defined as dangerous	209	0	0,31	0,00	0
V5	lahars defined as a threat to the city	209	0	0,34	0,00	0
V6	lahars associated with rain	66	143	0,11	0,00	0
V7	knowledge from experience	2	207	2,00	2,00	2
V8	knowledge from school	209	0	0,24	0,00	0

V9	knowledge from public event	209	0	0,16	0,00	0
V10	knowledge from media	209	0	0,62	1,00	1
V11	Expectancy of future lahars	205	4	3,66	4,00	4
V12	Awareness of risk plan	199	10	1,55	2,00	2
V13	Perception of risk zone	188	21	4,17	4,00	5
V14	Trust in zoning policy	204	5	0,41	0,00	0
S1	Strategy of multiple stories	209	0	0,00	0,00	0
S2	Strategy of a strong structure	209	0	0,07	0,00	0
S3	Technical modifications combined	208	1	0,15	0,00	0
S4	Strategy of evacuation routes	209	0	0,60	1,00	1
S5	Strategy of evacuation plan	209	0	0,35	0,00	0
S6	Strategy of river protection	209	0	0,03	0,00	0
S7	Involvement in community risk reduction	204	5	2,61	2,00	2
S8	protection strategies money saving	209	0	0,11	0,00	0
S9	Strategy of Insurance	209	0	0,06	0,00	0
S10	protection strategy community fund	209	0	0,03	0,00	0
S11	protection strategy other plot	209	0	0,26	0,00	0
S12	no protection strategy	209	0	0,36	0,00	0
S13	All strategies	204	5	1,77	2,00	1

Table 2: Descriptive statistics of all indicators generated as a frequencies table using SPSS Author's table

4.2.1 Characteristics of sample:

The final sample covered 212 households in five neighbourhoods each including a combination of risk zones: High medium and low in addition to some safe areas. Surveys were distributed equally within each neighbourhood with minor differences; the final number of surveys was 52 in Colaisa, 55 in San Felipe, 50 in Rumipamba and 50 in Sigsicalle and La Fae (La Fae and Sigsicalle were treated as one group as they are adjacent to each other and in order to cover a larger geographic area. Figure 12Figure 12**Error! Reference source not found.** shows maps indicating some of the distribution points in Sigsicalle, La Fae and Rumipamba and photographs of the distribution areas.

Figure 12: Maps of sample distribution points in Rumipamba (1,2,3,4) and Sigsicalle and La Fae (5,6,7). Map source: Latacunga Municipality 2019, images from Google Maps 2019.

Cross tabs were used to understand characteristics of the sampled population. An important aspect for the study was the duration of residency which was divided into 3-year categories as shown in Table 3.

After the 2015 eruptio	Neighbourhood Name				Total
	Duration of stay in neighbourhood	Colaisa	San Felipe	Sigsicalle & La Fae	Rumipamba	
Prior to the 2015 eruption	1-3	3	3	12	7	25
	4-6	2	7	7	5	21
	7-9	4	3	6	9	22
	10-12	2	4	3	7	16
	13-15	0	5	3	2	10
	16-18	0	1	1	2	4
	19-21	3	11	6	8	28
	22-24	2	2	3	0	7
	25-27	6	2	2	2	12
	28-30	6	5	3	1	15
	31-33	4	0	0	0	4
	34-36	2	2	1	0	5
	37-39	3	0	0	0	3
	40-42	2	2	0	3	7
	43-45	4	4	0	0	8
	49 and more	9	1	3	2	15
		52	52	50	48	202

Table 3: Residency durations per neighbourhood highlighting relocations into the risk are after the 2015 eruption Author's work.

The survey was distributed on the 10th of July/2019, three years and seven months after Cotopaxi's latest period of activity which ended in November 2015 (Bernard, Battaglia, et al., 2016). Therefore, residents who resided in the neighbourhood for three years or less were considered to have moved to the risk area after the eruption either from the city or from outside. The total percentage of new residents between the respondents is 12percent, most of which were in La Fae and Sigsicalle, while longer residency durations were concentrated more in Colaisa (26 years and more). The three other neighbourhoods show a range of durations but mostly concentrated between 4-15 years.

Respondents were asked about their exact age and the results were divided into seven groups. Table 4Table 4 shows the distribution of age groups according to neighbourhood. The highest number of respondents per age range was between 30 and 39 (36.3percent of all respondents). The younger respondents (between 18-39) were more in Colaisa while the older group of respondents (over 50) were the most in Rumipamba. The fact that younger residents were concentrated in the same neighbourhood with the oldest residency duration indicates that families have been there for multiple generations. This was confirmed during several interviews, for example the community leader from Nueva Vida (Colaisa) was born in the neighbourhood and his family had resided there for generations but he only built his house recently during the change of the zoning regulation.

Respondent age ranges								
Neighbourhood name	18-29	30-39	40-49	50-59	60-69	70-79	80 & older	Total
Colaisa	15	19	9	6	4	0	0	53
San Felip	9	12	11	4	0	0	0	36
La Fae & Sigsicalle	8	15	6	2	5	1	0	37
Rumipamba	7	15	6	6	5	2	1	42
Total	39	61	32	18	14	3	1	168

Table 4: Age ranges of respondents per neighbourhood. Author's work

Incomes of households were divided into 10 ranges. The students who distributed the survey said many respondents were reluctant to give their income levels; the total number of people who provided their income is 164 (77.4 percent from the total number of respondents). Table 5 shows the distribution of incomes based on neighbourhood.

Respondents income groups										
Neighbourhood name	0-250	251-500	501-750	751-1000	1001-1250	1251-1500	1501-1750	2001-2250	2251-2500	Total
Colaisa	6	15	16	7	3	0	0	0	0	47
San Felip	13	15	7	1	2	0	0	0	1	39
La Fae & Sigsicalle	1	23	3	14	4	0	1	0	0	46
Rumipamba	2	12	4	3	6	2	1	1	1	32
Total	22	65	30	25	15	2	2	1	2	164

Table 5: Respondents' income levels per neighbourhood. Author's work

Educational levels were divided into the following groups: No formal education, Primary school, Secondary school, Technical studies, University and Post graduate studies (Table 6). Half of the respondents who stated their educational level had primary education; these were mostly in San Felipe. Respondents from Rumipamba generally had higher levels of education with 27 percent of the respondents in the neighbourhood having technical, university or higher education.

Neighbourhood name	No formal education	Primary	Secondary	Technical studies	University	Post graduate education	Total
Colaisa	12	23	11	0	4	2	52
San Felip	7	38	10	2	0	0	57
La Fae & Sigsicalle	3	27	14	5	0	1	50
Rumipamba	5	16	14	4	4	5	48
Total	27	104	49	11	8	8	207

Table 6: Levels of education of respondents distributed by neighbourhood. Author's work

4.3 Households' perception of volcanic risk:

The concept of volcanic risk perception is constructed using three sub-variables: households' knowledge of the characteristics of lahars and the risk they impose, how households perceive their personal ability in coping with the risk, and their attitudes towards the risk management process.

4.3.1 Knowledge of the characteristics and implications of lahar risk

Knowledge of lahar risk was evaluated using two main indicators: The type of knowledge people possess was the first indicator and was divided into general and more scientific knowledge, or a combination of both. This was measured by the statements which respondents selected to describe the risk. The second indicator was the source of knowledge which is either direct through experience of lahars or a volcanic eruption, or indirect through media, school or a public event. Results showed 93 percent of respondents were able to describe lahars using at least one term. Some (36 percent) selected the "mudflows from the volcano" definition which is a more specific term, while 66percent selected general descriptions such as "a dangerous substance" or "a threat to Latacunga". However only six percent used two descriptions and none of the respondents used more than two. A few (three percent) described lahars as produced by rainfall; Such lahars occur more frequently but do not reach the city.

Despite the 2015 eruption and the havoc it caused, only 18.5percent of the respondents reported experiencing a volcanic eruption before. Table 7 shows the percentage of experience per residency duration period. Responses from more recent residents do not differ significantly from other duration groups as 20 percent of recent settlers said they have, in fact, experienced a volcanic eruption. The Chi-square test and Fisher's exact were also used to determine the association between the two indicators and the results showed no significant association.

Duration of residency in risky area	Eruption experience (%)	
	No	Yes
1-3	80	20
4-15	80	20
16-25	84	16
26-35	83	17
36-45	90	10
46-55	73	27
56 or more	75	25

Table 7: Percentage of respondents who experienced a volcanic eruption divided by the duration of residency in the risk area. Author's work

The source of knowledge indicators showed that knowledge is acquired mostly through various media sources (62 percent of responses). Other sources mentioned were schools (24 percent) and public events (15 percent). There is also a level of information transmitted through inter-generational communication, as the respondent from El Rosario describes it:

” *My father used to tell me during dinner if we have any kind of event or problem about the volcano please take your belongings and run away, go to that mountain and we can reunite in that place*”.

This respondent nonetheless, did not meet his grandparents and could not confirm if they transferred this knowledge to his father. Yet the community leader from Nueva Vida confirmed he learned about lahars through his aunt (over 80 years old) who coincided with the generation that witnessed the eruption. In an interview with the aunt she stated that lahars did not damage all the city as her family did not leave the house during the event and were not affected. The area she indicated is confirmed as a safe zone according to the municipality maps (Latacunga land use and management plan, 2019).

4.3.2 Attitude towards risk management:

The second sub variable of volcanic risk perception was formed by the attitudes of households towards risk management. These were measured using two indicators: Households' trust in authorities and their sense of responsibility towards the risk. To measure to what extent trust in authorities is an influential factor in risk perception respondents were asked if they believe following the government's zoning policy will protect them from the volcanic risk. Just over half of the respondents (59 percent) said following the risk zoning could protect them from the risk. However, 41percent did not believe so; a justification that occurred in the survey and during interviews was that people trust in God and believe that their being affected is strictly within his hands.

To measure if people see themselves responsible for the risk respondents were asked why they do not take any protective action. The answers were mixed, as 28 percent said it was not their priority to act upon it and 27 percent believed they are not at risk. Only 10 percent of respondents said they don't believe it is their responsibility indicating most people acknowledge their own role in protecting themselves from the risk.

4.3.3 Personal ability to cope with risk:

The ability to cope with the risk is measured by households' sense of exposure which is determined by their location to the risk, and how confident they are in the available protection. Confidence in protection was mentioned in the previous section through the trust in the zoning policy as the main long-term protection strategy provided by the government. In order to measure households', sense of exposure respondents were asked which risk zone they believe they were in and to what extent they believe the volcano will erupt during their lifetime. Most respondents (68percent) declared themselves in the medium or high-risk zones and only 7percent said they were in a safe zone. The sense of dread and fear towards the volcano was apparent in the number of respondents who believe the volcano could erupt during their lifetime (66percent) within which 22percent believed it is a certain possibility in comparison to 18percent who saw it as an impossible to low possibility.

Figure 13 shows a heat map made by asking respondents to select 10 points they believe are threatened by lahars compared to the actual risk map produced by the municipality. In order to analyse the map, areas with the highest selection (coloured in red, green and light blue) were calculated in Photoshop. The percentage of their overlap with the actual risk zone was then measured.

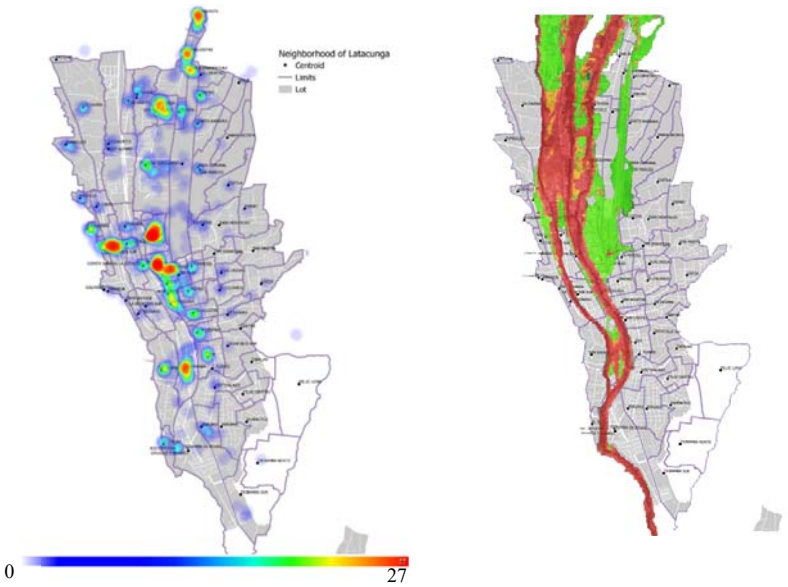

Figure 13: Comparison between actual risk zone and heat maps produced by respondents' selection. On the right: heat maps adapted from neighbourhood map (Grupo Faro 2019), on the right: risk zones according to the municipal risk zoning maps. Author's maps adapted from Latacunga municipality maps and Grupo Faro neighbourhood map 2019.

The heat map shows 56 percent of the area selected by respondents corresponds to actual risk zones. 13 percent of this area is highlighted in red reflecting multiple selections (27 or more). These areas are within the 5 neighbourhoods where the survey was distributed suggesting that respondents selected their own neighbourhoods as the risk areas.

4.4.4 Risk perception comparison between neighbourhoods:

The Chi-square test was used to find significant differences in volcanic perception indicators between neighbourhoods. Lahars defined as produced by rain, and the perception of risk zone indicators had a higher number of cells with an expected count less than five so Fisher's exact was used to verify their significance. Table 8 shows the results of the tests where stronger associations are in darker gradients. There is a significantly high association between the change in neighbourhoods and the type of knowledge and to a less extent with the source of knowledge.

Sub variable	Indicator	Strength of association (Cramer's V)	Significance level
Knowledge of the risk	lahars defined as mudflows	0.274	0.002
	lahars defined as dangerous	0.412	0.000
	lahars defined as a threat	0.321	0.000
	lahars defined as from rain	*	0.005
	Eruption experience	-	Nonsignificant
	knowledge from media	-	Nonsignificant
	Knowledge from school	0.321	0.000
	Knowledge from a public event	0.349	0.000
Attitude towards RM management	Trust in policy	0.286	0.001
	Responsibility towards the risk	0.351	0.000
Coping capacity	perception of the risk zone	*	0.010
	The expectancy of future lahars	0.244	0.000

Table 8: Association between volcanic risk perception indicators and neighbourhoods (Author's work), *Fishers exact was used to determine the significance of the association

An interesting finding was that when analysed by neighbourhood respondents from Colaisa showed the highest awareness about the government's risk zoning policy and the lowest trust in it. Respondents from La Fae, Sigsicalle and Rumipamba showed an opposing trend with less awareness of the policy but more trust in it. Interviews showed that respondents with more knowledge of the risk policy were the ones directly affected by it such as the community leader from Nueva Vida (Colaisa) who was told to hold construction of his house because of the change in the building regulation. This motivated him to learn more about the policy and evacuation plans and challenge both:

> "*When we started to hold these kinds of meetings [with the municipality] we knew more and had more technical data than the people who were working in the municipality and everything so what happened to us is we lost interest and stopped going to these kinds of meetings*". (community leader from Colaisa, 2019)

4.4 Households' perception of livelihood risk:

To understand what livelihood assets households relate to the location of the risk area, respondents were asked to rate the importance of locational and other factors. Chart 1 shows the indicators rated on a scale from 1-5. A high correlation was observed between the ratings as most of the respondents rated the factors as important and very important. A reliability test was performed which showed an acceptable reliability level (Cronbach's alpha=0.73). Accordingly, the indicators were combined into a new indicator and named Livelihood_Construct.

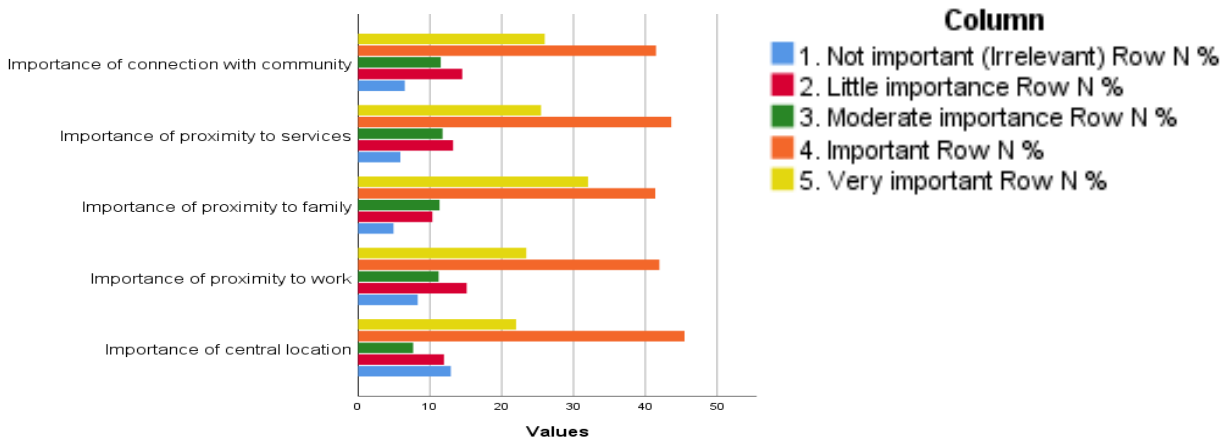

Chart 1: Rating of locational factors according to their importance. (Author's graph)

Respondents were also asked if the plot provides extra income (yes, no) and the type of tenure of their plot (5 categories). Only 26 percent said the plot provides additional income for the household. However, and in spite the primary use of the plot being residential, multiple interviewees mentioned the loss of investment made in the land and building due to the decline in land prices as a critical reason for them to remain in high-risk areas. "*My plot lost 40 percent of its value*" were the words of the resident from El Rosario. "*I stay here because I don't have anywhere else to go*". Chart 2 displays the percentages of tenure type where most of the respondents were owners of the land (61percent) and had either completed all payments (47percent) or still in the process of payment (14 percent) while only 30 percent were renters and 9percent had inherited the land which also implies the level of shared ownership was low.

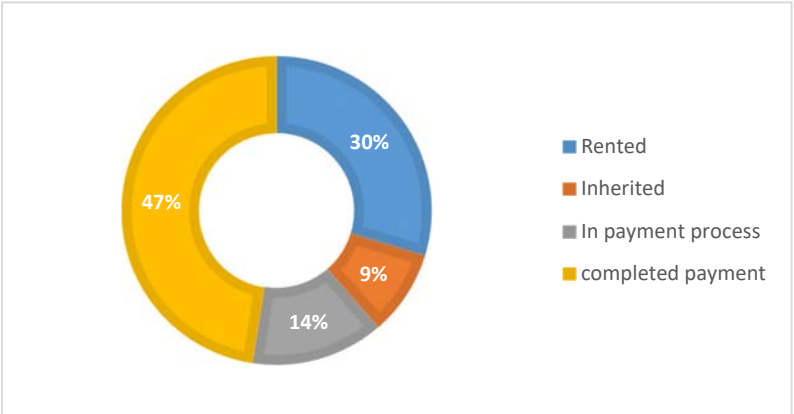

Chart 2: Types of tenure among the respondents. (Author's work)

A Chi-square test was performed for the indicators to find if the difference between neighbourhoods was significant. Table 9 displays the results of the test and shows that proximity to work, to the centre and to services, income provided from the plot, and the sense of community differ significantly between neighbourhoods.

Sub variable	Indicator	neighbourhood
Financial assets	Proximity to work (Cramer' V)	0.241
	Significance	0.000
	Income from location (Significance)	0.001
Natural assets	Proximity to the centre (Cramer' V)	0.238
	Significance	0.000
	Proximity to services (Cramer' V)	0.249
	Significance	0.000
	Tenure security (Significance)	Non significant
Social assets	Proximity to family (Significance)	
	I feel part of the community (Cramer' V)	0.252
	Significance	0.000

Table 9: Association between livelihood benefits provided by the location of the risk areas, the change in neighbourhood and the duration of stay in the area. (Author's work)

Chart 3 displays the importance of proximity to work, services and to the centre and being part of the community according to the differences between neighbourhoods. Between the groups, respondents from Rumipamba, Sigsicalle, and La Fae tended to value the proximity to the city centre more (74 percent of Rumipamba respondents said it was important and very important compared to 20 percent who said it was unimportant or irrelevant). However, a smaller number of respondents from San Felipe saw it as an important aspect (54 percent saw it was important compared to 39 percent who did not).

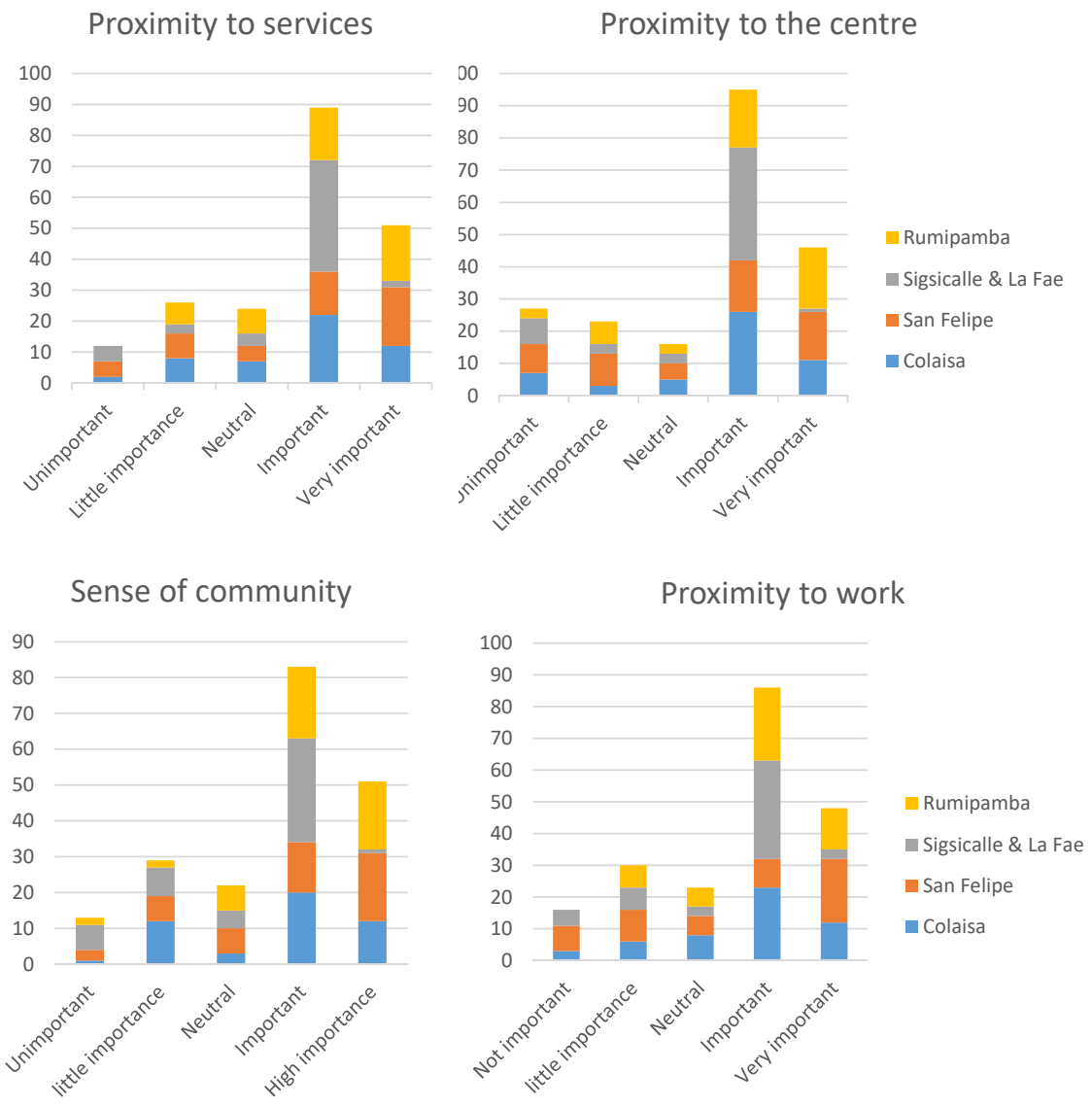

Chart 3: Importance of locational factors divided by neighbourhood.
Author's charts

Sigsicalle, La Fae and Rumipamba are the closest neighbourhoods to the city centre geographically. Through observation it was noticed that Rumipamba has the advantage of being on the other side of the Cutuchi river in a quiet zone less impacted by the traffic and commercialization of the centre while benefitting from direct connection to the centre through a bridge and tunnel. San Felipe conversely, is further to the west and is separated from the centre by two rivers and the zone between them making the connection less direct which could explain the results. Colaisa, while being the furthest from the centre, is on the same side of the river and is directly connected to the centre through the eastern road making it more accessible.

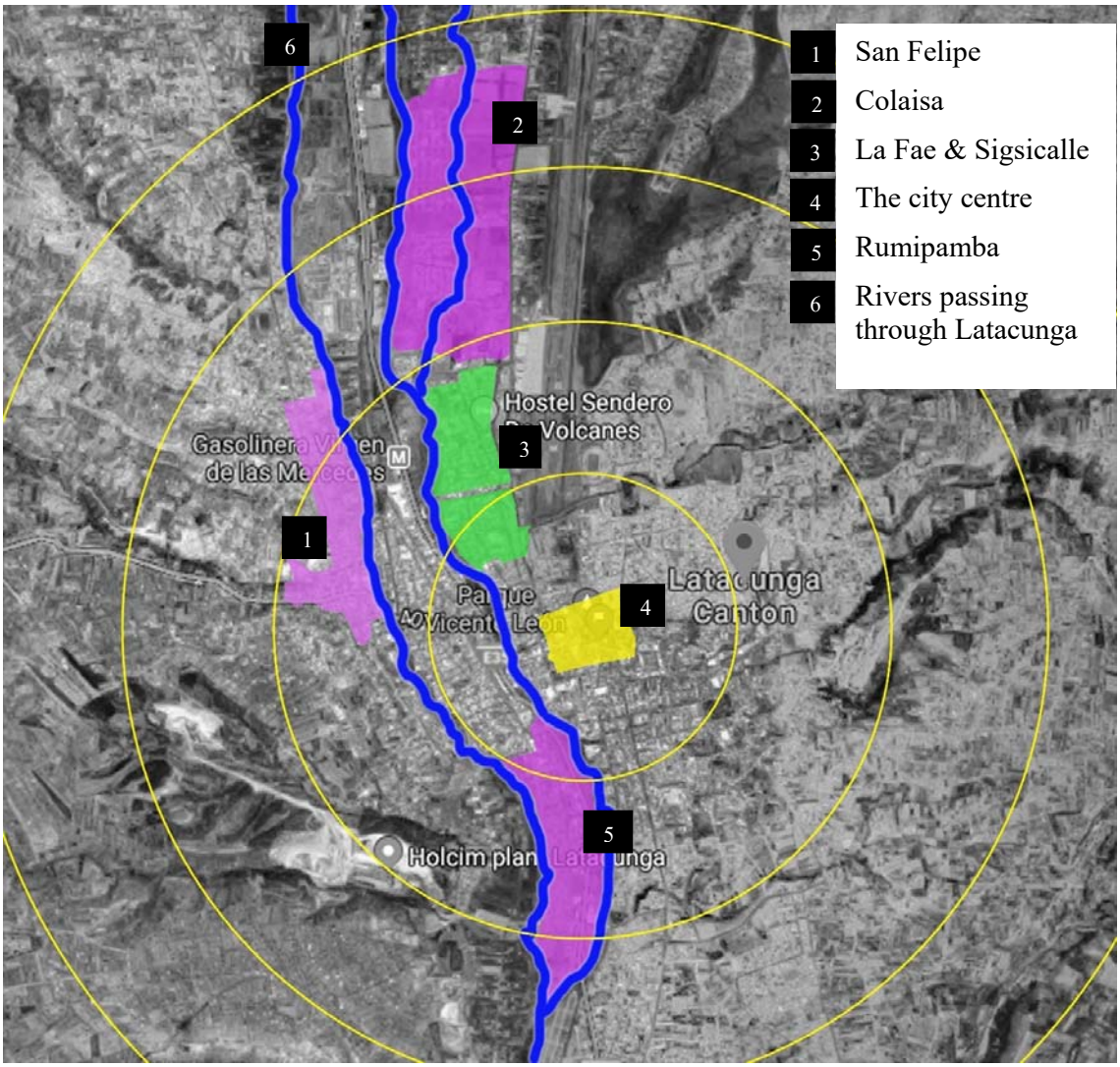

Figure 14: Aerial map showing the sampled neighbourhoods and their distances from the centre. Circles are offset from the central plaza at a 1 km radiuses. (Author's work)

The importance of the proximity to the centre also extends to the other aspects of location and while the maps of current land uses were not available to verify this, observations in the city and from google maps show a concentration of services in the centre. For example, the two main hospitals in Latacunga are within the one-kilometre radius from the centre, in addition to universities, civic and commercial buildings, and the main market. The new shopping mall located in Rumipamba is within the two-kilometre radius adjacent to a connecting bridge.

Personal assets were measured using the age and education level of respondents. Both characteristics can affect a person's behaviour and view of the world and hence impact decisions and life choices including how they use land (Koontz, 2001) and manage risk. The age range showed a significant correlation with the importance of being part of the community and the proximity to services indicating the importance of these factors increases with age and for older residents. At the same time duration of living within the neighbourhood showed a significant positive correlation with all five locational factors. The importance of community to the older respondents and those who have remained in the area for long indicates the significance of social capital in Latacunga: "*This is a small city, and everyone knows everyone, especially the older families*" was a comment made by the resident from El Rosario.

4.5 Households' strategies to protect from volcanic risk:

According to the literature review strategies used by households in case of volcanic risk could be divided into two outlining strategies: choosing to accept the risk by remaining in the risky areas or choosing to avoid it by relocating either partially or permanently. Within the surveyed households only 11 percent said they left the city to avoid the risk. As the resident from El Rosario said: "*people left the area. in some places they ... but they didn't like it and they came back*". Some of those who left never returned however, and although official statistics were not found to verify the number of residents who relocated permanently, it was mentioned in several interviews as the respondent from Rumipamba stated: "*The city started to look like a ghost city because the tenants started to leave*". A newspaper article published during the 2015 event interviewed residents who had left their houses temporarily and indicated that several neighbourhoods saw a significant decline in the number of occupants due to the event (El Comercio, 2015). Conversely, 42.5 percent of the respondents said they did not leave at all during the eruption and still reside in the risk areas.

Households within risk areas were asked which strategies they use to protect themselves from lahar risk. These were divided into personal strategies and group strategies. The personal strategies include technical modifications that could be applied by the household directly to the house and land such as having multiple stories, using protective walls or having a strong structure, and the non-technical strategies include having an additional plot in a safe area or a personal evacuation plan, having insurance or relying on private savings in case of a disaster. Group strategies are organized at the neighbourhood or city level such as evacuation routes and emergency community funds.

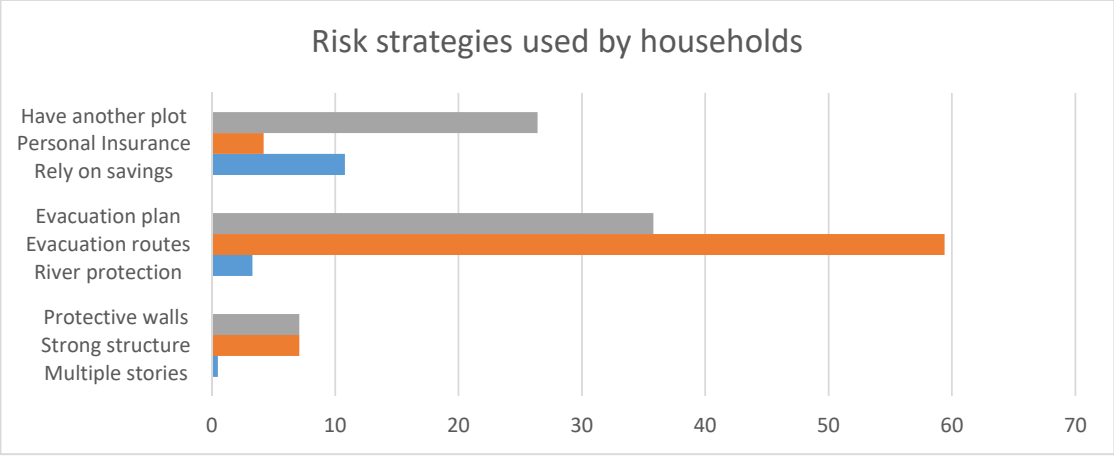

Chart 4: Risk management strategies used by households in Latacunga. (Author's work)

The most selected strategy among respondents (59.4percent) is to follow the official evacuation routes in the city. Evacuation signs are evident around Latacunga and its periphery (Photograph 5), and several respondents said they know to run to a high place in case of an eruption.

Photograph 5: evacuation signs in the city. (Author's photographs)

The official document provided by the national service for risk and emergency management include locations of evacuation centres per neighbourhood and the name of the road that should be followed in case of an eruption in addition to information about the alert systems, levels of the volcanic alert and information about the emergency kit (National service for risk and emergency,2019). No detailed maps were found that clarify the actual routes to be followed in case of an eruption. The document developed by the National Risk Service describes the lahar risk extent according to the maps created by IG EPN which do not match the municipality maps of the risk zones. The latter are more comprehensive and divide the risk into zones according to the typography of the area.

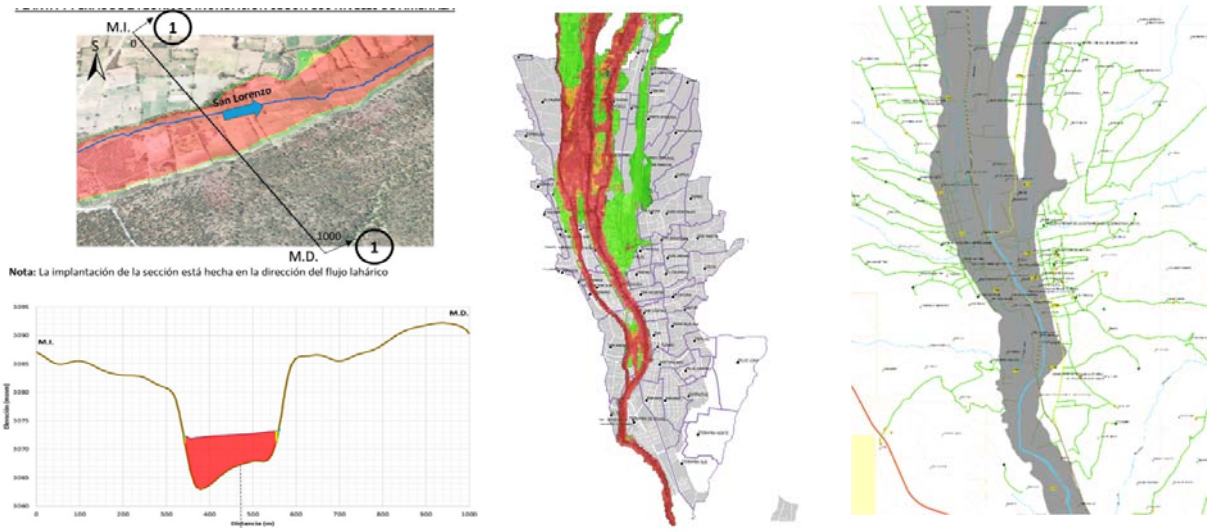

Figure 15: Maps showing the high-risk areas defined by (1) IG EPN maps and (2) Latacunga municipality maps. (3) shows a cross section within a risk area that is used to identify the different levels of the risk. (Source: National service for risk and emergency, 2019 and Latacunga land use and management plan 2019

A significant number of respondents (26 percent) said they have plots in safe areas that they will rely on in case of an eruption. This points out the fact that even though some have a safer option, they value the risky areas and chose to remain in them. The resident from El Rosario

described how during the 2015 emergency people evacuated to their other houses: "*people left in some places and some who had other houses went to live in them, but they didn't like it and they came back*". He described El Rosario as an attractive area to live in: "*The neighbourhood I live in I consider the best that anyone would be able to live in*". This was attributed to its safety compared to other neighbourhoods, in addition to its proximity to the city centre.

Only 19.8percent of respondents applied technical modifications to their property such as multiple stories and reinforced walls. The resident from Rumipamba who applied this strategy stated:

> "*The house is made of brick which is more resistant than volcanic rock, and has a steel structure, but we are aware that we need to raise the height of exterior walls of the house".*

Insurance was rarely used as a strategy as only 5.6 percent of surveyed respondents selected it. The insurance company interviewed mentioned that only three percent of the population in the city have disaster insurance as the cost is high compared to the probability of its need. This is despite insurance being a requirement of the new land-use plan for people residing in high-risk areas (Latacunga land use and management plan,2019).

In total 98.6 percent of the respondents selected at least one risk management strategy indicating people have some idea of what they will do in case of an emergency. Chart 5 displaying the number of strategies used per neighbourhood indicates that households in Rumipamba and San Felipe tend to use more strategies per household (three or four) compared to Households from Colaisa, Sigsicalle and La Fae who tended to use one or two strategies per household but the general trend is that fewer households use multiple strategies.

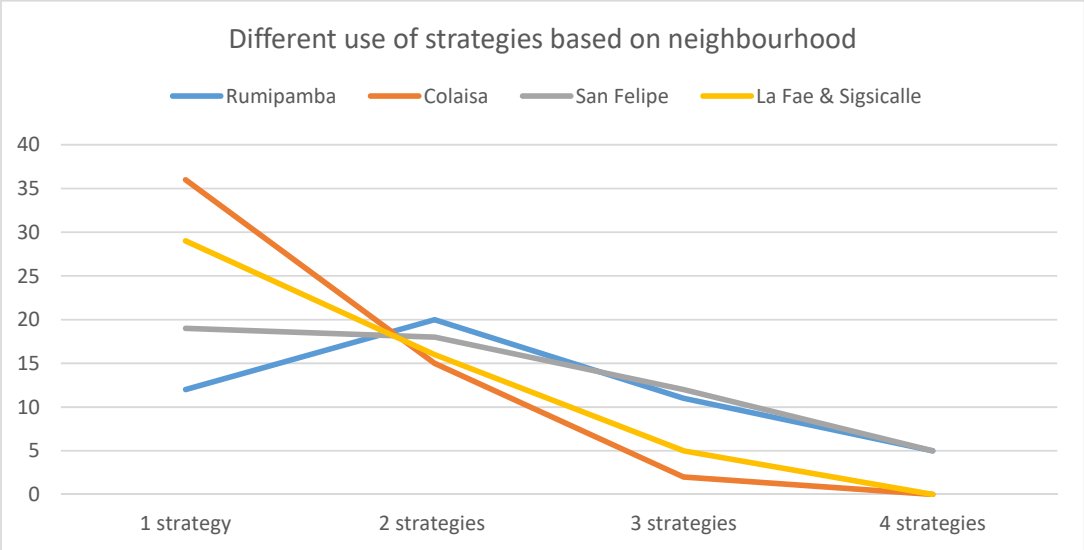

Chart 5: The number of strategies used per neighbourhood. (Author's work)

Table 10 displays the Chi-square tests to show if significant differences occur in the use of strategies between neighbourhoods. Two neighbourhoods showed opposite patters: respondents from Rumipamba rely more on having a plot in a safe zone and less on personal savings while respondents in San Felipe showed less reliance on additional plots but more on personal savings (Chart 6). The Chi-square was also used to test differences according to the tenure type and the duration of stay in the area, however no significant association was found.

Sub variable	Indicator	Strength of association (Cramer's V)	Significance level
Personal strategies	Technical modifications to building	0.270	0.002
	Evacuation plans	Non-Significant	0.000
	Rely on personal savings	0.401	0.000
	Have a plot in a safe area	0.308	0.000
Community strategies	Evacuation routes	0.238	0.008
	Participate in community risk reduction	0.227	0.002

Table 10: Strategies that show a significant difference between neighbourhoods. (Author's work)

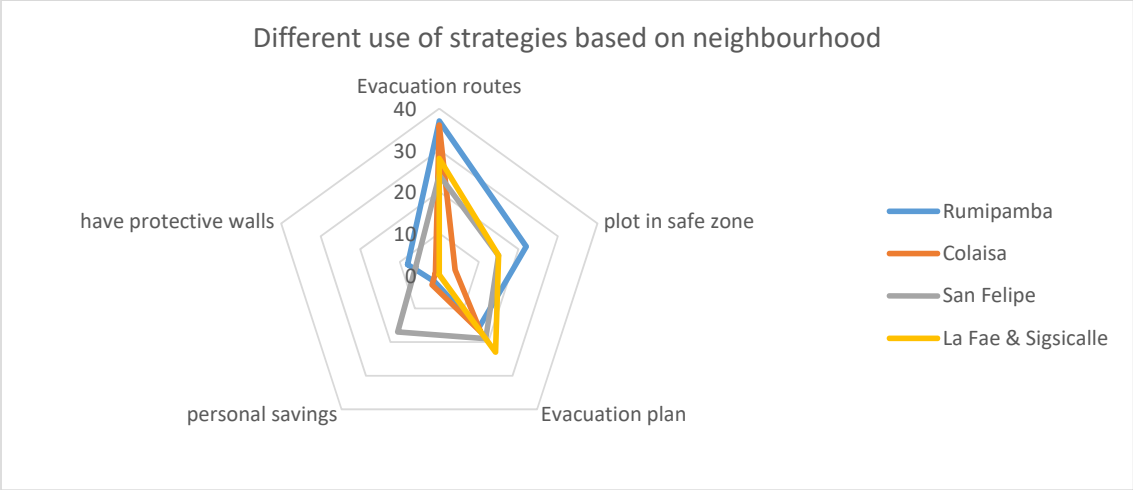

Chart 6: Differences in uses of risk management strategies between neighbourhoods. (Author's work)

Interviews revealed that the extent to which people plan for the risk differs considerably. This could be drawn from the type and number of strategies selected by households, and the extent to which their plans are developed. While 45.8 percent of respondents used only one strategy, only 5.6 percent used four or more strategies (Chart 7).

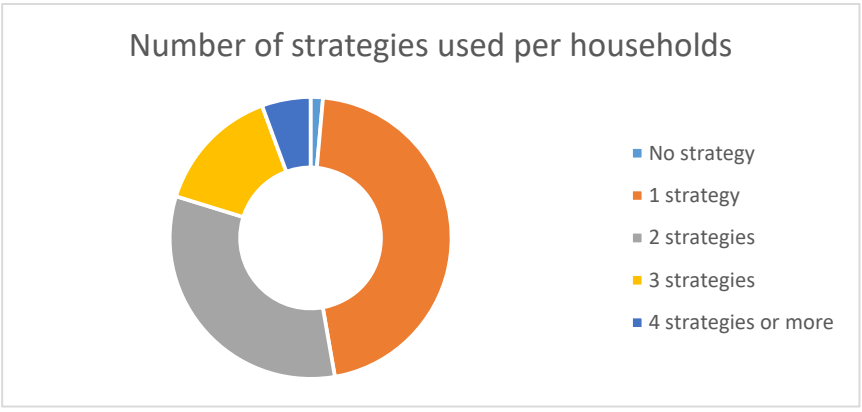

Chart 7: number of protective strategies used per households. (Author's chart)

The Chi-square test along with the Cramer's V test, Phi test, and Fisher's exact test were used to indicate significant associations between strategies of which the results are displayed in Table 11. Due to the low selection of these indicators the results only show significance of the relationship but not the strength or direction. Only the use of technical modifications in the building strategy and having a plot in a safe area strategy showed an intermediate significant positive association, both of which require significant financial resources. Reliability tests were then conducted for different combinations, but all results showed low reliability in combining different strategies.

	The strategy of evacuation plan	The strategy of river protection	protection strategies money saving	protection strategy community fund	protection strategy: another plot
Technical modifications combined					0.198
The strategy of evacuation routes					
The strategy of an evacuation plan					

Table 11: Associations between different types of strategies. The grey cells show associations tested using Fisher's exact test due to the small number of selections of the strategies. (Author's work)

Interviewed residents described detailed evacuation plans they formulated according to their perception of safety, their personal needs, prediction of the government's capacity to manage the risk and connections in other cities. Figure 16 shows the evacuation plan described by the community leader from Nueva Vida neighbourhood. He used the municipality evacuation plans as reference to how he plans his evacuation from the city in case of a lahar decent from the volcano.

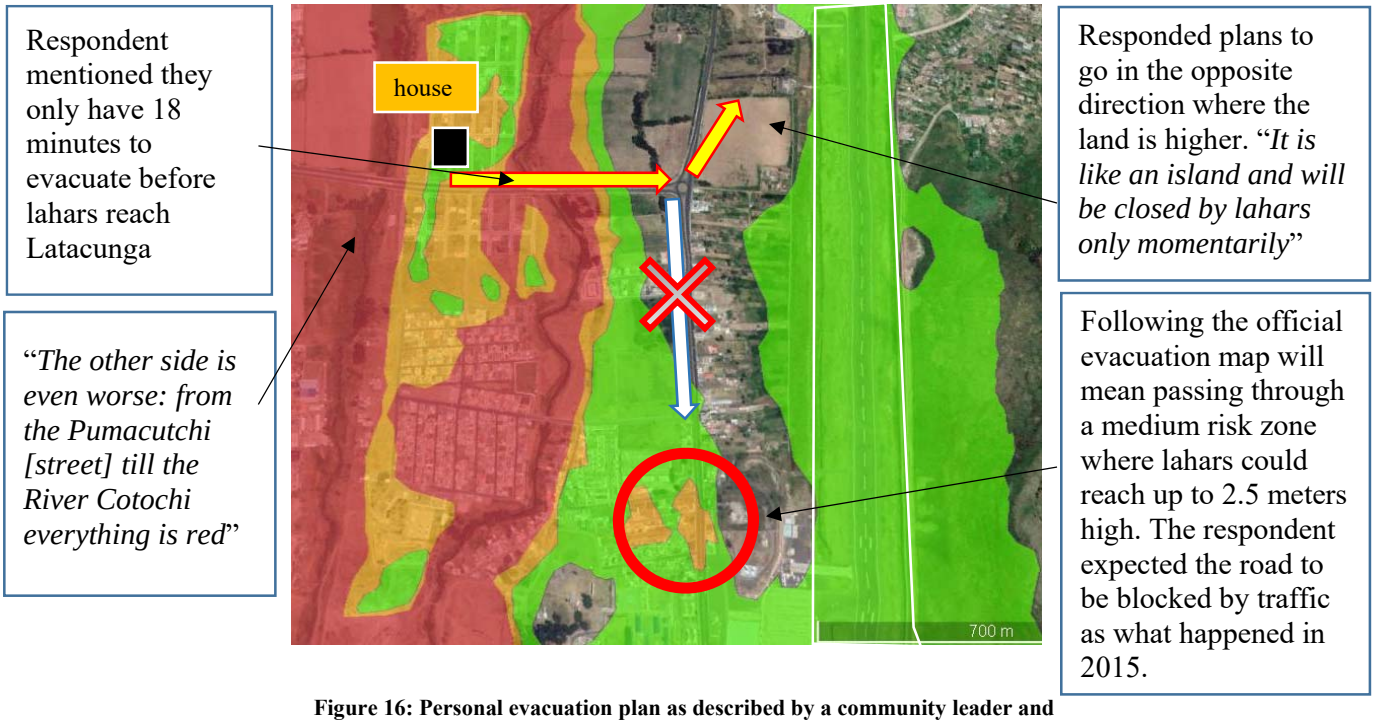

Figure 16: Personal evacuation plan as described by a community leader and resident of a high-risk zone. (Author's work based on the description of resident)

Figure 17 is a diagram of the evacuation plan described by the respondent from Rumipamba. Her plan is to leave the city to Salcedo because of its existing disaster response plan that was applied during the 2015 eruption where people found food and shelter. After Salcedo they will go to the city of Ambato where they have friends and there are good hospitals in the city. The respondent also mentioned that the two main hospitals in Latacunga, are in the high-risk zone which will reduce their probability of receiving care in case of a disaster. She described in detail the exact route she will evacuate through and how she and her family members have participated in evacuation training. This respondent's plan differs from the government plan due to personal circumstances and preferences.

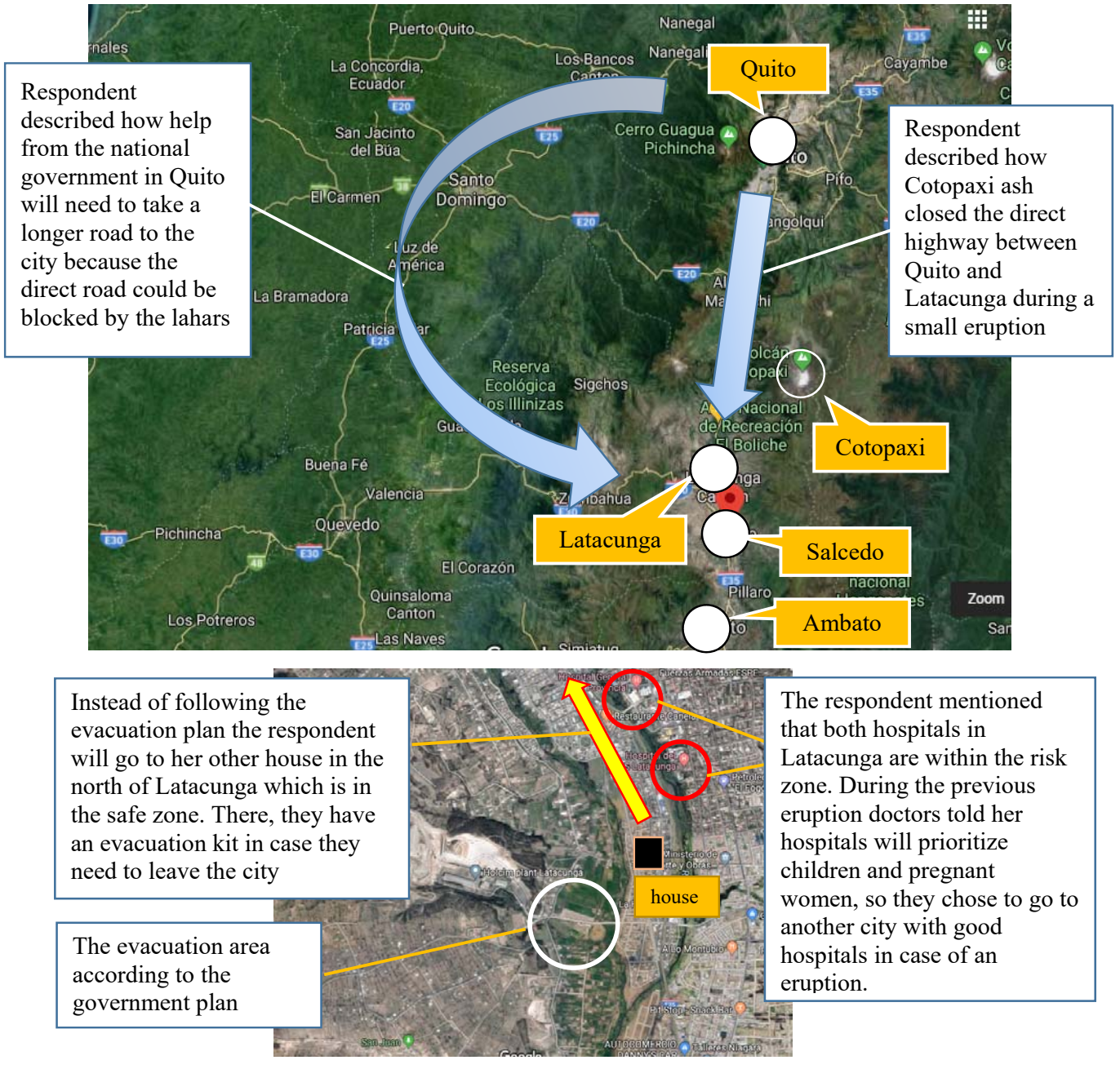

Figure 17: A description of he strategy planned by the resident from Rumipamba. (Author's work based on the description of resident)

In addition to those mentioned in the questionnaire, other strategies were referred to by multiple households during the research. The primary strategy mentioned was to go to a high location in case of an eruption: "*My family and I know that in case of an eruption we have run to a high place we have to go to a place called Las Balesmitas*" resident from El Rosario. A second strategy is having an evacuation kit that is prescribed by authorities in evacuation plans. Two residents mentioned having this kit and revising it frequently by replacing the food supply in case of an emergency: "*After 2015 I slept a year with the kit in front of my bed because I couldn't sleep at night*" resident of Rumipamba.

4.6 Risk perception and the use of protection strategies:

To answer the question of what factors drive the use of strategies in volcanic risk areas several tests were undertaken. First, the Chi-square test was used in combination with the Phi test, Cramer's V test and Fisher's exact test to highlight associations between the dependent and independent indicators. The Binary Logistic Regression test was then used to explain the relationship between the binary dependent variables (the use of each strategy), and the different independent variables. Several combinations were formed depending on the test results. Table 12 displays the outcomes of the Binary regressions.

	Knowledge source			Attitude to Management + Coping ability		Livelihood indicators		
Dependent variable (RM strategy)	Knowledge source: Public event	Knowledge from media	Knowledge from school + income range	Trust in Zoning policy	Trust in Zoning policy + Livelihood construct + Extra income from plot + Civic status	Livelihood Construct	Plot provides extra fund	Combination of school knowledge+ public event+ plot providing extra income + gender
Technical modification of building	6.7 %							
Reliance on plot in safe area				5 %	58.5 %	3.8 %		
Having Insurance		5.8 %						
Reliance on personal savings	7.9 %		16.65 %				21.6 %	26.3 %
Community Fund	8.2 %							

Table 12: Significant results of the binary logistic regression test. The green indicates the negative relationships and the yellow indicates the positive ones while the blue cells indicate the combined indicators. Author's work

The results show significant causal relationships to various levels. All the knowledge source variables lead to changes in strategies, except for the knowledge from experience. The change can be a negative one such as the knowledge gained from media and its affect on having risk insurance or could be positive such as the affect of gaining knowledge from school which causes 6.4 percent of the change in the reliance on personal savings. Knowledge from public

events was the indicator that affected the highest number of strategies and the reliance on personal savings strategy was the strategy that was affected by the greatest number of risk factors.

Based on the results combinations of indicators were created using independent and control variables. The highest causal relationship was found when combining the trust in the zoning policy with the livelihood construct, the plot providing extra income and the civil status of the respondent. Combined these risk factors lead to a 58.5 percent change in the reliance on having a plot in a safe area. The strategies that are affected by risk perception show a need for financial resources which could explain the importance of extra income. The trust in the zoning policy had shown a negative relationship with the purchase of land in a safe zone. This could indicate that most of those who do trust the zoning and have a safe plot have chosen to move out of the risky areas.

4.7 household decisions and land-use change:

According to the theory by Hersperger et al. (2010) the interactions amongst actors are a major driver of land-use change. This change had multiple faces in the case of Latacunga, however the change in land prices was mentioned by different actors as the main cause for people to remain within the risk areas. The following section highlights indicators of this change through the changes in land values.

4.7.1. Land value:

Multiple households mentioned the drop of land prices as a reason for remaining within the risk areas. Based on the market changes, the local cadastre updated the prices to include the risk factor. Figure 18 displays the location of the five selected neighbourhoods from the city centre and the cadastre prices of land in these areas prior to the 2015 eruption compared to a simulation of new prices which includes a risk factor. Cadastre prices are calculated according to the following formula:

$$\text{Land value} = Zg * A * (a+b+c+d+e) / 100$$

Zg = value per m2, A= Plot area, a = location factor, b = shape factor, c= typography factor, d = front/rear factor , e = facade factor. All prices are in the United States dollar which is the official currency in Ecuador.

A colour code based on the price ranges was created and applied to the maps according to the cadastre prices which range from 4$ to 550$. Before adding the risk factor, prices in Sigsicalle and La Fae which are the closest to the city centre had the highest price range between the sampled neighbourhoods ranging from 200$ to 350$ in the southeast plots. A gradual reduction in prices is visible moving north further from the centre through Colaisa where prices began from 200$ and dropped to 40$ in the northeast part of the neighbourhood. Price patterns were different in San Felipe and Rumipamba. The middle strip between the two main roads in San Felipe were the plots with the highest prices (90$ per square meter) while the lowest price in the neighbourhood was 30$ per square meter. The middle area in Rumipamba which falls between the two rivers passing through Latacunga had the highest price in the neighbourhood (80$ per square meter) except for a small strip at the north corner which is closer to the centre and was priced for 350$ per square meter. The lowest price in Rumipamba is the furthest to the south priced 30$ per square meter.

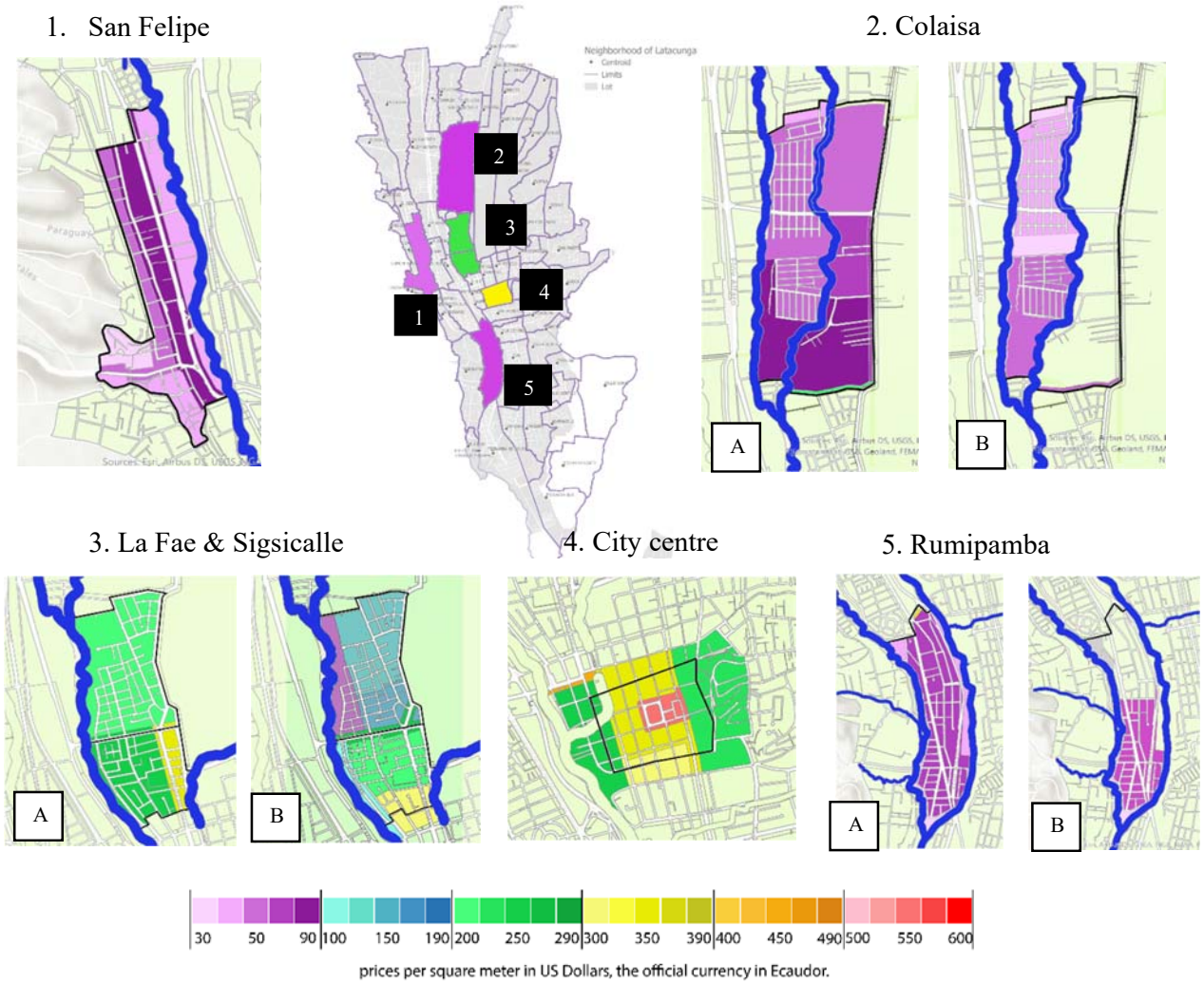

Figure 18: prices per square meter before and after adding the risk factor in 4 neighborhoods that are sampled in addition to the city center prices before adding the risk factor. Source: Authors own work based on data from various sources (Latacunga Cadastre data 2019, Latacunga municipality zoning maps 2019, Grupo Faro 2019)

Plan A shows the distribution of land prices per square meter in the neighbourhood before adding the risk factor while plan B shows the areas within each zone where the prices had changed according to the new price simulation. Neighbourhoods were impacted differently by the change in prices, San Felipe was the only neighbourhood where there were no changes in the land prices according the new simulation. Conversely, La Fae and Sigsicalle showed 100 percent change in prices with the change covering all price zones in both neighbourhoods and some plots dropping 57 percent of their square meter price.

While these prices are normalized based on the cadastre formula, they reflect the actual changes in land prices which took place due to the change in land zoning policy. This was verified by the cadastre and the fact that the update only took place following the changes in market prices which were registered in transactions that took place after the zoning policy.

The previous section shows how prices of land changed within the city due to the introduction of a new variable. Plots that were previously the most expensive were near the centre and

included commercial and service areas in addition to residential areas. While further empirical research could measure the exact impact in the land uses, interviews highlighted that many shops had closed due to the recession that followed the eruption. The market demand for these areas also dropped as the resident from Rumipamba stated how her house has been on the market for 4 years but was not able to sell it. Several similar cases were reported within areas that were once the most attractive within the city.

Chapter 5: Conclusions and recommendations

"*For us to be free from the volcano we must not fear its presence, instead we must respect the Gods by taking care of our environment and our people*" (Amongst fire, 2017)

This research started by asking the question is there room for the volcano? More specifically is it possible to make room for volcanic lahars such as the solution made for flood risk in the Netherlands room for the river project? The answer to this complex question began by studying the reality of the risk, or more specifically the reality of those who would be impacted by it the most: the households of a city residing within areas where volcanic lahars could reach up to three meters high.

5.1 How do households in Latacunga perceive different types of risk?

The research attempted to shed light on the bottom-up aspects of governing land with water and while the dynamics of this relationship shapes human settlements in various ways, the context of lahar risk adds a unique dimension to it. The research has hence viewed lahar risk in the combined lens of water management, risk governance, and land governance in order to explain the position of households and their decisions and actions within this context.

Much of the literature in risk management identifies risk perception as a motivation for action towards risk. The research hence explored the different angles of risk perception; lahar risk is an integral part of Latacunga as a city and its history where eruptions have shaped its socio-economic and political development for generations (Bromley, R. D. 1979). A high percentage of knowledge was found amongst residents who knew about the risk and what it could mean, however the important dimension of experience which is usually a key motivator for action was missing from their knowledge. Residents instead gain knowledge from secondary sources such as media, public events, and schools. These sources although secondary have proved to impact the actions people take to protect from the risk.

On the other hand and similar to research by Kellman (2008) and others, the study showed that livelihoods are a key aspect for people to remain in risk areas, as relocating could result in the loss of valuable livelihood assets. While most research focuses on dynamic aspects of livelihoods such as work opportunities, the study looked at the importance of the natural capital which is a principal factor that connects households to risky locations. The research found that households place a high value on various locational factors of the land such as social networks and the proximity to the centre. These values shape the relocation processes and decisions for households as they surpass the monetary value of the land which had dropped due to the change in policy rendering these areas valuable inspite the devaluation. Further research could look more at the nonmonetary values of land in areas at high risk to identify other factors that could increase this value and how this relates to perceptions of risk and livelihoods.

Social capital as a locational factor of high importance to residents can have an indirect effect on relocation decision as having other family members in the neighbourhood or strong social ties can make it more difficult for residents to leave even if they purchase land in safer areas. Two of the interviewed residents indicated they have family commitments that oblige them to stay within the risk area.

Results showed that although there was a level of trust in the risk management policy, this trust was from neighbourhoods who knew less about the policy and were probably not affected by it directly. Although the increase in awareness led residents to question the policy and its implications, it created a dialogue between the actors which could lead to better outcomes through knowledge sharing and awareness.

5.2 What strategies do households undertake to protect themselves and their assets from lahar risk?

The two main risk management strategies mentioned in the literature review were found in Latacunga, as some residents chose to avoid the risk by leaving the risky areas, while others continue to benefit from the risk and remain within areas prone to volcanic lahars despite the risk. Of these and like the level of knowledge about the risk, most households were found to have a basic idea about what action to take in case of an eruption. The most relied on strategy was to follow the evacuation routes and to have an evacuation plan. Another strategy that was highlighted in the interviews was to go to a high place. However, personal preferences and needs played a role in the planning process and although the government evacuation plans were known to many, the perception of evacuation was not necessarily harmonious. This was evident from the personal evacuation plans made by respondents which can differ significantly from the official plans.

Households tended to rely less on strategies that were specifically dedicated to the risk such as technical modification to the building and the purchase of insurance. This can show little awareness about the importance and the existence of such options as most official programs focus more on evacuation and relocation but could also reflect a lower willingness to invest solely in risk protection. The second explanation implies that combining strategies with multiple benefits could be more attractive for households.

Many people were reported to have relocated from the city due to the previous eruption, these took with them the valuable knowledge and experience of facing such a threat which could have been beneficial for the continuum of knowledge in the city. Further research could look at the extent to which such knowledge already exists in Latacunga as a city that has faced multiple eruptions in its past. Interviews showed that some knowledge is transferred through generations highlighting an important dimension for risk perception which is known to be used in rural and nonliterate communities (Bromley, R. D. 1979). Understanding the extent of such knowledge and its current impact is useful for policy aiming to change risk perception and inspire more proactive risk strategies.

5.3 How do different types of risk impact the households' choices and use of risk management strategies?

The types of strategies used by households were shaped by both volcanic risk perception through the sources of knowledge and trust in authorities and to a less extent by the livelihood aspects of the land. However, combinations of risk factors and socio-economic factors such as income, gender, and civil status showed to increase the impacts of these factors. In spite the little affect of risk experience on the selection of risk management strategies, the research showed that the source of knowledge is still an important factor in the type of strategies people use. Secondary sources of knowledge show causal relationships with several strategies highlighting that action motivated by knowledge is not limited to that gained from experience. Further research is needed to investigate more the value of other knowledge sources in motivating action which could be useful in the case of low probability high impact risks such as the lahars in Latacunga.

Although knowledge gained from public events was selected less as a source of knowledge about the risk, it had the most diverse effect on the selection of management strategies. Public events can have the advantage of more personal experience and provide the opportunity of live interaction with speakers and a more direct sharing of information.

The study found that strategies that showed significant relationships with risk factors were active and proactive strategies that require the use of financial resources. This correlates with research that indicates the poor are the most vulnerable to risk, as they have fewer assets.

The survey and interviews showed that people rely on religious beliefs as a coping strategy to tolerate the risk and be at peace with it. While Cotopaxi is a beautiful site to see, the sense of its presence and the damage it is capable of causing is strongly felt and seen in Latacunga. The Chilintosa rock carried to the city by the force of the lahars is surrounded by hundreds of boulders some the size of a car. The textile factory buried in the city centre is evidence of the magnitude lahars can have and evacuation signs are seen all through the city and in the rural areas whereas most households identify themselves as at risk or in a risk area. The belief that something is stronger than Cotopaxi seems to make the fear more tolerable and puts people at ease. Respondents in the survey put the risk in the hands of God highlighting the uncertainty of the event and its unpredictability.

Photograph 6: A high statue of the Virgin Mary is positioned near one of the evacuation centres. (Authors photograph)

5.4 The impact of risk on land-use change

Impacts on the land-use change could be explained through the lens of Hersperger et al. (2010) theory. Communities in high-risk areas form a strong informal institutional structure reflected in their attachment to community and to family. This attachment of older generations reoccurs through the new ones creating temporal feedback loops that extend through multiple timeframes. The role of risk as a driving force influencing this system is one that is continuously transforming increasing and decreasing according to the level of risk but is embedded within the system as an increase in religious beliefs and reliance on a stronger power. When risk is low other driving forces shape the decisions of households including economic and political forces, however the increase of risk or changes in its status can alter the dynamics within the system. This change could have a direct effect on land-use change such as the 1877 eruption which demolished large parts of the city and took the lives of people and families disrupting the existing spatial and social systems. It could also be a more indirect effect such as the 2015 event which affected the formal actors and led to changes in policy, these changes added a new dimension of risk perception to households as many started to comprehend the spatial dimension of the risk more realistically. The drop of land prices was one of the externalities of the policy that acted as a force that kept people in risk zones. Another indirect

effect of the 2015 event was the impact on the economic system which also led to changes in land uses such as the closing of many shops and businesses. This change reflects the integration and unity of the city as a complex system, as the economic situation did not only affect certain areas but all of the city. This has been the case historically in Latacunga where continuous volcanic disasters damaged the economic and political status it once enjoyed (Bromley, R. D, 1979). And as the risk continues so does the negative feedback it imposes on the economy unless other forces overcome it.

5.5 What factors drive the use of risk management strategies of households in Latacunga - Ecuador?

In terms of lahar risk, the source of knowledge and the trust in the zoning policy were found to be the factors that trigger the most change in different risk management strategies while the combination of locational factors that reflect the nonmonetary value of the land showed to have a significant effect on one strategy of those covered in the study which is having a plot in a safe area. The research showed that the effect of these factors varies between neighbourhoods. In addition, socio-economic and demographic factors such as gender, income, and duration of residency can change what strategies people rely on and how they combine them. Further research can look in more detail at the combinations of strategies and factors in order to identify additional factors and combinations.

5.5 Is there room for the volcano?

Similar to river floods in the Netherlands lahars are over floods of river streams that occur due to an increase in the amount of flow and damage the surrounding areas. Unlike water however, the damage executed by lahars is due to their velocity, speed and extent (Vallance, J., 2000). Lahars in the case of Cotopaxi are highly unpredictable as a small change in the amount of water or pattern of explosion could lead to very different outcomes (Mothes et al, 2017).

The solution applied in the room for the river project included integrated water governance and collaborations through different power scales in addition to clearing measurable space to make more for the water (Rijke et al. 2012). Comparing the technical aspects of both projects could be challenging as, in the case of Latacunga clearing such space according to the official geological maps requires evacuating over 80 percent of the city (IG EPN, 2019). The solution applied by Latacunga Municipality was to design a more detailed map using typographic information to exclude the higher areas from the risk zone, hence making less room for lahars. Providing more space for the volcano includes large financial investments, and although this was attempted through the land management plans and the designation of risk zones, important public buildings remain within the risk area as well as ten thousand houses and hundreds of businesses and public infrastructure.

However, the integrated governance approach applied in the Room for the River project could be analysed through a risk governance framework in order to provide valuable lessons that could be replicated in Latacunga.

5.6 Recommendations:

The 2015 eruption provided a valuable learning experience for the people of Latacunga. It surfaced the areas in the evacuation routs and information system that could be improved, and taught people what they might need to prepare in case of a future eruption. Many citizens educated themselves about the risk after that and can provide an important source of citizen science the government could benefit from.
While the government plans for the risk in a more structured top-down scheme, household strategies are organic developed according to their knowledge of the risk and their preferences

and personal experiences. Still, the general public plan to rely on the government evacuation routes and temporary centres in case of an eruption. Planning for an event with such high uncertainty however, could be extremely challenging particularly with the difficulty of predicting the outcomes. In such cases the word safe zone is highly circumstantial as changes in the strength of the eruption or amount of melting snow can transform the outcomes drastically. This makes the possible scenarios endless and creating a “one size fits all” solution rather questionable. Although multiple strategies can assist in managing such situations, safe zones and how to reach them should consider the most extreme of scenarios and should be given priority in how to share this knowledge with the public. It goes without saying that applying more participatory approaches can provide a wider space for innovation and knowledge sharing; a space where households and local government can meet half way.

Strategies were indicated in this study in a general manner based on strategies found in volcanic risk management literature, and while the research can indicate the types of strategies people tend to rely on, a more detailed study is needed that considers the implications of such strategies and the extent and complication for each. The outcome of such research could be a rating system that measures in more detail various indicators related to each strategy in order to gain results that are more comparable.
While this study focused on bottom-up strategies used by households, these overlap in various aspects with the strategies used by the government and in a risk governance framework interact and impact each other. Further research should look more at the types of such interactions and the outcomes they create in different contexts. As both directions converge and diverge highlighting these points can identify spaces for resource sharing and collaboration in order to reach more sustainable outcomes.

Photograph 7: Cotopaxi Volcano, Author's photograph

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Annex 1: Research Instruments

Room for the Volcano survey - Latacunga

Standard: Introducción/Introduction (4 Questions)
Block: General Information (7 Questions)
Standard: Perception of risk (9 Questions)
Standard: Risk management strategies (5 Questions)
Standard: Place Attachment / Apego al Lugar (1 Questions)
Standard: Información demográficas (5 Questions)
Start of Block: Introducción/Introduction

Good afternoon, My name is Tasneim Gaafar. I would like to ask you to fill in the following survey as part of an investigation of the Erasmus University of the Netherlands in collaboration with the Faro Group, the Cotopaxi Higher Technological Institute and the German Technical Cooperation Agency (GIZ). The objective of the research is to understand how the citizens of Latacunga view volcanic risk and what strategies they use to protect from them. This survey is NOT an exam so there is no correct or incorrect answer. Feel free to respond in a sincere and relaxed manner. Your participation in the research is voluntary and all data is used confidentially and is used only for academic purposes.

Q.a ¿Es usted residente de Latacunga? Are you a resident of Latacunga?

O Sí. Yes

O No. Le agradecemos su interés en participar en el estudio y lo (a) invitamos a invitar a otras personas -amigos, familiares, conocidos-, a participar en esta encuesta. (2)

Q.b ¿Are you 18 years old or more?

O Si. Yes.

O No. Le agradecemos su interés en participar en el estudio y lo (a) invitamos a invitar a otras personas -amigos, familiares, conocidos-, a participar en esta encuesta. (2)

Q.c Survey code (Neighborhood/Date/Number):_____

Start of Block: General Information_____

Q1 Lugar de residencia: Place of residence:

O Nombre del barrio: Name of neighbourhood_____

Q2 ¿Cuántos años llevas viviendo en esta zona?
Q2 How many years have you lived in this area?

_____

Q3 ¿Cuál es el ingreso total de su hogar por mes?

Q3 What is the total income of your household per month?

prefiero no decirlo

0 250 500 750 1000125015001750200022502500

Ingreso Mensual en dolares $ ()	

Q4 ¿Cuál es su papel en la toma de decisiones en su hogar?

Q4 What is your role in making decisions in your home?

O Tomo las decisiones importantes. I make important decisions

O Me consultan en decisiones importantes, pero no tengo la última palabra.
They consult me in important decisions, but I do not have the last word

O Conozco las decisiones importantes del hogar, pero no contribuyo a hacerlas.
I know the important decisions of the home, but I do not contribute to making them.

O No participo en la toma de decisiones. I do not participate in decision making.

O Otro: Other _____

Q5 La casa donde usted vive es: Q5 The house where you live is:

O Arrendada. Rented

O Propia y en proceso de pago. Owned and in the process of payment

O Propia y pagada completamente. Owned and payed completely

O Heredada. Inherited

O Otro (4) _____

Q6 Califique de 1 a 5 qué tan importante son las siguientes características para que usted considere que la ubicación de su vivienda actual sea favorable (1 es el aspecto más importante y 5 el aspecto menos importante):

Q6 Rate from 1 to 5 how important are the following characteristics for you to consider that the location of your current home is favorable (1 is the most important aspect and 5 the least important aspect):

	No importante Not important	Algo importante little importance	Moderadamente importante. Moderate importance	4. Importante important	5. Muy importante Very important
La vivienda está cerca del centro de la ciudad. The house is near the center of the city.	O	O	O	O	O
La vivienda está cerca de mi lugar de trabajo. The house is near my place of work	O	O	O	O	O
La vivienda está cerca de mi familia. The house is close to my family	O	O	O	O	O
La parroquia incluye buenos servicios. The parish includes good services.	O	O	O	O	O
Soy parte de la comunidad local. I am part of the local community.	O	O	O	O	O
Esta parroquia hace parte de mí. This parish is part of me.	O	O	O	O	O
Otro. Other	O	O	O	O	O

Q7 ¿Su edificio proporciona una fuente adicional de ingresos para la familia (alquiler, usos comerciales, etc.)?

Q7 Does your building provide an additional source of income for the family (rent, commercial uses, etc.)?

O no somos dueños del edificio. We do not own the building

O Sí. Yes

O No. No

O No lo sé. I dont know

Start of Block: Perception of risk

Q8 ¿Alguna vez has presenciado una erupción volcánica antes?

Q8 Have you ever witnessed a volcanic eruption before?

O No. No

O Sí. Yes

Q9 Si es así, ¿dónde te quedaste durante la evacuación?

Q9 If so, where did you stay during the evacuation?

O No evacuamos. We did not evacuate

O En un refugio del gobierno. In a government shelter

O Con parientes en otra ciudad. With relatives in another city

O Me quedé en una segunda casa que poseo en otra ciudad. In my house another city

O Otra. ¿Cuál? Other. Where?_____

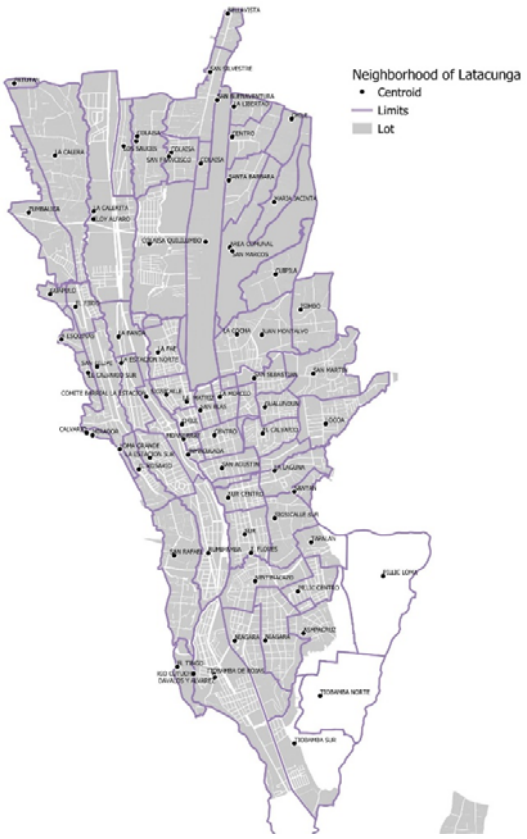
Q10 ¿Qué significa para ti el término riesgo de lahar? Seleccione todas las que correspondan.

Q10 What does the term risk of lahar mean to you? Select all that apply.

- El lodo fluye desde el volcán. Mud flows from the volcano,
- sustancia peligrosa dangerous substance
- Una amenaza para la ciudad de Latacunga A threat to the city of Latacunga.
- Puede ocurrir durante la temporada de lluvias. It can happen during the rainy season.
- Nada. No lo sé. Nothing, I dont know
- Otros (6) Other. _____

Q11 En el siguiente mapa, identifique el área que cree que puede verse afectada por lahares volcánicos:

Q11 On the following map, identify the area that you think may be affected by volcanic lahars:



Q12 ¿Cómo sabes acerca de los lahares volcánicos (flujos de lodo del volcán):

Q12 How do you know about volcanic lahars (volcanic mud flows):

Los he experimentado. I have experienced them

Aprendí sobre ellos en la escuela. From school

De un seminario público. Public seminar

Desde los medios de comunicación (TV, internet, etc.). Media (TV, internet, etc.).

Nada. No lo sé. Nothing, I do not know

Otro Other _____

Q13 En su opinión, ¿cuál es la posibilidad de que los lahares afecten a Latacunga durante su vida?

Q13 In your opinion, what is the possibility that the lahars affect Latacunga during his life?

	Imposible Impossible	Poca posibilidad little possibility	Neutral Neutral	Alta posibilidad high possibility	Claro que va a pasar Certain possibility
Posibilidad Possibility	O	O	O	O	O

Q14 Conozco plan de ordenamiento y uso territorial del cantón de Latacunga.

Q14 I know the planning and territorial use plan of the canton of Latacunga.

O Sí (1)

O No (2)

Q15 Sé en qué nivel de riesgo se encuentra mi vivienda.

Q15 I know what level of risk my home is in.

O Sin riesgo. Safe zone

O Riesgo bajo. Low risk zone

O Riego medio. Medium risk zone

O Riesgo alto. High risk zone

O No sé en qué nivel de riesgo se encuentra mi vivienda.
I dont know the risk zone of my house

Q16 Quiero que permanecer fuera de las zonas de riesgo designadas por el plan puede proteger mi propiedad.

Q16 I believe staying out of the risk areas designated by the plan can protect my property.

O Sí. Yes

O No. No

Start of Block: Risk management strategies

Q17 ¿Aplica alguna de las siguientes estrategias para proteger su casa de los lahares antes de una erupción? (seleccione todo lo que corresponda)

Q17 Do you apply any of the following strategies to protect your home from lahars before an eruption? (select all that apply)

- Construí múltiples historias. I built multiple stories
- Tengo una estructura lo suficientemente fuerte como para soportar lahares
- I have a structure strong enough to support lahars
- Yo uso paredes protectoras. I use protective walls
- Tengo Seguro. I have insurance.
- Tengo otras características protectoras. I have other protective characteristics

_____

- No aplico ninguna característica específica para la protección.
- I do not apply any specific feature for protection.

Q18 ¿Qué características están incluidas en tu vecindario para protegerte de los lahars? (seleccione todo lo que corresponda)

Q18 What features are included in your neighborhood to protect you from the lahars? (select all that apply)

- Hay rutas de evacuación adecuadas. There are adequate evacuation routes
- Tenemos un plan de evacuación. We have an evacuation plan
- Está fuera de la zona de riesgo de lahar. It's outside the lahar risk zone
- Hay estructuras protectoras alrededor de los ríos. There are protective structures around the rivers
- Hay características especiales de protección (nombre de ellos)
- There are special protection features (name of them)

_____

Q19 ¿Hasta qué punto estás involucrado en iniciativas comunitarias para protegerte del riesgo de lahar?

Q19 To what extent are you involved in community initiatives to protect yourself from the risk of lahar?

	No involucrado not involved	poco involucrado little involvement	neutral neutral	involucrado involved	activamente involucrado actively involved
La implicación en la gestión del riesgo The involvement in risk management	o	o	o	o	o

Q20 En caso de que se emitiera una advertencia de lahar en la ciudad, ¿qué estrategias piensa aplicar durante la erupción ?

Q20 In the event that a lahar warning is issued in the city, what strategies do you plan to apply during the eruption?

- [ ] Tengo ahorros personales en los que confiaré. I have personal savings that I will trust.
- [ ] He comprado un seguro en mi vida I have bought insurance in my life
- [ ] He comprado un seguro en mis propiedades. I have purchased insurance on my properties
- [ ] Soy parte de un fondo comunitario para emergencias.I am part of a community fund for emergencies.
- [ ] Tengo una parcela o casa en una zona segura. I have a plot or house in a safe area
- [ ] Lo pensaré si ocurre. I'll think about it if it happens

Otro other _____

Q21 No aplico ninguna de las estrategias de manejo de lahar anteriores porque (antes de la erupción o durante una erupción) porque:

Q21 I did not apply any of the previous lahar management strategies because (before the eruption or during an eruption) because:

- O No creo estar en riesgo. I don't believe I'm at risk
- O No es mi prioridad. Its not my priority
- O No es mi responsabilidad. It's not my responsibility
- O Otro. Other _____

Start of Block: Información demográficas

Q22 ¿Cuál es su edad? Q22 How old are you? _____

Q23 ¿Cuál es su género? Q23. What is your gender?

- O Feminino. Female
- O Masculino. Male

Q24 ¿Cuál es su último grado académico completado? Q24. What is your level of education?

O Primaria Primary school

O Secundaria Secondary school

O Universitario university

O Técnico. Vocational studies

O Maestría o PhD. Master or PhD

O Licenciatura Bachelor Degree

O Ningunov None

Q25 Estado civil: Marital status

O Soltero Single

O Casado Married

O Unión Libre Liberal union

O Divorciado Divorced

O Viudo Widowed

Q26 Etnia: Ethnicity

O Indígena. Indigenous

O Afroecuatoriano Afro-Ecuadorian

O Negro. Black

O Mulato. Mulato

O Montuvio. Montuvio

O Mestizo. Mestizo

O Blanco. White

O Otro. Other

O No registra. Not registered

Annex 2: Tables and diagrams

Classification of activity	percent
Wholesale and retail trade - Automotive and motorcycles vehicle repair	44.5percent
Manufacturing industries	21.6percent
Public administration and defence	7.7percent

Figure 19: Main activities that generate more income. Source: INEC economic census

Neighbourhood name	Having protective walls	Evacuation routs	Evacuation plan	Personal savings	Plot in a safe area	Total
Colaisa	12	23	11	0	4	52
San Felip	7	38	10	2	0	57
La Fae & Sigsicalle	3	27	14	5	0	50
Rumipamba	5	16	14	4	4	48
Total	27	104	49	11	8	207

Table 13: Risk management strategies divided by neighbourhood. (Author's work)

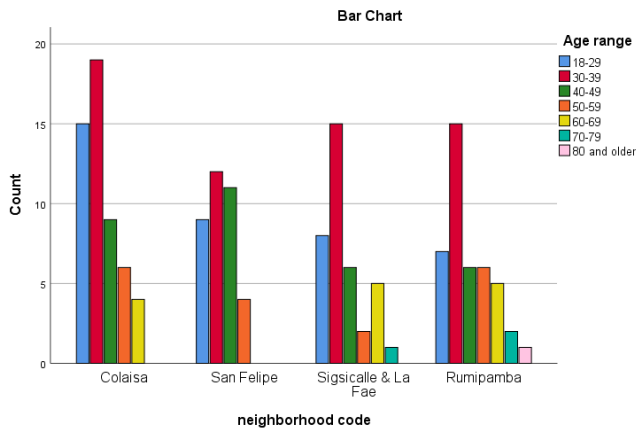


Chart 9: Age groups divided by neighbourhoods. (Author's work)

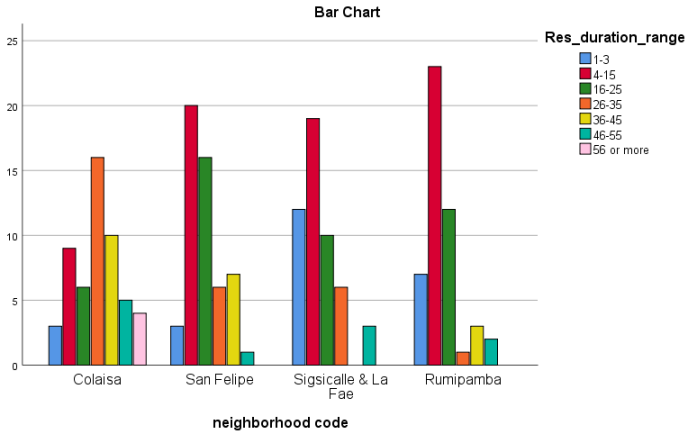


Chart 8: Differences in the durations of residency in the risk area between sampled neighbourhoods. (Author's work)

Tenure type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Rented	60	28,7	29,7	29,7
	inherited	18	8,6	8,9	38,6
	Property in payment process	28	13,4	13,9	52,5
	property and completed payment	96	45,9	47,5	100,0
	Total	202	96,7	100,0	
Missing	other	3	1,4		
	System	4	1,9		
	Total	7	3,3		
Total		209	100,0		

Table 14: Tenure types and their frequencies within sample. (Author's work)

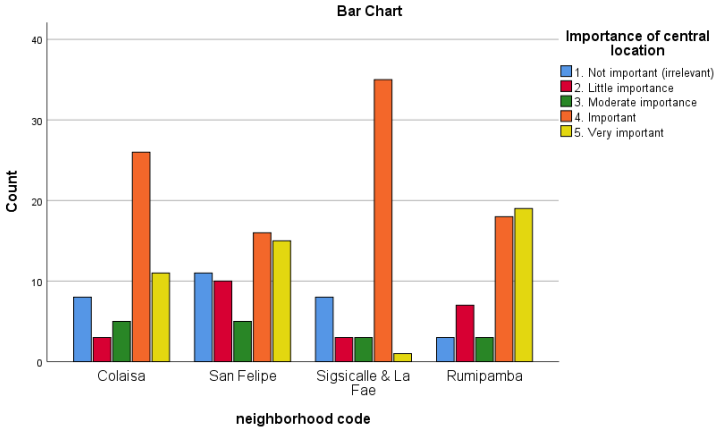


Table 16: importance of central location divided by neighbourhood. (Author's work)

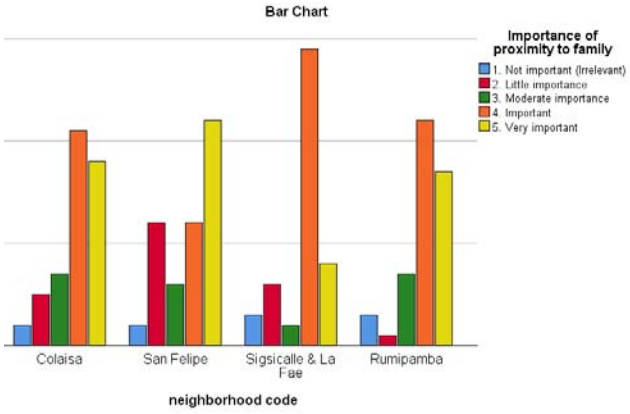


Table 15: importance of proximity to family divided by neighbourhood. (Author's work)

Annex 3: SPSS tests

Correlation, association and reliability tests

<table>
<tr><th>Dependent and independent variables</th><th>Test type</th><th>Test results</th></tr>
<tr><td>-Neighbourhood code
- Lahars defined as mudflows</td><td>Chi square test
Cramer’s V
Low: <0.1
Medium: 0.1-0.3
High: >0.3</td><td>
Chi-Square Tests
<table>
<tr><th></th><th>Value</th><th>df</th><th>Asymptotic Significance (2-sided)</th></tr>
<tr><td>Pearson Chi-Square</td><td>14,440[a]</td><td>3</td><td>,002</td></tr>
<tr><td>Likelihood Ratio</td><td>14,218</td><td>3</td><td>,003</td></tr>
<tr><td>Linear-by-Linear Association</td><td>4,832</td><td>1</td><td>,028</td></tr>
<tr><td>N of Valid Cases</td><td>207</td><td></td><td></td></tr>
</table>
a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 18,36.
Symmetric Measures
<table>
<tr><th></th><th></th><th>Value</th><th>Approximate Significance</th></tr>
<tr><td>Nominal by Nominal</td><td>Phi</td><td>,264</td><td>,002</td></tr>
<tr><td></td><td>Cramer's V</td><td>,264</td><td>,002</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>207</td><td></td></tr>
</table>
</td></tr>
<tr><td>- Neighbourhood code
- Lahars defined as dangerous</td><td>Cramer’s V
Low: <0.1
Medium: 0.1-0.3
High: >0.3</td><td>
Chi-Square Tests
<table>
<tr><th></th><th>Value</th><th>df</th><th>Asymptotic Significance (2-sided)</th></tr>
<tr><td>Pearson Chi-Square</td><td>35,150[a]</td><td>3</td><td>,000</td></tr>
<tr><td>Likelihood Ratio</td><td>33,514</td><td>3</td><td>,000</td></tr>
<tr><td>Linear-by-Linear Association</td><td>1,126</td><td>1</td><td>,289</td></tr>
<tr><td>N of Valid Cases</td><td>207</td><td></td><td></td></tr>
</table>
</td></tr>
</table>

		a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 15,22. **Symmetric Measures** Nominal by Nominal — Phi: Value ,412; Approximate Significance ,000 Nominal by Nominal — Cramer's V: Value ,412; Approximate Significance ,000 N of Valid Cases: 207
- Neighbourhood code - Lahars defined as a threat to the city	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	**Chi-Square Tests** Pearson Chi-Square: Value 19,741[a]; df 3; Asymptotic Significance (2-sided) ,000 Likelihood Ratio: 19,993; 3; ,000 Linear-by-Linear Association: 11,135; 1; ,001 N of Valid Cases: 207 a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 17,15. **Symmetric Measures** Nominal by Nominal — Phi: Value ,309; Approximate Significance ,000 Nominal by Nominal — Cramer's V: Value ,309; Approximate Significance ,000 N of Valid Cases: 207
- Neighbourhood code - Knowledge from school	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	**Chi-Square Tests** Pearson Chi-Square: Value 21,331[a]; df 3; Asymptotic Significance (2-sided) ,000 Likelihood Ratio: 22,894; 3; ,000 Linear-by-Linear Association: ,494; 1; ,482 N of Valid Cases: 207

		a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 12,32.
- Neighbourhood code - Knowledge from public event	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 7,97.
- Neighbourhood code - Expectancy of future lahars	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	a. 4 cells (20,0percent) have expected count less than 5. The minimum expected count is 1,72.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,321	,000
	Cramer's V	,321	,000
N of Valid Cases		207	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	25,266[a]	3	,000
Likelihood Ratio	25,290	3	,000
Linear-by-Linear Association	4,451	1	,035
N of Valid Cases	207		

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,349	,000
	Cramer's V	,349	,000
N of Valid Cases		207	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	36,394[a]	12	,000
Likelihood Ratio	32,537	12	,001
Linear-by-Linear Association	,883	1	,347
N of Valid Cases	203		

Symmetric Measures

			Value	Approximate Significance
		Nominal by Nominal	Phi	,423	,000
			Cramer's V	,244	,000
		N of Valid Cases		203	

- Neighbourhood code - Awareness of RM policy	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	**Chi-Square Tests** Pearson Chi-Square: 24,059[a], df 3, Asymptotic Significance (2-sided) ,000 Likelihood Ratio: 24,946, 3, ,000 Linear-by-Linear Association: 5,392, 1, ,020 N of Valid Cases: 197 a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 20,76. **Symmetric Measures** Nominal by Nominal – Phi: ,349, Approximate Significance ,000 Cramer's V: ,349, ,000 N of Valid Cases: 197
- Neighbourhood code - Trust in zoning policy	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	**Chi-Square Tests** Pearson Chi-Square: 16,497[a], df 3, Asymptotic Significance (2-sided) ,001 Likelihood Ratio: 16,700, 3, ,001 Linear-by-Linear Association: 14,766, 1, ,000 N of Valid Cases: 202 a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 20,79. **Symmetric Measures** Nominal by Nominal – Phi: ,286, Approximate Significance ,001 Cramer's V: ,286, ,001 N of Valid Cases: 202

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>- Neighbourhood code
- Sense of responsibility towards the risk</td><td>Chi square test:
Cramer’s V
Low: <0.1
Medium: 0.1-0.3
High: >0.3</td><td>
Chi-Square Tests
<table>
<tr><th></th><th>Value</th><th>df</th><th>Asymptotic Significance (2-sided)</th></tr>
<tr><td>Pearson Chi-Square</td><td>49,163[a]</td><td>15</td><td>,000</td></tr>
<tr><td>Likelihood Ratio</td><td>48,884</td><td>15</td><td>,000</td></tr>
<tr><td>Linear-by-Linear Association</td><td>1,296</td><td>1</td><td>,255</td></tr>
<tr><td>N of Valid Cases</td><td>133</td><td></td><td></td></tr>
</table>
a. 16 cells (66,7percent) have expected count less than 5. The minimum expected count is ,81.

Symmetric Measures
<table>
<tr><th></th><th></th><th>Value</th><th>Approximate Significance</th></tr>
<tr><td>Nominal by Nominal</td><td>Phi</td><td>,608</td><td>,000</td></tr>
<tr><td></td><td>Cramer's V</td><td>,351</td><td>,000</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>133</td><td></td></tr>
</table>
</td></tr>
<tr><td>Livelihood factors</td><td></td><td></td></tr>
<tr><td>Neighbourhood code +
Importance of central location</td><td>Chi square test:
Cramer’s V
Low: <0.1
Medium: 0.1-0.3
High: >0.3</td><td>
Chi-Square Tests
<table>
<tr><th></th><th>Value</th><th>df</th><th>Asymptotic Significance (2-sided)</th></tr>
<tr><td>Pearson Chi-Square</td><td>35,260[a]</td><td>12</td><td>,000</td></tr>
<tr><td>Likelihood Ratio</td><td>40,664</td><td>12</td><td>,000</td></tr>
<tr><td>Linear-by-Linear Association</td><td>1,183</td><td>1</td><td>,277</td></tr>
<tr><td>N of Valid Cases</td><td>207</td><td></td><td></td></tr>
</table>
a. 4 cells (20,0percent) have expected count less than 5. The minimum expected count is 3,86.

Symmetric Measures
<table>
<tr><th></th><th></th><th>Value</th><th>Approximate Significance</th></tr>
<tr><td>Nominal by Nominal</td><td>Phi</td><td>,413</td><td>,000</td></tr>
<tr><td></td><td>Cramer's V</td><td>,238</td><td>,000</td></tr>
<tr><td>N of Valid Cases</td><td></td><td>207</td><td></td></tr>
</table>
</td></tr>
</table>

- Neighbourhood code

-Proximity to work

Chi square test:

Cramer's V

Low: <0.1

Medium: 0.1-0.3

High: >0.3

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	35,330[a]	12	,000
Likelihood Ratio	42,305	12	,000
Linear-by-Linear Association	,863	1	,353
N of Valid Cases	203		

a. 4 cells (20,0percent) have expected count less than 5. The minimum expected count is 3,86.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,417	,000
	Cramer's V	,241	,000
N of Valid Cases		203	

-Neighbourhood code

-Proximity to services

Chi square test:

Cramer's V

Low: <0.1

Medium: 0.1-0.3

High: >0.3

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	37,592[a]	12	,000
Likelihood Ratio	44,045	12	,000
Linear-by-Linear Association	,843	1	,359
N of Valid Cases	202		

a. 4 cells (20,0percent) have expected count less than 5. The minimum expected count is 2,97.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,431	,000
	Cramer's V	,249	,000
N of Valid Cases		202	

-Neighbourhood code + -Connection with community	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	**Chi-Square Tests** Pearson Chi-Square: 37,716[a], df 12, Asymptotic Significance (2-sided) ,000 Likelihood Ratio: 45,313, 12, ,000 Linear-by-Linear Association: ,152, 1, ,697 N of Valid Cases: 198 a. 4 cells (20,0percent) have expected count less than 5. The minimum expected count is 3,15. **Symmetric Measures** Nominal by Nominal – Phi: ,436, ,000 Cramer's V: ,252, ,000 N of Valid Cases: 198
Reliability test for 5 indicators: -Proximity to centre -Proximity to family -Proximity to services -Proximity to work -Sense of community	Reliability test	**Reliability Statistics** Cronbach's Alpha: ,730; N of Items: 5 **Case Processing Summary** Cases – Valid: 193, 92,3 Excluded[a]: 16, 7,7 Total: 209, 100,0 a. Listwise deletion based on all variables in the procedure.
Strategies general		
- Neighbourhood code - Technical modifications	Chi square test: Cramer's V Low: <0.1	**Chi-Square Tests** Pearson Chi-Square: 15,020[a], df 3, Asymptotic Significance (2-sided) ,002

	Medium: 0.1-0.3 High: >0.3	Likelihood Ratio 16,263 3 ,001 Linear-by-Linear Association 6,623 1 ,010 N of Valid Cases 206 a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 7,61. **Symmetric Measures** Nominal by Nominal – Phi: Value ,270; Approximate Significance ,002 Cramer's V: Value ,270; Approximate Significance ,002 N of Valid Cases 206
- Neighbourhood code - Evacuation routes	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	**Chi-Square Tests** Pearson Chi-Square 11,700[a] 3 ,008 Likelihood Ratio 11,811 3 ,008 Linear-by-Linear Association 1,115 1 ,291 N of Valid Cases 207 a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 20,05. **Symmetric Measures** Nominal by Nominal – Phi: Value ,238; Approximate Significance ,008 Cramer's V: Value ,238; Approximate Significance ,008 N of Valid Cases 207
- Neighbourhood code -Community risk reduction	Chi square test: Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	**Chi-Square Tests** Pearson Chi-Square 31,226[a] 12 ,002 Likelihood Ratio 34,124 12 ,001 Linear-by-Linear Association 5,042 1 ,025 N of Valid Cases 202 a. 4 cells (20,0percent) have expected count less than 5. The minimum expected count is 2,61.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,393	,002
	Cramer's V	,227	,002
N of Valid Cases		202	

- Neighbourhood code
- money saving

Chi square test:
Cramer's V
Low: <0.1
Medium: 0.1-0.3
High: >0.3

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	33,368[a]	3	,000
Likelihood Ratio	32,454	3	,000
Linear-by-Linear Association	3,634	1	,057
N of Valid Cases	207		

a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 5,31.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,401	,000
	Cramer's V	,401	,000
N of Valid Cases		207	

- Neighbourhood code
- Other plot

Chi square test:
Cramer's V
Low: <0.1
Medium: 0.1-0.3
High: >0.3

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	19,633[a]	3	,000
Likelihood Ratio	22,606	3	,000
Linear-by-Linear Association	17,914	1	,000
N of Valid Cases	207		

a. 0 cells (0,0percent) have expected count less than 5. The minimum expected count is 13,29.

Symmetric Measures

		Value	Approximate Significance

		Nominal by Nominal / Phi: ,308 (,000) Nominal by Nominal / Cramer's V: ,308 (,000) N of Valid Cases: 207
Volcanic risk and strategies		
-Awareness of government zoning plan The use of evacuation plan	Chi square test Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	Medium association (0.176) with a high significance level significant (0.013)
- Livelihoods and strategies		
-Importance of central location, proximity to family, proximity to work, proximity to services, community -Evacuation plan,	Chi square test Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	Part of community:0.212 sig. 0.057
-Importance of central location, proximity to family, proximity to work, proximity to services, community -Safe plot	Chi square test Cramer's V Low: <0.1 Medium: 0.1-0.3 High: >0.3	Proximity to family: 0.225 sig. 0.034 Part of community:0.22, sig. 0.044

Binary regression tests:

Dependent variable (RM strategy)	Independent variable	Type of relationship	Direction of correlation
Technical modification of building	Knowledge source: Public event	Significant (0.02). 6.7percent of the variability in the dependent variable is accounted for by the independent variable,	Positive correlation: knowledge gained from public seminars increases the likelihood of using technical modifications
Reliance on plot in safe area	Trust in Zoning policy	Significant (0.008). 5percent of the variability in the dependent variable is accounted for by the independent variable,	Negative correlation: the more trust in the policy the less likelihood of having a plot in a safe area
Reliance on plot in safe area	Livelihood Construct	Significant (0.024). 3.8percent of the variability in the dependent variable is accounted for by the independent variable.	Positive correlation: the more important the livelihoods the more likely of having a plot in a safe area
Having Insurance	Knowledge from media	Significant (0.034). - 5.8percent of the variability in the dependent variable is accounted for by the independent variable,	Negative correlation: Gaining knowledge from media reduces the likelihood of using insurance
Reliance of personal savings	Knowledge source: school	Significant (0.006). - 6.4percent of the variability in the dependent variable is accounted for by the independent variable	Positive correlation: knowledge gained from school increases the likelihood of having savings as a lahar protective strategy
	Knowledge source: Public event	Significant (0.028). - 7.9percent of the variability in the dependent variable is accounted for by the independent variable,	Negative correlation: knowledge gained from public event decreases the likelihood of having savings as an lahar protective strategy
	Financial asset: Plot provides an extra source of income	Significant (0.000). - 21.6percent of the variability in the dependent variable is accounted for by the independent variable,	Positive correlation: the plot providing extra income increases the likelihood of having savings as an lahar protective strategy
	combination of school knowledge+ public event+ plot providing extra income+ gender	Significant (0.00). -26.3percent of the variability in the dependent variable is accounted for by the independent variable,	Positive correlation: the plot providing extra income increases the likelihood of having savings as an eruption protective strategy

Community Fund	Knowledge source: Public event	Significant (0.02). - 8.2percent of the variability in the dependent variable is accounted for by the independent variable,	Positive correlation: knowledge gained from public seminars increases the likelihood of being part of a community fund
Personal evacuation plan	Independent variable indicators	No significant correlation	
Use of evacuation routes	Independent variable indicators	No significant correlation	

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