

## Article

# Managing Risk Mitigation in Urban Expansion Areas of Argentina's Drylands: The Gap between Perception and Environmental Behaviour

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**Abstract:** Accessibility to rigorous scientific information to promote risk mitigation measures by citizens is crucial, especially in the context of climate change and extreme weather events. This study focuses on the perception of flood risk and the implementation of mitigation strategies by residents in drylands urban sprawl areas. Risk perception, defined as the subjective assessment of the likelihood and potential consequences of flooding, is a key element of mitigation. While many studies have explored the link between risk perception and behaviour, this research addresses gaps in understanding how public information affects these perceptions and actions. In areas of rapid urban expansion, where regulation often overlooks environmental features, the lack of adequate information poses significant barriers to effective risk mitigation. This research reveals that although residents claim to understand flooding, their descriptions often indicate a lack of understanding of the phenomenon. This 'passive optimism' could be mitigated by providing rigorous information and specific technical recommendations. This study highlights the disconnect between residents' awareness of flood risks and the inadequacy of preventive measures, underlining the importance of targeted information and collaboration between the scientific community, government sectors, and local populations.



**Citation:** Sales, R.; Rescia, A.J. Managing Risk Mitigation in Urban Expansion Areas of Argentina's Drylands: The Gap between Perception and Environmental Behaviour. *Land* **2024**, *13*, 1216. <https://doi.org/10.3390/land13081216>

Academic Editor: Yuan Zhang

Received: 17 July 2024

Revised: 4 August 2024

Accepted: 5 August 2024

Published: 6 August 2024



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**Keywords:** passive optimistic attitude; environmental awareness; urban sprawl

## 1. Introduction

Given the increasing likelihood of extreme weather events due to climate change, it is important to understand how citizens' access to information can influence the preventive measures taken to cope with growing environmental risk. Analysing the factors that influence the decisions of local actors in the face of the possibility of flash floods, especially in arid areas, presents a complex challenge. In this context, the analysis of risk perception emerges as one of the main elements in disaster mitigation [1], as understanding how risk is perceived and how this perception influences behaviour and allows for the identification of key aspects for preventive action.

Risk perception represents a widely debated theoretical construct, especially in the context of events such as flash floods. For the purposes of this study, risk perception refers to the subjective assessment of the probability of occurrence and the potential consequences of a flash flood by residents of vulnerable areas [2]. In this sense, the relationships between risk perceptions and mitigation actions have been extensively researched [3–5].

This makes even more sense in areas of rapid urban expansion, where accelerated land-use changes accentuate wealth inequality and cause significant losses in biological diversity [6]. In Latin America, the expansion of cities into rural–natural territories generates social, economic, and environmental consequences that have a stronger impact on drylands

undergoing desertification processes [7]. In many of these areas, although citizens perceive the alluvial risk, they do not have a deep understanding of the local environmental characteristics. This lack of understanding constitutes a significant obstacle to the implementation of effective risk mitigation strategies.

In countries like Chile and Argentina, various natural disasters such as desertification, forest fires, earthquakes, heavy rainfall, and flash floods represent constant threats. This study focuses on the interaction between inhabitants and flash floods, defined as sudden and swift movements of materials such as mud, soil, and rocks, which travel along streams or steep gullies for several kilometres. These can occur within minutes or even hours after heavy torrential rainfall, a dam break, or a sudden release of water from an ice dam [8]. Although their origin is multifactorial, they are mainly associated with extreme weather events, such as torrential rains [9]. The relevance of this type of disaster has increased in recent years due to climate change, which has intensified precipitation and, consequently, the risks of flooding and flash floods [10].

This risk is particularly critical in areas of urban expansion with little, lax, or no land-use planning. According to the United Nations (2017), flash floods are one of the most common disasters in Latin America and the Caribbean, a region with the second-highest frequency of these events. In the decade between 1995 and 2005, 548 floods and landslides were recorded in the region, with economic losses reaching USD 1 billion and 53 million people directly affected [11]. In Argentina, the frequency of alluvial events has increased significantly. In the 1990s, 13 floods were recorded in the country, while in the 2000s, the number almost doubled, reaching 24 events [12]. These floods have had a considerable impact on the local population. This indicates that, despite advances in environmental land-use planning, in some cases, planning is insufficient to control rapid urban expansion in high-risk alluvial zones. On one hand, it is noted that in numerous situations, regulations do not consider the environmental characteristics of these areas, whilst on the other hand, they are often not respected by real-estate developers.

Urban expansion, in most cases, is not adapted to the piedmont environment, which generates impacts related to intensive use of water and soil, the deforestation of native vegetation, and the modification and correction of alluvial channels among other impacts. The interaction of these degradation factors generates a process of accentuation or enhancement of the alluvial risk characteristics of the area. In this regard, we find numerous studies on risk perception in tropical humid areas and particularly in coastal zones [10,13]. In addition, there are various works that analyse the link between environmental perception and behaviour, as well as studies related to the advantages and challenges of environmental communication [14]. Among these, numerous researchers have focused on reflecting on educational tools to influence students with aimed at the improvement and protection of the environment [15]. However, it remains a challenge to investigate the obstacles to applying risk mitigation strategies in cases where citizens recognise the possibility of a flood. Moreover, there is little work that seeks to address the discrepancies between perception and behaviour, especially when it comes to factors such as access to public information. Likewise, it is necessary to propose solutions to the insufficiency or lack of application of these mitigation strategies by citizens.

In the field of risk management, communication plays a key role, especially in Latin America. Environmental communication, understood as the exchange of information between individuals, groups, and institutions, fosters stakeholder participation and improves the quality and efficiency of public policies and regulations [16]. Among the highlights of previous research is the implementation of effective communication through early warning systems in order to minimise the potential impacts of hazards during natural events [17]. Although there are studies that analyse risk communication after natural events, there is still the challenge of articulating communication with environmental information as a tool to influence behaviours that favour risk mitigation [18].

With this in mind, the overall objective of this study is to explore and analyse the perception of flood risk and the implementation of mitigation strategies by residents in

urban sprawl areas. In this regard, it is argued that disruptions between the perception of the possibility of flooding and the implementation of mitigation strategies by residents are linked to a great extent to the lack of environmental information. Therefore, this study also aims to develop a proposal for environmental communication as a tool for citizen decision-making to improve the adoption of risk mitigation measures. To this end, the specific objectives are (a) to analyse the perception of flood risk, paying special attention to the possibility of occurrence perceived by citizens, (b) to analyse the strategies applied within the framework of preventive behaviour against flood risk, and (c) to identify discrepancies between perceived flood risk and applied mitigation strategies.

## 2. Materials and Methods

### 2.1. Data Collection and Analysis

Data collection was conducted primarily through structured surveys, administered in digital format. Informants were selected using the snowball sampling technique, justified by its effectiveness in contexts where access to key informants is limited and they are dispersed within a community. This method consists of selecting an initial number of potential subjects as respondents, who then distribute the questionnaires to secondary subjects, thus expanding the sample size through non-probability sampling [19].

The initial informants were selected based on two fundamental criteria—that they had resided in the area for more than 5 years, to ensure an informed environmental perception and avoid the inclusion of newly arrived residents, and that they were key figures in the neighbourhood organisation. Initially, key informants were identified as members of neighbourhood associations, administrators of neighbourhood WhatsApp groups, and municipal representatives.

This strategy facilitated the redistribution of the surveys, reaching a sample size of 134. Filters were applied to ensure the integrity of the responses, resulting in a final sample of 117 surveys. Surveys eliminated through filtering were those with less than 75% of the questions answered.

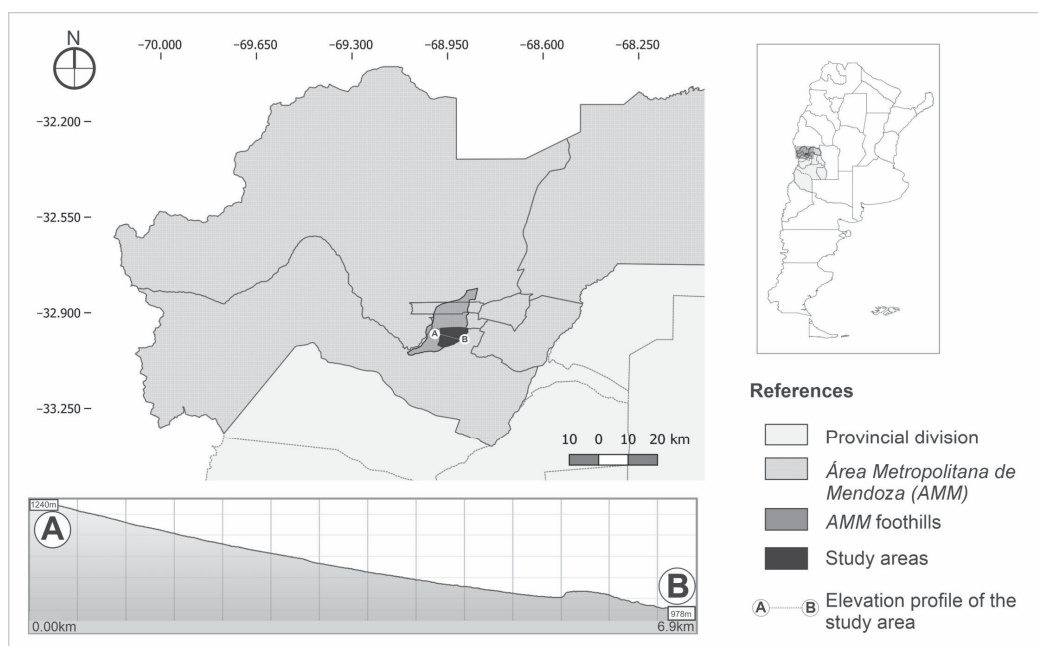
During the months of May and June 2022, a pilot phase of the survey was carried out with the participation of 30 respondents, of which 10 were specialists in environmental issues and 20 had no academic background in the area. The purpose of this pilot phase was to evaluate the effectiveness of the survey and adjust its design according to the results obtained. This stage was crucial to assess the time required by each respondent to answer certain questions and make the necessary modifications. Subsequently, between July and August of the same year, the final surveys were conducted. In general terms, the survey design combined open and closed questions, addressing aspects such as basic demographic data (age, gender, educational level, occupation, and geographical location), perceptions about alluvial risk, and preventive measures adopted. Additionally, a spatial dimension was incorporated through the use of an online survey that included an integrated question with Google Maps, allowing the geolocation of certain responses. This survey was created by specialists who collaborated in the research through the development of a website using the Python programming language (Appendix A).

During 2023, semi-structured interviews were conducted with key informants to gather perspectives on alluvial risk. For the analysis of the data obtained, firstly, the interviews were recorded with the participants' consent and subsequently transcribed verbatim. The key informants were selected through snowball sampling, aiming to capture diverse perspectives based on whether they live in open, semi-closed, closed, or country neighbourhoods. The theoretical sampling strategy was applied, prioritising the potential of each story to achieve the objective rather than the number of interviews [20]. Additionally, during each field trip, notes were taken after each interview. These field notes were recorded in writing with the objective of documenting the researchers' observations. Subsequently, the notes were shared with another researcher present during the field trip to discuss and contrast what was recorded.

The information collected, both from the interviews and the field notes, was disaggregated and analysed line by line to identify key words and phrases. From this analysis, based on the exchange and discussion between the authors, 18 codes were constructed to represent the relationship between the data collected and the existing theories. These codes were used to derive central variables supported by the data, allowing for the definition of relationships that identify key concepts related to the experience of alluvial risk, the perception of its occurrence, potential impacts, and strategies adopted both before and after an alluvial event. The coding phase was conducted with the support of the software tool ATLAS.ti 24 (Appendix B).

## 2.2. Study Area

The study area is located in the drylands of Argentina and forms part of the Andean foothills, specifically in the foothills of the Mendoza Metropolitan Area, where the Verientes del Pedemonte district (Luján de Cuyo, Mendoza, Argentina) is situated (Figure 1). Drylands, classified according to the aridity index, include hyper-arid, arid, semi-arid, and dry sub-humid regions, covering approximately 41% of the planet's total surface. These areas present both highly productive zones and others of great environmental fragility [11]. Small changes in these regions can lead to major ecological changes and affect the quality of human life. National reports state that in Argentina, climate change scenarios indicate that droughts will be accompanied by more frequent periods of torrential rains of short duration and intensity, which will generate flooding in populated areas and accentuate soil erosion processes.



**Figure 1.** Location of the study area and elevation profile. Based on data from Secretaría de Ambiente y Ordenamiento Territorial, Mendoza and Google Earth, 2024.

In this context, the selected area is at risk from very severe flash flood events, mainly in the summer season, associated with significant convective storms of high intensity and short duration that give rise to runoff in dry channels. These channels are ephemeral and only show activity during storms. Additionally, the area is part of the arid zones of Argentina, characterised by low, infrequent, and irregular rainfall; a marked thermal amplitude between day and night; and soils with low levels of organic matter and humidity.

The choice of this area was based on the remarkable transformations it has undergone due to urban expansion into rural–natural lands in the last 15 years. This growth, characterised by its accelerated pace without adequate planning, has led to a significant increase

in rainfall runoff, which in turn has resulted in more frequent occurrences of flash floods and inundations [21]. In areas with steep slopes, such as the one studied here, intense precipitation causes an increase in the speed of rainwater, eroding channels and dirt roads, while causing temporary flooding in low-lying areas [22].

The advance of urbanisation, in most cases, is not adapted to the piedmont environment, resulting in significant environmental impact and degradation. Among the most notable impacts of rapid spontaneous urbanisation are environmental degradation, the intensive use of scarce water and soil resources, the destruction of natural vegetation, and modifications to soil and runoff. These impacts translate into the exacerbation of risks, particularly those related to alluvial events, by modifying slopes and watercourses [23]. These, in turn, increase the speed of land degradation processes in drylands, leading to reduced or lost productivity, biological complexity, and economic viability [24].

The area is characterised by the diversity of its uses, which include tourist, residential, sand-extraction, recreational, open-air landfill, and livestock activities among others [25]. Regarding residential areas, there are 54 consolidated neighbourhoods, reflecting the varied social composition of the area, where residents of middle and lower-middle class predominate. Among the most prominent issues highlighted by district residents is the absence of drinking water. Likewise, there are areas without access to electricity or gas networks.

### 3. Results

#### 3.1. Perception of Flash Flood Risk by Neighbourhood Type

The results are presented taking into account a classification of neighbourhood types made after the analysis of the data. This decision was based on the need to analyse the data in a cross-sectional way, taking into account that neighbourhoods represent the smallest scale for decision-making in local government environmental and territorial management, allowing for a more targeted and effective intervention. In addition, local residents report that they take action to protect the environment through neighbourhood organisations. These community-based initiatives are crucial as they allow for greater coordination and effectiveness in environmental conservation and protection efforts. Neighbourhood organisations act as collaborative platforms, where resources, knowledge, and strategies are shared, enhancing the impact of actions taken by individuals. Also, the different types of neighbourhoods reflect the economic capacity of households to implement self-financing risk mitigation strategies, as residents in gated communities are more capable of self-financing than those living in semi-gated and open neighbourhoods.

Through the analysis of the data obtained in the field, the neighbourhoods existing in the study area were classified into open neighbourhoods, semi-closed neighbourhoods, closed neighbourhoods, and gated communities.

1. Open neighbourhoods lack a closed physical perimeter and have unrestricted public access. Most of these neighbourhoods do not have access to potable water or natural gas services. They often have limited connectivity to internal streets, which can influence mobility and accessibility. Monthly fees for expenses are not required, and neighbourhood organisation is generally formalised through neighbourhood associations. Social composition is usually dominated by middle and lower-middle class residents.
2. Semi-closed neighbourhoods have some form of access restriction controlled by barriers, guardhouses, or surveillance, but do not have a completely closed perimeter. They often have limited connectivity to internal streets, although in most cases, they have a main access road to regulate the entry and exit of vehicles and people. Residents contribute a monthly fee, sometimes voluntary, for the maintenance of resources that control access to the neighbourhood. The social composition inside is heterogeneous, mostly made up of middle and upper-middle class residents.
3. Closed neighbourhoods have a completely closed and controlled physical perimeter, restricting access to authorised residents and visitors. Homes are located within a clearly defined boundary, with common spaces and exclusive services for residents.

Although internal street connectivity within the neighbourhood is high, problems with linkage to main roads within the district are common. Residents must pay a monthly fee (expenses) to maintain common spaces, exclusive services, and security services. The social composition inside these neighbourhoods is predominantly upper-middle class.

4. Gated communities are luxury real estate developments with a completely closed and controlled physical perimeter, restricting access to authorised residents and visitors. Additionally, they have exclusive recreational and sports areas. Residents must pay a high monthly fee (expenses) to maintain common spaces, exclusive services, and security services. Within these neighbourhoods, sectors can be identified as neighbourhoods within neighbourhoods, requiring passing through a second security barrier to access them. These sectors also allow defining lot sale prices. Unlike open, semi-closed, and closed neighbourhoods, there is a potable water service provided by real estate developers, although this implies a considerable cost. Additionally, they stand out for high internal connectivity and their proximity to highways or quick access to facilitates and connection to urban centres. The social composition of these neighbourhoods is predominantly made up of upper class residents.

From the data collected through semi-structured interviews, it was observed that residents do not have a complete understanding of the delimitation of the different neighbourhoods within the district. In some cases, they were not even identified as part of the foothills of the Mendoza Metropolitan Area. This is a complex challenge to address since decision-makers consider neighbourhoods as the small-scale management unit on which actions that include citizens are defined. For this reason, the inquiry about the place of residence was carried out in the survey through a question about the street they live on. This information allowed the grouping the profiles of the respondents by the type of neighbourhood they reside in—open, semi-closed, closed, and gated communities.

Overall, in all types of neighbourhoods, adults aged between 31 and 60 predominated, accounting for 70.94% of all respondents. Regarding gender, the difference in the number of responses was minimal considering that 54.70% were men and 45.3% were women. The majority of the responders were between 31 and 60 years of age and with higher education (complete or incomplete), representing 78.31% of the total number of respondents.

Regarding the predominant occupation of the respondents, the data indicate that 36.75% worked as employees, while 25.64% worked independently; the rest correspond to retirees, students, teacher/researchers, unemployed individuals, and other professionals.

Within each type of neighbourhood identified, the data indicate that, despite differences in the purchasing power of the inhabitants, one of the most frequently mentioned reasons for choosing a place of residence is linked to the semi-natural environment. This reason was cited by 26.25% of respondents in open neighbourhoods, 44.44% in semi-gated neighbourhoods, 42.86% in gated communities, and 55.56% in gated communities (Table 1). In addition, the aesthetic value of the landscape appears as the second most mentioned reason by residents in open neighbourhoods (35%), semi-gated communities (22.22%), and gated communities (11.11%).

Furthermore, 98% of the respondents indicated that they are familiar with what a flash flood is. Likewise, 77.68% of the total respondents expressed that there is a possibility of a flash flood occurring in the area (Table 2). It is noteworthy that this affirmative response was consistently observed across all types of neighbourhoods. While in the conducted interviews, residents pointed out that “although we experience very strong storms, we see water running downhill and it is impossible to go anywhere because of the water, we have not experienced a flash flood yet” (interview conducted with a resident of a closed neighbourhood, 2023); and “there have been no reported damages to homes from flash floods, only road closures” (interview conducted with a resident of an open neighbourhood, 2023).

**Table 1.** Reasons for choosing to live in the study area by neighbourhood type.

Type of Neighbourhood	Reasons for Choosing to Live in the Study Area						
	Price of Land	Aesthetic Value of the Landscape	Semi-Natural Environment	Proximity to Commercial Areas	Tourist Area	Had No Other Option	Other
Open (n = 80)	21.25%	35.00%	26.25%	2.50%	0.00%	5.00%	10.00%
Semi-closed (n = 14)	22.22%	22.22%	44.44%	0.00%	0.00%	0.00%	11.11%
Closed (n = 14)	28.57%	14.29%	42.86%	0.00%	0.00%	14.29%	0.00%
Gated communities (n = 9)	11.11%	11.11%	55.56%	0.00%	11.11%	0.00%	11.11%

**Table 2.** Possibility of alluvium occurrence in the area by neighbourhood typology.

Type of Neighbourhood	Possibility of Alluvium Occurrence in the Area	
	Yes	No
Open	81.25%	18.75%
Semi-closed	66.67%	33.33%
Closed	64.29%	35.71%
Gated communities	77.78%	22.22%

Among residents of open neighbourhoods who recognise the possibility of a flash food, 77.5% recommended living in the area because of its aesthetic value. Similarly, those who live in semi-enclosed (33.3%) and enclosed (55.56%) neighbourhoods and believe that a landslide could occur also based their recommendation on the area's aesthetic value. However, 35% and 30%, respectively, expressed concerns about insecurity in the area. Specifically, in gated communities, 57.14% of residents who recognised the risk of a landslide would still recommend living there because of its aesthetic value, while 42% would not recommend it due to the lack of management by local government.

The surveyed residents from all types of neighbourhoods indicated to a great extent that flash floods can affect their daily lives (73.21% of the total respondents). Those who live in open and semi-closed neighbourhoods mentioned that flash floods can cause economic losses related to damage to homes, as well as road closures and blockages that hinder transportation. In terms of infrastructure damage, residents of open, semi-closed, and closed neighbourhoods highlighted impacts on access roads, while those living in gated communities maintained that homes could be the most affected by a flash flood.

Different perceptions of residents residing in different neighbourhoods regarding the existing risks in the area where they live were also observed. In this regard, the data indicate that for residents of open neighbourhoods and gated communities, flash floods represent the greatest risk in the area followed by wildfires. On the other hand, those living in closed and semi-closed neighbourhoods indicated that wildfires are the greatest risks in the area followed by flash floods (Table 3).

**Table 3.** Most perceived risks in the area by neighbourhood type.

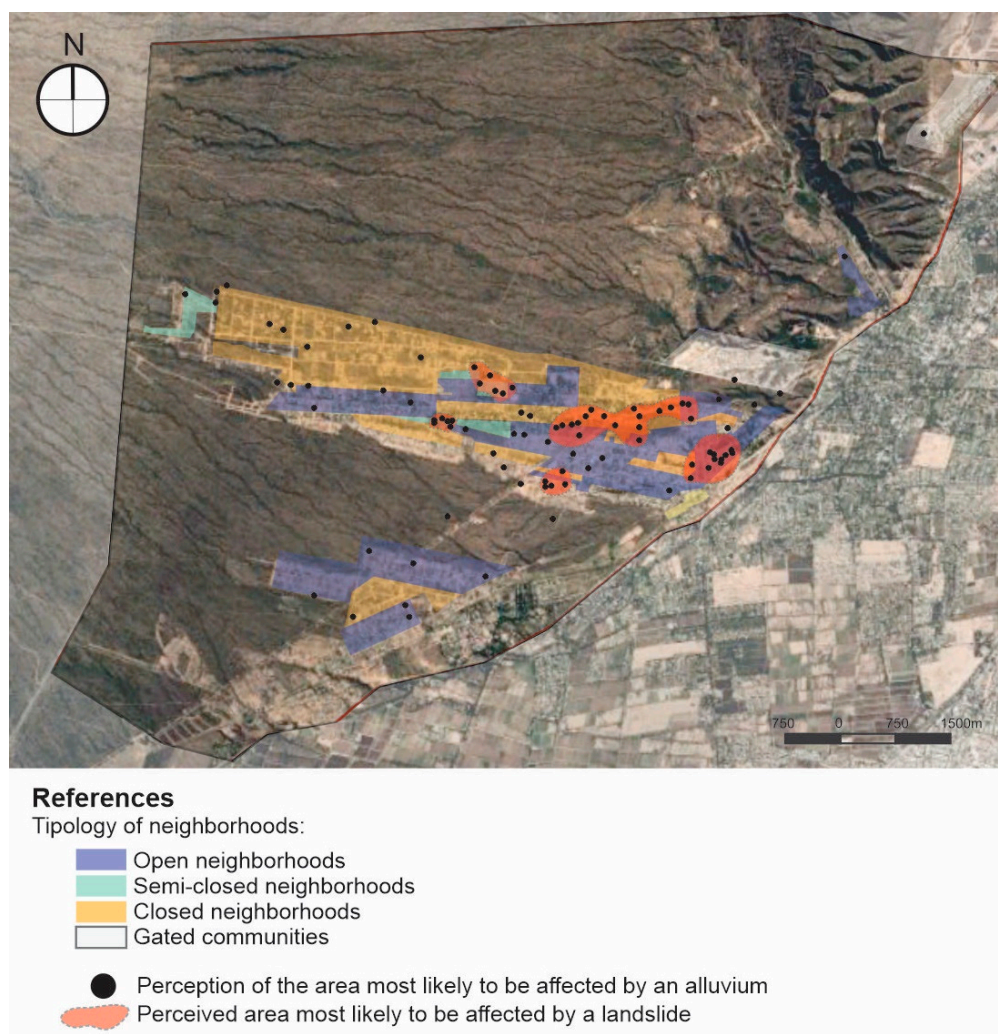
Type of Neighbourhood	Perceived Risks in the Area				
	Fires	Granizo	Earthquakes	Alluvium	None of the above
Open	28.95%	10.53%	1.32%	52.63%	6.58%
Semi-closed	50.00%	0.00%	16.67%	33.33%	16.67%
Closed	71.43%	0.00%	7.14%	14.29%	7.14%
Gated communities	33.33%	0.00%	0.00%	50.00%	16.67%

Despite the significance of flash floods in the area, the data show that in all types of neighbourhoods, the majority of residents (77.78%) indicated that they have not experienced a flash flood in the area.

### 3.2. Preventive Behaviour in Response to Flash Flood Risk

The collected data reveal that, within the total group of respondents, 50.5% identified alluvial risk as a pending issue to be addressed, while 33.66% perceived this as an existing threat. Those who believed that the risk has already been addressed, either by homeowners or real estate developers, constituted 11.88% of the total respondents, who were mainly residents of open neighbourhoods. With a smaller percentage (2.97%), respondents indicated that they have not considered alluvial risk. However, the interviews conducted reveal that, despite these figures, the majority of respondents expressed demands to the State regarding access to public services, particularly the supply of drinking water, which is understandable given its vital importance for daily sustenance. Nevertheless, there are no recorded complaints related to the minimisation of alluvial risk.

Of the total respondents, 85% indicated that they do not perceive their neighbourhood as a risk zone in the face of an alluvial event. Additionally, in Figure 2, there is a clustering of points showing areas susceptible to greater impact from an alluvial event, located in open and semi-closed neighbourhoods near a heavily trafficked provincial route.



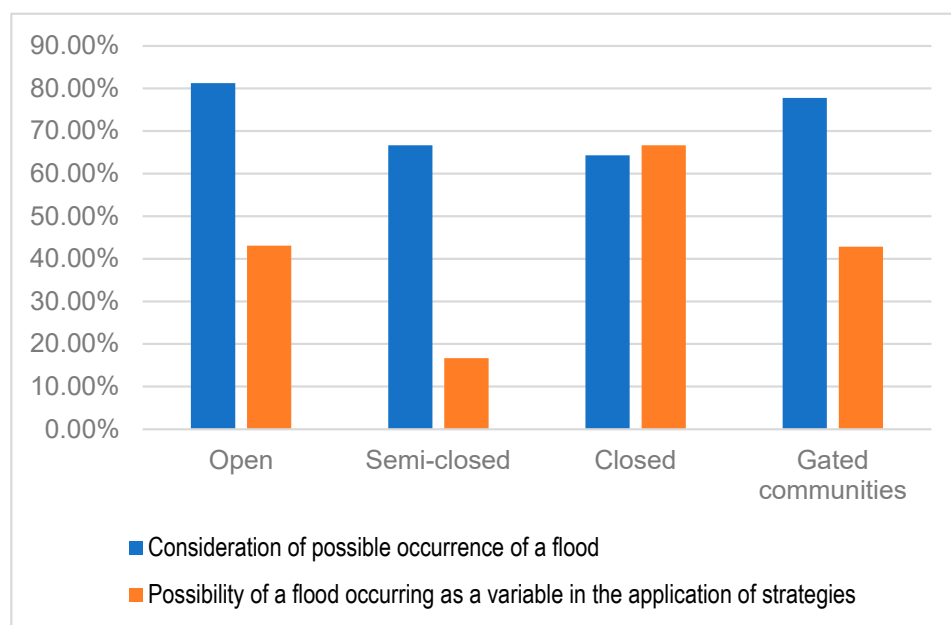
**Figure 2.** Areas likely to be most affected by a landslide by type of neighbourhood. Based on survey data, 2024.

These data indicate that residents in open neighbourhoods identify observed flooding as the main cause for designating areas as most dangerous (32.08%). Similarly, all respondents living in semi-enclosed neighbourhoods considered that observed flooding justifies the identification of dangerous areas. Conversely, in gated communities (28.57%) and rural areas (50%), residents indicated that a lack of planning is the main cause for identifying areas as more dangerous.

This shows that, although the risk of alluvial events is perceived towards the west of the study area and despite the fact that most respondents indicated access roads as the places with the greatest impact on the landscape, when incorporating the spatial variable into the responses, areas further away from the route were not identified as potential areas of greater impact.

When choosing a plot to rent a house or buy to build, the respondents from open, closed, semi-closed, and gated communities mostly stated that they the possibility of an alluvial event take into account (51.35%). Meanwhile, 38.74% did not consider the possibility of an alluvial event, and 9.91% of respondents did not have the opportunity to choose a plot.

It is noteworthy that a considerable proportion of the respondents from open (47.5%), semi-enclosed, enclosed (62.29%), and rural (44.44%) neighbourhoods considered the possibility of facing flooding. Surprisingly, however, although most respondents acknowledged the possibility of landslides, they did not consider this when choosing where to live (see Figure 3). It should be noted that these data correspond to residents with complete formal education at primary and secondary levels, in accordance with Law No. 27.621 for the Implementation of Comprehensive Environmental Education, which defines environmental education as a permanent educational process with specific and transversal thematic content. Additionally, 20% of respondents had completed university education, and 5% had undertaken postgraduate studies (Figure 3).



**Figure 3.** Relationship between the possibility of a flood occurring in an area and the consideration of this perception in decisions about the place of residence. Based on survey data, 2024.

Ninety percent of the respondents revealed that to mitigate flash flood risk, they would opt for land-filling to raise the height of the houses, as well as intervention in the natural terrain to modify natural watercourses. Additionally, data analysis from interviews revealed that only 8% of those surveyed would choose to build far from natural watercourses. However, in justifying this choice, they expressed that “I observe the landscape

and if there is no watercourse, I consider it a good area” (interview conducted with a resident of a semi-closed neighbourhood, 2023). Likewise, the strategy related to raising the level of houses, as indicated by the interviewees, does not involve consulting specialised professionals in the field. In most cases, this elevation is carried out by increasing the height of the foundation beam (approximately 50 cm above ground level).

In addition, the interview data indicate that residents learn about the characteristics of the area through information provided by those who sold them the plots, consultations among neighbours, and observations made during tours of the area. None of the residents interviewed mentioned access to scientific or academic information or data available through municipal regulations. In this regard, an interviewee who lives in a country house said “It’s been at least 20 years since a flood. This area is very dry; it won’t happen again. Why should we take precautions”? (interview conducted with a resident of a gated community, 2023). This viewpoint is also reflected in the testimonies of other interviewees, as expressed by a resident of an open neighbourhood, who stated that “Living in a dry and increasingly dry area, there will never be another alluvial event like before. It might rain heavily and water may flow, but nothing more” (interview with an open neighbourhood resident, 2022).

#### 4. Discussion

The discrepancies between environmental perception and the risk mitigation strategies implemented by local residents are strongly linked to the lack of access to environmental information. In this regard, our results indicate that, although most residents in the urban expansion area studied recognise the possibility of a landslide occurrence, the risk mitigation measures implemented are scarce and lack technical scientific support.

The types of neighbourhoods defined have their own characteristics related to lifestyle, economic capacity, and types of lots, among other factors. These characteristics are closely linked to local government environmental management. Each neighbourhood typology represents differentiated environmental perceptions, reflecting the diverse realities and priorities of its inhabitants. These differences underline the need for state environmental management to be adaptable and sensitive to the particularities of each neighbourhood, ensuring that the policies implemented are effective and relevant to the specific needs of each community.

##### 4.1. Neighbourhoods as an Environmental Management Unit

Neighbourhoods represent a local scale that allows for more precise management adapted to the specific needs of the community. In Argentina, as in other countries, environmental management may vary according to the type of neighbourhood. Gated communities, closed, semi-closed, and open neighbourhoods may have different approaches and environmental challenges due to their specific characteristics. For example, gated communities and closed neighbourhoods may have more controlled and centralised management related to strict internal rules and regulations, framed within national, provincial, and municipal laws, regarding land use, maintenance of green areas, and waste management. In these cases, risk management in particular may be related to a punitive framework in which non-compliance is punishable by a fine. In semi-enclosed and open neighbourhoods, environmental management at the local level is more dependent on community-led strategies and more individualised state control mechanisms. However, in both situations, the risk mitigation strategies implemented do not necessarily represent a decision made by local residents in response to the environmental characteristics of the area in which they may choose to live.

Previous research affirms that one of the limiting factors for implementing preventive measures against alluvial risk is access to financing by residents [26]. In the case analysed, those living in gated communities and closed urbanisations have greater possibilities than those living in open and semi-closed communities to invest economic resources in structural preventive measures, reforestation, and opportunities to choose plots of land, among other

measures. However, in general terms, it is observed that the perception of risk and the application of preventive measures are indistinguishable among residents with different purchasing power.

Several studies on environmental behaviour start from the assumption that individuals make reasoned decisions. Some authors indicate that those who implement strategies for environmental care choose the alternatives with the greatest benefits compared to the lowest costs (in terms of money, effort, and/or social approval) [27]. In the case analysed, it is observed that citizens, despite the economic differences identified across neighbourhood types, implement few or no mitigation measures. Additionally, it should be noted that there are currently no state funding lines to support these measures within the neighbourhoods.

In addition, previous research has shown that when the emotional attachment to a place is strong, people tend to reduce risk mitigation measures, even when they perceive a high level of risk [28]. However, the results of this study indicate that, despite the perceived threat of alluvial events, individuals prefer to reside in semi-natural environments and are willing to implement strategies to reduce risk [29], although this practice is not always effective.

Another limiting factor for the implementation of risk prevention measures is economic constraints when choosing a plot of land to live on. In some cases, this leads people to opt for more risky but cheaper plots. In these circumstances, people's investment is mainly directed towards resolving basic housing issues. It is in these situations where state intervention must play a prominent role in addressing the real estate speculation of some and the housing needs of others [7]. In this regard, previous research indicates that housing and land prices tend to decrease in areas affected by natural events [30,31].

Although this study does not focus on analysing land price dynamics, it is important to note that despite the relatively low prices compared to other areas [32], these are not the main reason for choosing to reside in the area. Residents surveyed primarily value the characteristics of the semi-natural environment, although in many cases they do not fully identify the specific characteristics of the piedmont in which they reside. This lack of identification can lead to confusion in understanding the regulations and information related to alluvial risk provided by local authorities.

It is essential for the state to promote environmental and risk management strategies prior to urban expansion processes [33]. However, it is also relevant to examine how alluvial risk influences the environmental behaviour of residents, as this could be a valuable input for the design of effective public policies in risk management.

In the framework of risk management, neighbourhoods as units of implementation of strategic measures are efficient [34]. This study allowed us to observe that, despite the neighbourhood differences that contextualise flash flood perceptions, it is possible to coin the term "passive optimists" to describe residents. The term "passive optimist" describes a person who, despite being aware of the possibility of a flood or other hazard, believes that it will not affect them personally and therefore does not take preventive measures. This attitude may be due to a misperception of invulnerability or an underestimation of risk, leading to a lack of adequate preparedness and prevention. In the context of risk management, this attitude can be problematic, as the lack of preventive measures increases the vulnerability of residents to potential disasters.

While there are many psychological factors that influence risk perception, previous research on global pandemic risk perception, such as COVID-19, indicates that these factors include anxiety, threat perception, self-confidence, and gender. One of the most influential factors is trust in information received from governments and experts, based on empirical sources [35]. This is key both for dealing with health risks in a pandemic and for facing the challenges of environmental risk

In this sense, and taking into account the identification of passive optimistic residents, it is essential to confront this passivity through state strategies that provide tools for environmental education and awareness-raising. Promoting a culture of prevention that

emphasises the importance of preparedness and the implementation of risk mitigation strategies is essential to reduce vulnerability to both health and environmental hazards.

#### *4.2. Implementation of Strategies to Mitigate Flash Flood Risk*

Numerous studies suggest that individuals who have experienced natural phenomena tend to be more aware of risks and more likely to respond to hazards than those without previous experience [31]. Along these lines, the results of this study indicate that, despite the apparent lack of direct experience, residents have significant knowledge about the impacts and likelihood of alluvial occurrences in the area. This is interesting because it challenges the idea that a lack of experience leads to less interest in implementing risk mitigation strategies. In this case, it is not a lack of experience but rather a lack of explicit terminology; residents describe alluvial events without naming them as such. This may be related to a lack of knowledge about their environment, particularly its dynamic processes, which are often governed by unpredictable events [36]. This issue is even more evident in areas of accelerated urban expansion over natural areas with little intervention, as these are not traditional inhabitants but new residents.

Although alluvial risk is observed to influence the decision to buy or rent a house, field surveys and the location of houses near watercourses indicate low compliance with local building standards and a lack of sufficient regulatory bodies. As the Sendai Framework for Disaster Risk Reduction 2015–2030 indicates, this scenario highlights the need for a review and strengthening of existing regulations to ensure safety and effective risk mitigation in these vulnerable areas [37].

From 2003 to the present, there have been incidents causing material damage and obstructing traffic in the streets. Despite these incidents, the preventive measures implemented to reduce risk are mainly focused on filling in land to raise the height of houses and altering the natural terrain to modify watercourses. However, these measures may not be adequate, as altering the natural ground is not considered advisable for preventing the impact of alluvial events. On the contrary, urbanisation is one of the processes that most affects the natural conditions of a watershed and its hydrological cycle [33]. This process involves soil sealing and compaction, modification of natural drainage channels, and increased pollution of water resources. This evidence suggests that, despite the perception of risk and awareness of the need for preventive measures, the strategies implemented are not adequate to effectively mitigate alluvial risk. This may be related to the lack of information available for residents to make informed decisions.

Public information campaigns play a crucial role in shaping residents' perceptions and opinions, which in turn can significantly influence their willingness to adopt or reject preventive measures [38]. In the context of the water and dryland constraints present in the province, especially in the case under study, environmental information campaigns are mainly focused on raising awareness about the responsible use of drinking water and forest fire prevention. These campaigns are widely disseminated, particularly during the summer season. Informants maintain the perception that, living in a dry area, watercourses do not pose a danger unless they observe the presence of running water. This perspective may be associated with a limited understanding of the alluvial hazards characteristic of the piedmont.

Furthermore, previous research suggests that people tend to be more aware of risks when they experience natural phenomena in the vicinity of their place of residence. However, the results obtained in this study indicate a lack of correspondence between the location of residence and the perception of higher-risk areas. In other words, the places where people reside are perceived as relatively safer from alluvial risk. This phenomenon could be attributed to several factors, such as a belief in the community's ability to mitigate risks or simply an underestimation of the hazard based on familiarity with the immediate environment.

Numerous research studies highlight the gap between public perception and actual behaviour in various environmental contexts, including studies that analyse the differences

between the perception of water consumption and actual consumption, showing how individuals may have biased perceptions of their resource use. This observation is relevant for policymakers and communication strategists seeking to design effective awareness campaigns capable of reducing this gap [2,39]. Environmental behavioural analysis provides insight into how people make decisions before, during, and after natural events. By analysing these aspects in depth, it is possible to identify ingrained and naturalised actions—or the absence of actions—towards risk mitigation. These findings can be key elements in designing risk mitigation strategies. By understanding people's potential attitudes towards risks, more effective mitigation programmes can be implemented to encourage the adoption of specific measures [40]. In this context, some authors indicate that individual environmental decisions, which mitigate or prevent environmental problems, are determined by multiple factors. The connection between environmental awareness, concern, attitude, and behaviour is neither direct nor clear. However, most work in the field of environmental psychology, with the exception of a few studies [25,41], has not delved into the analysis of contextual factors. While such research studies are numerous, there is little research on the relationship between individual behaviour and environmental knowledge [38,42]. However, in the case studied, the available information is scarce and confusing, potentially leading to the erroneous decision that there is no need to implement flood risk mitigation measures. This situation is exacerbated by the belief that floods will not recur in drylands. Furthermore, in this region, the central issue reported by citizens is the lack of access to safe drinking water for human consumption, which prioritises perceived environmental and infrastructure concerns, relegating concerns about flooding to the background.

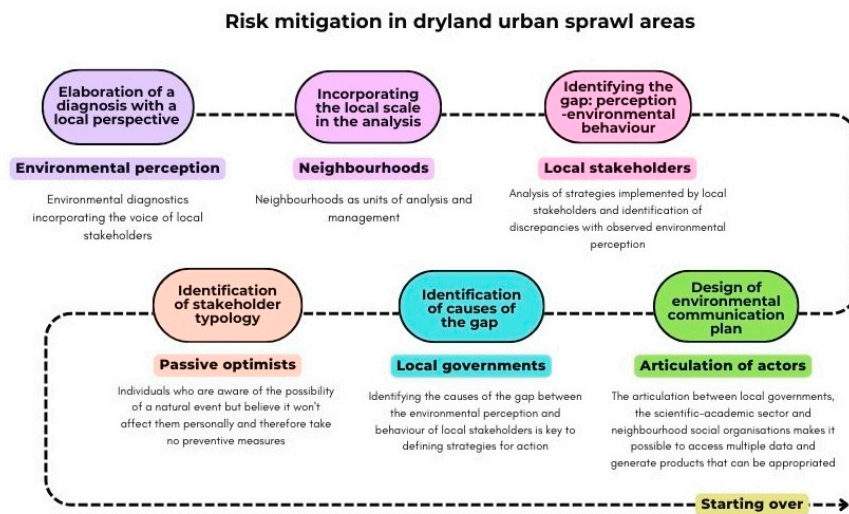
Additionally, given that this is a newly urbanised area, demographic data provided by the local government indicates a higher proportion of the adult population in the area. This is significant, as environmental information needs to reach beyond educational establishments to reach a larger number of people. Improving the accessibility and clarity of environmental information is critical to foster a proper understanding of risks and the effective implementation of mitigation measures.

When formulating public policies, it is essential to consider the local scale, especially at the neighbourhood level. This is crucial in areas of urban sprawl, where significant differences between neighbourhoods are observed in a small area. These variations, often linked to economic capacities, lifestyles, and plot types, share a common problem—the lack of recognition of the potential implications of flooding in residential areas. Although real estate speculation tends to obscure these features to avoid affecting land values, local government land-planning policies must address these issues to achieve environmentally sustainable outcomes.

While it is known that land-use planning should avoid urban sprawl in high-risk areas, the reality is that housing has already encroached on fragile environments. In this context, it is necessary to implement risk mitigation measures to minimise potential impacts. The first step is to provide the population with information on the environmental characteristics of their surroundings through materials accessible to the general public. To this end, the development of an environmental communication plan that integrates the efforts of local governments, the scientific/academic sector, and neighbourhood social organisations is recommended.

A specific strategy for local governments in this context is to develop an online environmental viewer for risk mitigation, featuring rigorous scientific information accessible to the public at large. This tool is key to consolidating, through spatialised data and audiovisual material, the environmental characteristics of the area, with a special focus on alluvial aspects, sustainable risk mitigation practices, implications of potential alluviums, and their impacts according to the type of neighbourhood and location, as well as existing social organisations. Additionally, a public agenda of scientific environmental workshops for the general public is proposed, managed in coordination with neighbourhood representatives

to ensure citizen participation and the systematisation of mitigation strategies applicable to different neighbourhoods (Figure 4).



**Figure 4.** Synthesis of the steps to generate insights in spatial planning and risk management. Based on survey data, 2024.

## 5. Conclusions

This article contributes to the fields of risk management and territorial planning studies, providing knowledge that can be applied both in the promotion of risk mitigation strategies and in the design of urban public policies. The results highlight that most residents recognise the possibility of a flash floods event occurring in the residential area, as well as the potential impact on their daily lives and the surrounding landscape. Although there is some awareness of the risk and attempts are made to implement preventive measures, the findings reveal that the perception of the actual and serious risk remains insufficient. This lack of awareness makes it difficult both to implement adequate measures from the administration and to convince residents to take their own preventive measures as well.

While it can be assumed that those who are able to implement sustainable practices are those with greater access to finance, in this case, it is observed that, despite the economic differences analysed across neighbourhood types, the implementation of mitigation measures remains low. Also, in most cases, it is a question of altering the natural conditions of the area without sufficient knowledge of the consequences this may have. This underlines the importance of access to adequate and accessible environmental information for all sectors of the population, thus promoting wider adoption of environmental behaviours and effective mitigation measures.

The lack of accessible environmental information for citizens contributes to confusion about how to perceive a landslide. While citizens claim to understand what a landslide is, their descriptions of landslide events in their accounts often refer to water running through the streets, suggesting a misunderstanding of the phenomenon. This passive optimism, where individuals underestimate the risk of severe environmental events if their homes are not directly impacted, could be significantly reduced by providing rigorous environmental information and specific technical recommendations supported by scientific evidence. These aspects are crucial for defining effective risk mitigation strategies within the framework of environmental behaviour.

Formulating policies to promote more sustainable and responsible behaviour requires an understanding of how risk perception evolves over time and the decision-making processes that lead to actions to mitigate alluvial risk. Furthermore, the data reveal that while risk perception influences the implementation of mitigation strategies, these strategies are

not always adequate or environmentally sustainable. Therefore, further surveys and analysis of the strategies adopted by residents would lay the foundations for the formulation of public policies aimed at territorial management and the reduction of alluvial risks in the area.

Among the actions that local governments can implement within the proposed environmental communication plan, it is suggested that audiovisual material be produced for dissemination on social networks, with the aim of communicating the environmental characteristics of the area and developing content on alluvial risk. In addition, it is proposed to organise an agenda of environmental scientific talks, in collaboration with social organisations, using material prepared by the scientific academic sector and aimed at the general public. It is also important to systematise and disseminate the sustainable mitigation strategies applied by residents in order to encourage their replicability. As a concrete product, the creation of an environmental viewer containing specific information on urban expansion areas in drylands is recommended. This material, freely available online and aimed at the general public, will allow people to access relevant information about the area and the products mentioned above.

Finally, this study raises new questions aimed at improving the formulation of environmental awareness strategies by local governments. It is proposed that these strategies should focus on residents' perceptions to better understand the community's needs and develop appropriate and sustainable management guidelines. In any case, it is essential to consider individuals' perspectives when designing risk mitigation strategies.

**Author Contributions:** Conceptualization, R.S. and A.J.R.; methodology, R.S. and A.J.R.; software, R.S.; formal analysis, R.S.; investigation, R.S.; resources, R.S. and A.J.R.; data curation, R.S.; writing—original draft preparation, R.S. and A.J.R.; writing—review and editing, R.S. and A.J.R.; visualization, R.S.; supervision, A.J.R. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** The research data are available at <http://hdl.handle.net/11336/236919>, accessed on 16 July 2024.

**Acknowledgments:** We would like to thank the Instituto Regional de Planeamiento y Hábitat-UNSJ-CONICET for their support in carrying out this research. We also thank geographer Luis Verdugo for his collaboration in the digitisation of the field data and Marcela Orbiscay and Rubén Soria for programming the online survey. We are also grateful for the support of the Instituto Universitario de Desarrollo y Cooperación (IUDC-UCM). This study was carried out in the framework of the CONICET scientific research career.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A

### Survey

1. Age. Please select one option  
(a) Between 18 and 30; (b) 31–60; (c) Over 60
2. Gender. Select one option  
(a) Male; (b) Female; (c) Not binary
3. Highest level of education attained. Select one option  
(a) Primary school completed; (b) Incomplete primary; (c) Completed secondary education; (d) Secondary incomplete; (e) Tertiary complete; (f) Incomplete tertiary; (g) University degree complete; (h) Incomplete university; (i) Post-university complete; (j) Post-university incomplete; Street where you live. Write in the following field
4. What mainly motivated your choice to live in the Vertientes del Pedemonte district? Select one option  
(a) Price of land; (b) Aesthetic value of the landscape; (c) Semi-natural environment; (d) Proximity to commercial centres; (e) Tourist area; (f) I had no other choice

5. Do you associate any of the images with the existing risks in the area where you live?  
Select one option

A



B



C



D



E None of the above

6. Do you know what an alluvium is?  
(a) Yes; (b) No
7. Do you consider that alluviums can modify or cause damage to any of the following elements of the landscape? Please select the option(s) you consider to be correct (you can select more than one)  
(a) Houses; (b) Roads; (c) Vegetation; (d) Landforms; (e) Fauna; (f) Tourist attractions; (g) Beauty of the place; (h) Other; (i) May not modify or cause damage to landscape features; (ii) Cannot modify or cause damage to landscape features

8. Did you experience any flooding in the area?  
(a) Yes; (b) No
9. Do you think that a flood could occur in the area where you live?  
(a) Yes; (b) No
10. In the case that the previous answer was affirmative. Select the main reason for which you consider that floods occur in the area where you live.  
(a) Intense rainfall and in a short period of time; (b) Lack of infrastructure to prevent flooding; (c) Proximity to natural watercourses; (d) The area is risky
11. How do you perceive the alluvial risk? Select one option  
(a) Danger; (b) Concern (problem to be solve(d)); (c) Problem already solved by me; (d) Problem already solved by local governments; (e) Problem solved by real estate developers; (f) I haven't thought about it
12. How often do you think a flood could occur?  
(a) Weekly; (b) Monthly; (c) annually; (d) every ten years; (e) never
13. Do you think that an alluvium can affect your daily life?  
(a) Yes; (b) No
14. Why do you think it could affect you? Write in the following field
15. Click on the map the area you think could be most affected by an alluvium and please answer the questions about that area.
  - a. In the face of a flood, do you consider this area to be:  
(a) very vulnerable (more susceptible to serious damage or loss); (b) vulnerable; (c) not very vulnerable; (d) not at all vulnerable to a flood
  - b. As for the previous answer, could you tell us why? For example: "hardly vulnerable at all, because I have never seen flooded areas in that sector". Write in the following field
16. When choosing the lot to build your house or rent, did you take into account the possibility of a flood in the area?  
(a) Yes; (b) No
17. In the case of an affirmative answer, please explain which aspects you considered. Write in the following field
18. For the location of your house on the land, did you take into account the sector and height of the lot in relation to the alluvial risk? (For example: yes, because I decided to put my house in the highest area of the lot).  
(a) Yes; (b) No
19. If yes, what strategies did you apply? Write in the following field
20. Would you recommend this place to your family and friends? Why? Select one option and write in the following field  
(a) Yes; (b) No

## Appendix B

### Interview Guide

The following questions/topics are indicative for the interviews, as they are semi-structured. They guide the conversation, but if the interviewee decides to address other topics in their discourse, the interviewer should adapt and follow their lead.

- How long have you lived here, and why did you decide to move to this area?
- How many neighbourhoods are there in the area? Do you know their boundaries? Does it make sense for you to organise as a neighbourhood unit? Why?
- Have you noticed any changes in the area over the last five years? If so, what are they?
- What, if anything, attracted you most to live in this place, assuming you had a choice?
- Have you experienced heavy rainfall in a short period of time? What caused this, and did you notice changes in the area after the rain?
- Have you experienced a flood? If so, how do you think it might affect you?
- Can you describe a day of heavy rainfall in the area?

- Can you identify the issues that you feel most affect you while living in this area?
- Have you received environmental information about the area from the local government? If so, what kind of information and through what means?

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