COLLABORATIVE MAPPING

TO FLOOD RESILIENCE

IN NUEVA VILLA LA IGUANÁ

FINAL REPORT

Description of the development and results of a collaborative mapping project to contribute to the flood resilience of an urban settlement in Medellín (Colombia).

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Introduction

The La Iguaná creek basin covers an area of approximately 50.99 km² and is located in the central-western part of Medellín. This basin played a crucial role in the city's development and is now a space where different neighborhoods connect, many of which originated from families that migrated due to the armed conflict. Due to its proximity to the Cerro El Volador Metropolitan Natural Park, it serves as a hub for various socio-environmental processes in the city. Despite its significance, much of the population in this area suffers from high levels of poverty, overcrowding, and limited access to healthcare and education services—conditions further exacerbated by the high vulnerability to flooding.

Since 1880, La Iguaná creek has experienced numerous floods and blockages, earning it the reputation as the most dangerous waterway in the city. These events have led to infrastructure damage, the displacement of numerous families, and the loss of lives. The frequency of these events seems to have increased since the 1980s, particularly during rainy seasons (García 2017, Botero 2015, Múnera 1991). Members of various communities living within the basin have called for interventions to reduce their vulnerability (El Colombiano, 2022). Although some interventions have been carried out by the DAGRD, including the establishment of risk management commissions, there has been no long-term support to foster and promote self-management of risk.

To help enhance the capacity to address flood vulnerability with self-management tools, this collaborative mapping project was initiated in Nueva Villa La Iguaná, one of the settlements established within the basin. This proposal was funded by the prize from the integrated flood and drought vulnerability management competition led by young people (Sponsors: Global Water Partnership and World Meteorological Organization). The development of this project focused on three specific objectives: 1) Gathering cartographic information of the neighborhood to contribute to flood risk management, 2) Promoting territorial recognition through the use of maps, and 3) Identifying elements that increase vulnerability to establish actions that enhance flood resilience.

Descripción del área

Nueva Villa la Iguaná is part of the lower section of the Iguaná stream basin, near its confluence with the Medellín River in Colombia. It is located in the central-western part of Medellín and borders the metropolitan park "Cerro el Volador" to the north. Although there is limited information available about the neighborhood, some residents have reported that it has experienced several flooding events, which appear to be mainly linked to the rainy season and increased precipitation associated with the La Niña phenomenon, with one of the most alarming overflows occurring in 2011.

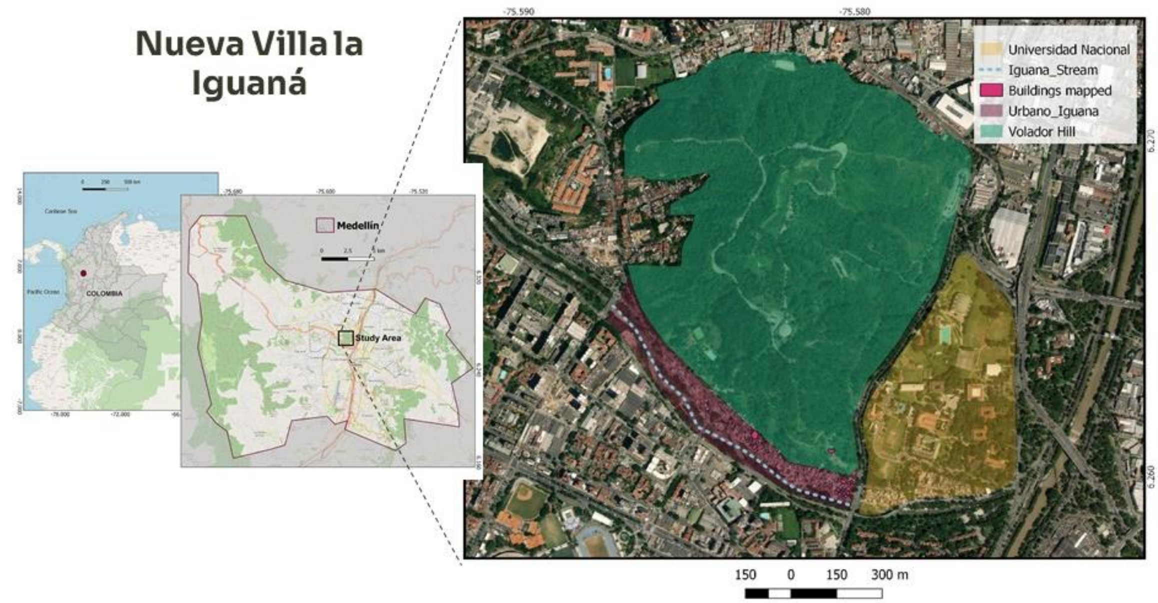


Figure 1. The study area. The neighborhood is highlighted in pink. In green is found the Volador natural Park.

Methodology

This project was carried out over approximately six months through four different phases (Approaching, Mapping and Vulnerability, Mapping, Analysis, and Results). Each phase produced a different outcome. The first report was an early version of the final report, which includes information from the workshops conducted and was made available on a webpage to eventually share this information with the community (See page). The outputs of the second and third phases were cartographic data added to OSM (link to OSM in the neighborhood), Mapillary (link), and KoboToolbox (link to the survey).

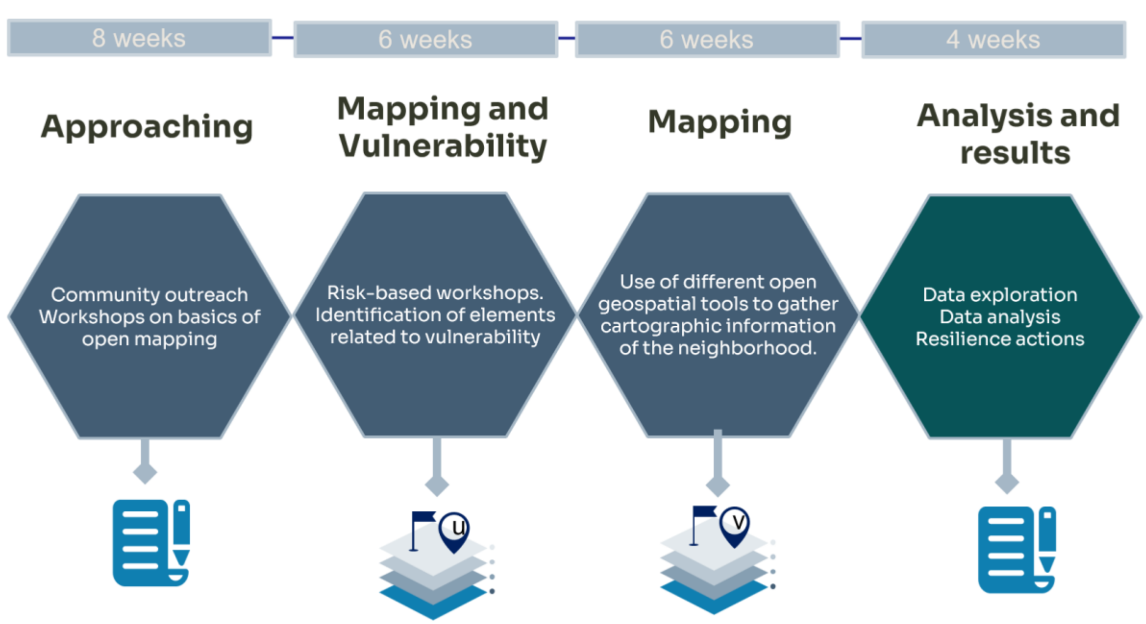


Figure 2. project phases and duration.

The final product is this comprehensive report, which is available to any interested reader, with the intention that these ideas be improved upon, utilized, and supported for flood risk management.

Approaching:

This phase included an initial approach to the community to communicate and coordinate with the leaders regarding the timeline, resources, and concept of the project. From there, key community groups and actors were mapped to extend an invitation to a call for the formation of the focus group. Following this, the development of workshops began. These workshops were planned with a dynamic structure that aimed not only to provide training but also to offer a creative space where the work done would leave a lasting impression. This required a significant investment of time and creativity.

Figure 3. Approaching phase: A) Collaborative work, B) Spatial thought, C) Introduction Open Street Map (OSM) Platform, D) Appropriation and social fabric

The community was trained on the fundamentals of open and collaborative mapping. There were four workshops prepared to address 1) Collaborative work: What is it, what are the most important values to reach it and why it is important in the community decision-making (figure 3, A) 2) Spatial thought: Recognition of the neighborhood both from their mental image as the way the settlement is seen through a satellite image. Thus, they were being able to use these pictures in open geospatial tools (figure 3, B). 3) Open Street Map (OSM) Platform: Introduction of the open mapping database to add cartographic data. This session allowed a familiarization and exploration of the main geospatial tool to collect and create a community map (figure 3, C). 4) Appropriation and social fabric: In order to strengthen the bonds of the community group and its ownership by the neighborhood an activity "la Iguaná tiene quien le escriba" was conducted in which each participant wrote a letter to express anything they feel about it (figure 3, D).

Figure 4. Risk Management: A) Flood mapping, B) Early Warning System: SIATA, C) Risk management: DAGRD

Mapping and Vulnerability:

After engaging the community in the project with the first phase, we planned this set of workshops to link risk and the use of cartographic information to generate a better understanding of their use in risk management. This phase has sessions focused on 1) Flooding. The general understanding of flooding, and the relation with maps as a tool to identify elements related to their vulnerability (figure 4, A). 2) Early Warning System: SIATA (The Institution in Medellín that implements warning systems for different hazards) was invited to talk about this system, how it works, and the importance of the information collected in the project to their establishment. (figure 4, B). 3) Risk management: DAGRD (The institution in Medellín in charge of the risk management of the city) was involved in giving understanding to the community about what risk was, their components, and the co-responsibility in risk management (figure 4, C) (the importance of active communities in the risk decision making). Two training sessions were held to teach the community about the use of Kobo toolbox and Mapillary (figure 6)

Figure 5: Open Spatial tools: A) Mapillary, B) KoboToolBox

Mapping: open geographic data collection

During this pase, all the cartographic information of the neighborhood, which was previously unabailable, was gathered. Four main tools were used for this purpose: OpenStreetMap (OSM), Mapillay, Field Papers, and Kobo Toolbox. OSM allowed for adding data by using an orthophoto taken as part of the project (12 cm resolution and approximately 687,573 m² area) with a Parrot Anafi 4k drone provided by one of our partners, the Humanitarian OSM team. This high-resolution image enabled the creation of an initial layer of buildings and roads observed in the area. The mapping was carried out with the community group as well as students from Sagema (YouthMappers Chapter at the Universidad Nacional de Colombia) and Geolab (YouthMappers Chapter at the Universidad de Antioquia) over approximately five sessions of four hours each.

Three walking routes were conducted using the Mapillary application, which captures georeferenced photographs that can be visualized on the OSM platform, allowing for the addition of more infrastructure features to the map. using a digital image provided by OSM and the pictures taken, we added details such as power poles, building levels, and critical infrastructure like shelters, churches, and pharmacies (See this Concluding Video). Field papers and Kobo Toolbox were employed to map with more detail the flooded area (that we previously marked by local knowledge using OSM Tracker app). For this, each building was drawn and assigned a unique code in Field Papers, which was also used in the Kobo Toolbox survey. With this, it was validated that the structure was correctly mapped in OSM and had a code that allowed for correlating information to a surveyed dwelling.

Analysis and Results

The data obtained through collaborative mapping allowed for various estimations and the representation of the findings in the form of maps. These results are presented at two scales: one providing an overview of the "*neighborhood" (1:2200)* and another focusing on specific elements within the flood-prone area referred to as the "*flood area*" (1:750) in the text. According to Table 1, approximately 37% of the buildings in the neighborhood experience flooding during the rainy season (due to water runoff) and when the stream overflows. Additionally, about a quarter of the electrical wiring and commercial establishments are located within the flood area, resulting in higher exposure to flooding risks.

Tabla 1. Estimations

Estimations	Neighborhood	Flood area
Area	64,995.90 m²	51,294 m²
Number of roofs in digital image (edifications)	684	118
Average of buildings	1,823	684
Average number of people	3,133	177*
Average mumber of people per building	3	3*
Number of electric poles	61	15
Number of commercial properties	45	10
Number of manholes covers	31	14
Back alleys	-	1.4km
Green area	17,848.586 m²	0

In the general map of the neighborhood (Figure 6), the physical infrastructure of the areas is displayed, along with the zones that influence the dynamics of the La Iguaná Stream. The mapped data shows the location of buildings, roads, pedestrian paths, and alleys (which are not visible in satellite images due to their proximity to the houses). It highlights critical infrastructure, such as recreational areas, churches, community action boards, and facilities housing vulnerable populations like shelters (Instituto de Bienestar Familiar de Colombia). According to Triade (2018), this information helps address vulnerability by being useful for studying accessibility to homes, planning evacuation routes, identifying safe meeting points, and formulating appropriate responses in case of an emergency.

According to Karamouz et al (2011), solid waste and increased sedimentation can affect water flow and storage capacity in channels, contributing to urban flooding. Figure 6 shows an informal waste disposal site (red arrow, labeled as “improper waste disposal”) that appears to be causing high sedimentation in this section of the stream. Just in front of this point lies the stretch of the stream that is not channelized (represented by a grey line, labeled as “Unchanneled stream”) which coincides with the area where water overflows. It is known that channelizing a water body can lead to an overflow in non-channelized sections due to increased flow velocity and higher discharge rates downstream (Saad et al 2021). Completing the channeling and decreasing residual waste in the neighborhood could be significative important to reduce the risk of flooding in this area.

These effects underscore the importance of considering the trade-offs and broader impacts on the entire watershed when implementing gray infrastructure interventions, such as channeling water bodies. Hybrid infrastructure (integration of gray, green, and blue infrastructure) represents an opportunity to address high flood exposure, manage stormwater, and handle waste water in informal settlements. These measures can enhance the sustainability of urban populations while promoting community management from an ecosystem-based approach, as suggested by Mulligan et al (2020). The “Renaturalization Program”, integrated into Medellín´s city planning, aims to improve green spaces and increase ecosystem services, including flood mitigation. This project has been presented to the program´s leader to propose Nueva Villa la Iguaná as a candidate for such interventions. The goal is to utilize the collected data for informed decision-making within the program´s framework (Alcaldía de Medellín 2022).

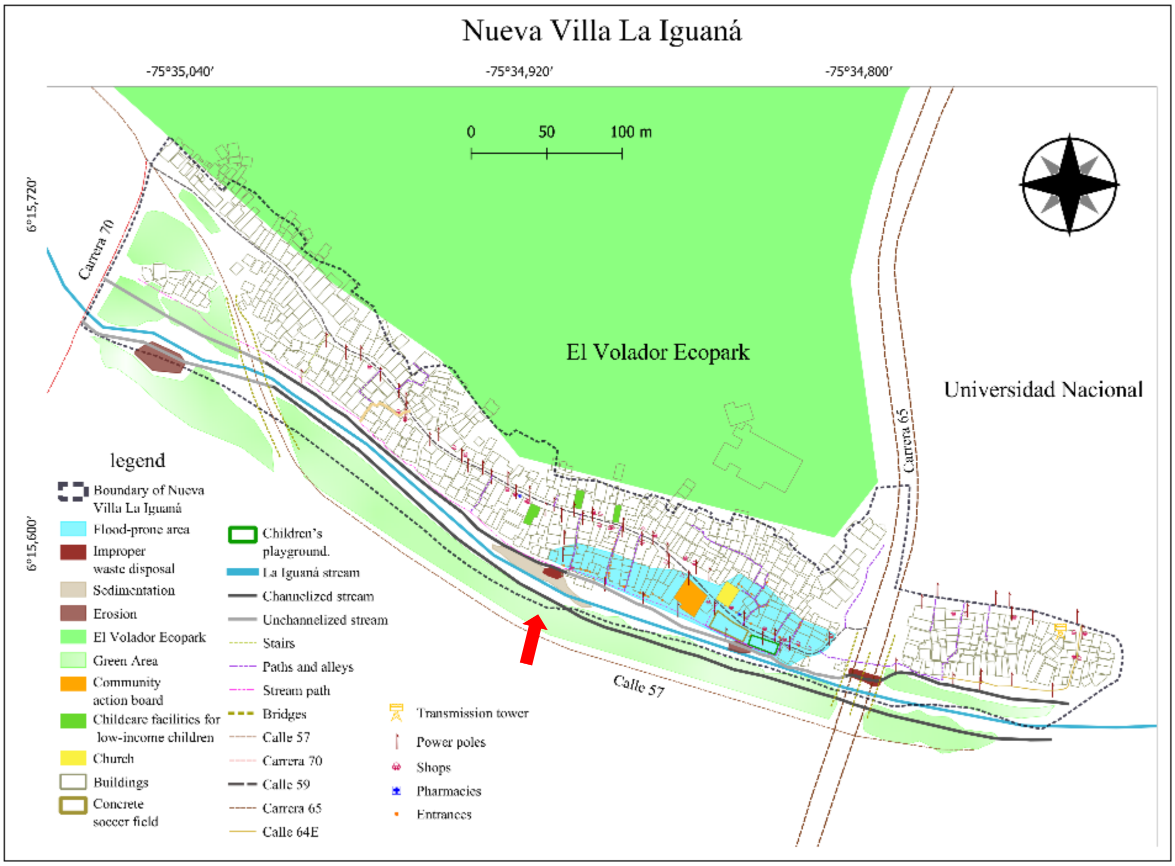


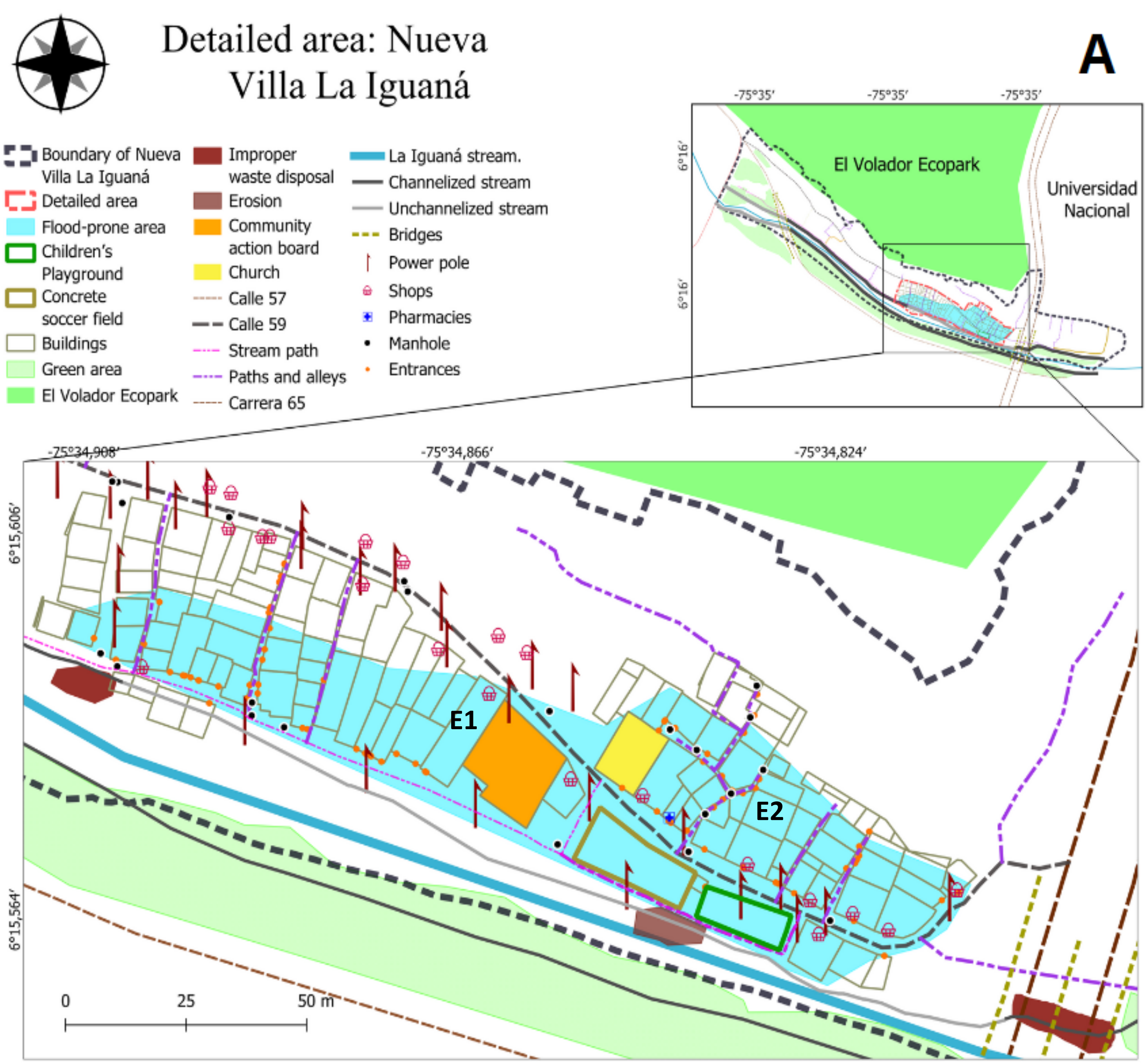
Figure 6. General map Nueva Villa la Iguaná.

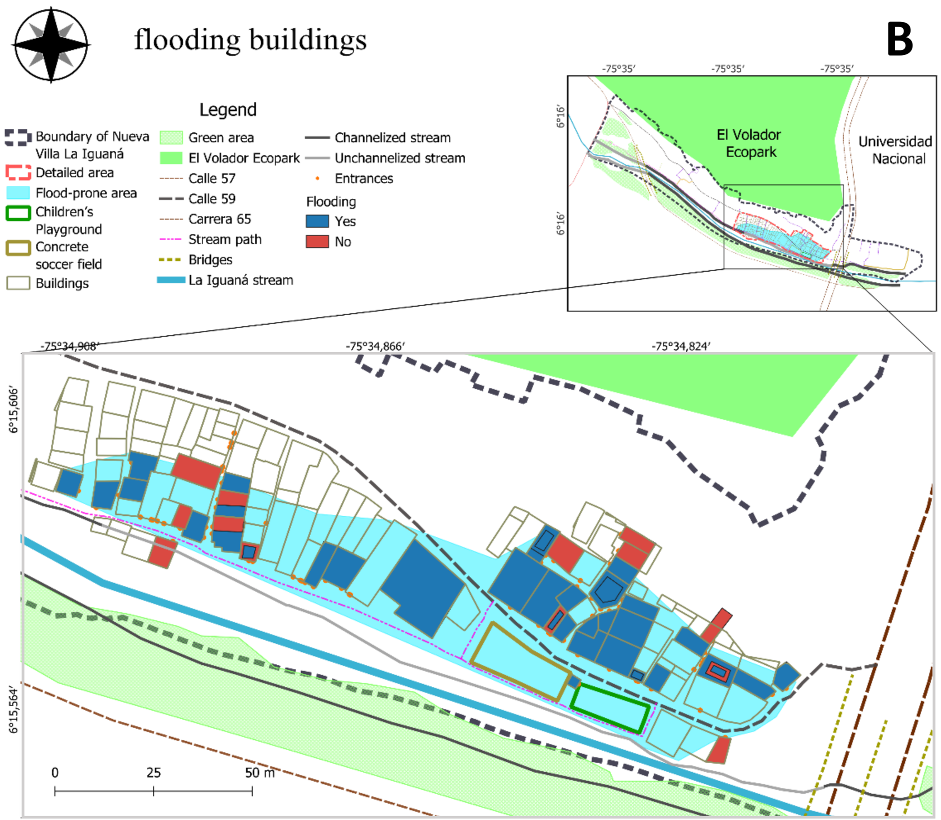
At the scale of the flood area, it is evident that community gathering places, such as the Community Action Board, the church, and recreational spaces like parks, are located within the flood zone. This suggests the need to either relocate these community gathering places to areas with lower exposure or to modify the neighborhood's physical infrastructure to reduce the flood impact on these important sites for the community. Losing these spaces could hinder community planning in various aspects of the neighborhood, including flood risk management (Figure 7 A and B).

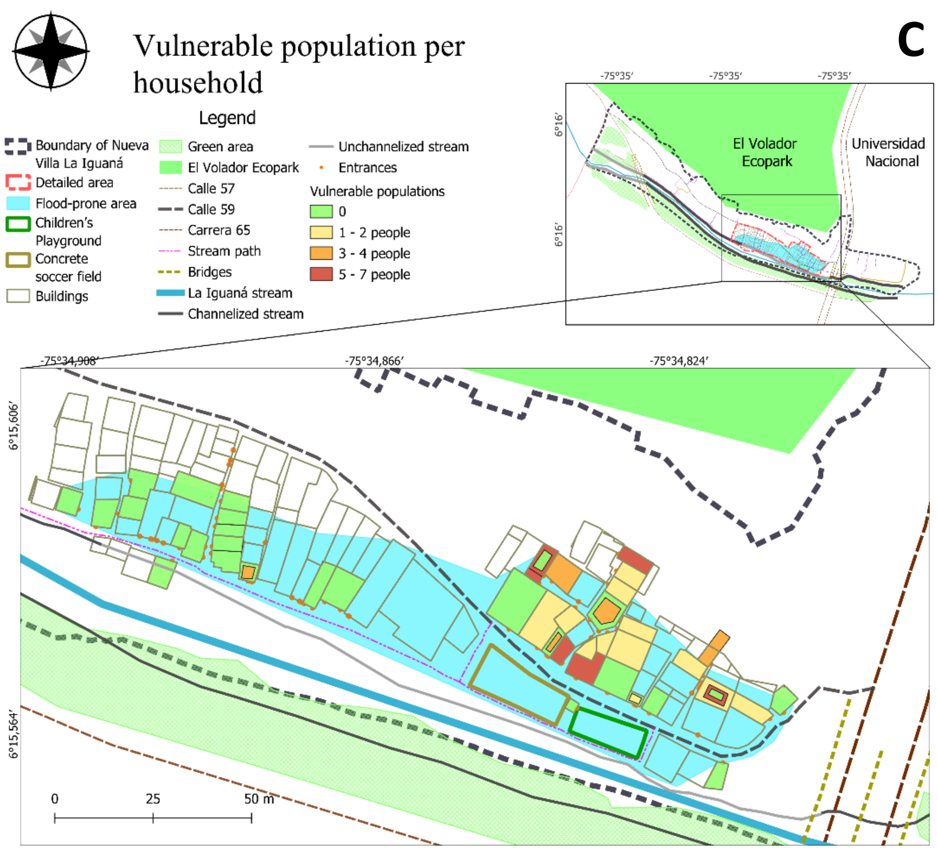
There does not appear to be a specific pattern associated with the flooding of buildings. However, if we reference Calle 59 and take a horizontal cross-section of the flood zone, there are two distinct areas: one area exposed to the west directly adjacent to the stream (hereafter referred to as E1, in

Figure 7A) and another area that borders Calle 59 and does not have direct contact with the stream (hereafter referred to as E2, in Figure 7A). Flooding in buildings within E2 seems to be more associated with runoff from Cerro El Volador, which flows through narrow alleys (shown by the purple dashed line in Figure 7A) with an inefficient drainage system, rather than with overflow from the stream. This highlights the need for different flood mitigation measures in this zone compared to E1, as well as a higher exposure to landslide threats.

The situation in E2 could worsen if the practice by some community members of opening sewer manholes to allow water flow continues, as this creates a drowning hazard during floods with sediment and mud. This information is crucial because flood mitigation strategies might need to include measures to increase water retention in the Volador Park ecosystem. Additionally, it is important to strengthen community risk management measures through training on proper handling protocols and actions during rain and flood events, especially given that this area houses the most vulnerable population (Figure 7C).




flooding buildings
B
Legend
Boundary of Nueva Villa La Iguaná
Detailed area
Flood-prone area
Children's Playground
Concrete soccer field
Buildings
Green area
El Volador Ecopark
Calle 57
Calle 59
Carrera 65
Stream path
Bridges
La Iguaná stream
Channelized stream
Unchannelized stream
Entrances
Flooding
Yes
No
El Volador Ecopark
Universidad Nacional
-75°34,908'
-75°34,866'
-75°34,824'
6°15,606'
6°15,564'
0
25
50 m


Vulnerable population per household
C
Legend
Boundary of Nueva Villa La Iguaná
Detailed area
Flood-prone area
Children's Playground
Concrete soccer field
Buildings
Green area
El Volador Ecopark
Calle 57
Calle 59
Carrera 65
Stream path
Bridges
La Iguaná stream
Channelized stream
Unchannelized stream
Entrances
Vulnerable populations
0
1 - 2 people
3 - 4 people
5 - 7 people
El Volador Ecopark
Universidad Nacional
-75°34,908'
-75°34,866'
-75°34,824'
6°15,606'
6°15,564'
0
25
50 m

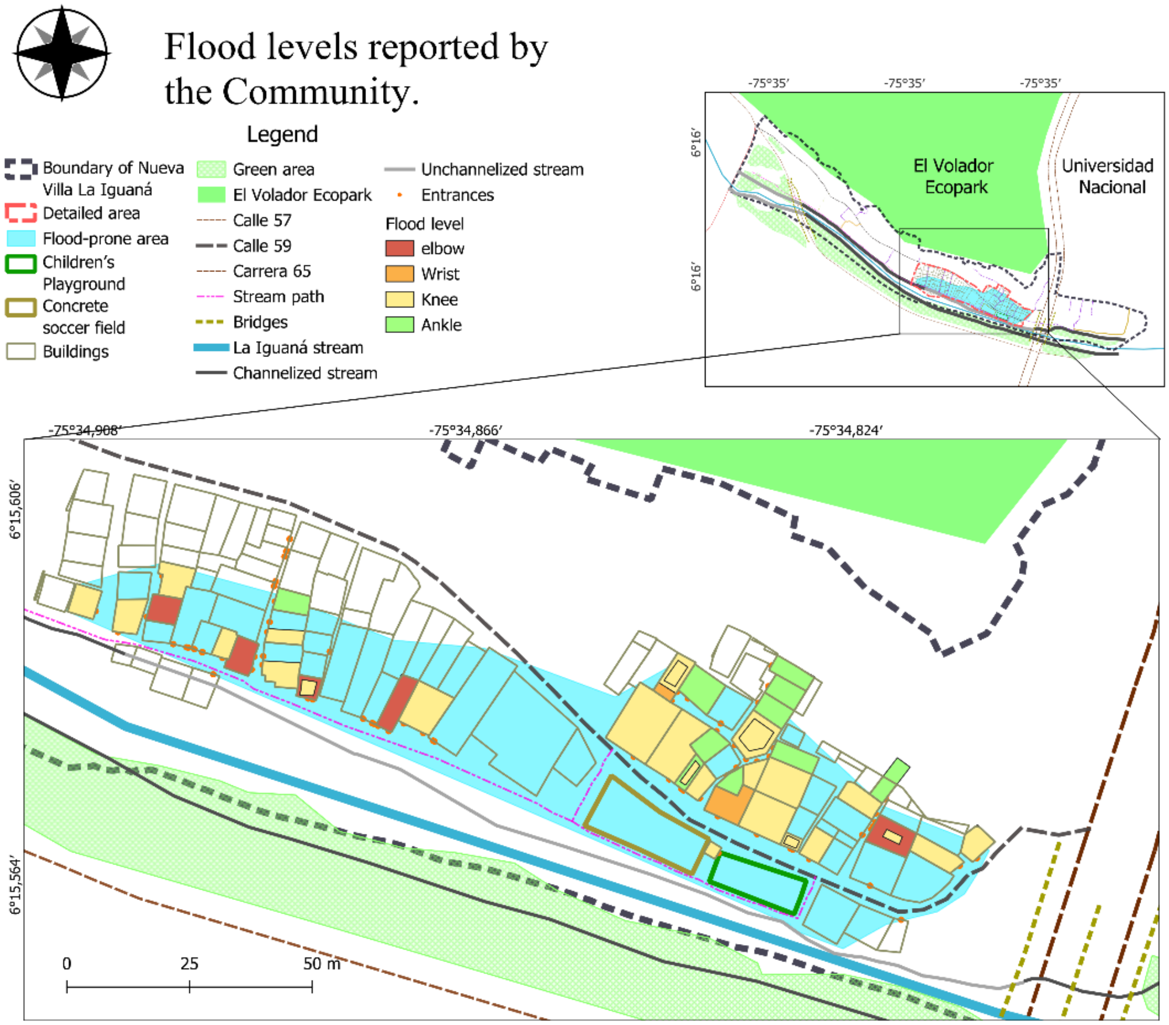
7. Map of the flooding area. A) Detailed aérea: Nueva Villa la Iguaná, B) Fooded buildings. C) Vulnerable population (children, adultos mayores a 60 años y personas con movilidad reducida.

Aunque varias viviendas no pudieron ser encuestadas debido a que no había personas presentes al momento de realizar la encuesta. La zona E1 presenta una concentración significativa de personas con discapacidades de movilidad y adultos mayores, donde la mayoría de las viviendas se inunda (Figura 7 C). Estas personas requieren especial atención en caso de una emergencia por inundación, pues según el IPCC (2014) son los más propensos a sufrir los efectos negativos de inundaciones y otros fenómenos hidrometeorológicos extremos. Esta podría ser una zona roja dentro del barrio, debido a que el acceso y salida de estas personas es únicamente a través de un callejón, lo cual amerita la toma de medidas especiales en esta área. Esta información es importante sea considerada dentro de los sistemas de alerta temprana y la planificación de rutas y protocolos de evacuación adecuados donde se prioricen y optimice protocolos de acuerdo a las condiciones específicas de estas familias.

According to Kyoung Lee et al (2019) water depth is a crucial factor in estimating a loss of life due to flooding and should be considered in evacuation plans. The speed of evacuation activities can be influenced by water depth. The homes experiencing the highest water levels (at elbow height according to surveys) are primarily located in area E1 (Figure 8). Risk management authorities need to include the necessary equipment and machinery for rescuing and evacuating individuals living close to the stream, especially when the entrances to homes in this area are in front of the stream, as shown in Figure 7A.

In most homes in the flood-exposed area, water levels rise to knee height (Figure 8) This is concerning because, according to Buttler et al (2018), once floodwater reaches 0.5 meters above the ground floor level, properties can be significantly impacted, including damage to internal surfaces, electrical sockets and equipment, kitchen cupboards, furniture, and personal belongings. Additionally, the structural integrity of the building can be compromised. This highlights the need to study mitigation measures and infrastructure interventions to reduce long-term damage.

Despite this, many people with high exposure do not perceive the area as high-risk (according to Kobo Toolbox surveys). This indicates a communication gap between the risk management authority and the community regarding risk awareness. This situation could be improved with the implementation of community-based early warning systems (SAT-Sistema de alerta temprana in Spanish), which have already proven successful in areas near the La Iguaná stream, as described by Zuleta (2024).



8. Flood levels Map. Based on surveyed families.

While it is known that these families are low-income and have limited access to healthcare, formal employment, and education, the flood-exposed area generally exhibits short recovery times. Homes that experience higher water levels are the same ones that require more time to recover after a flood event (Figure 9). According to Murdock, Bruijn, and Gersonius (2018), the recovery rate depends on various factors related to the vulnerability and coping capacity of the affected systems. Identifying and enhancing the key elements behind the recovery rate of these families could lead to the development of targeted flood adaptation strategies, thereby significantly strengthening their ability to cope with flooding.

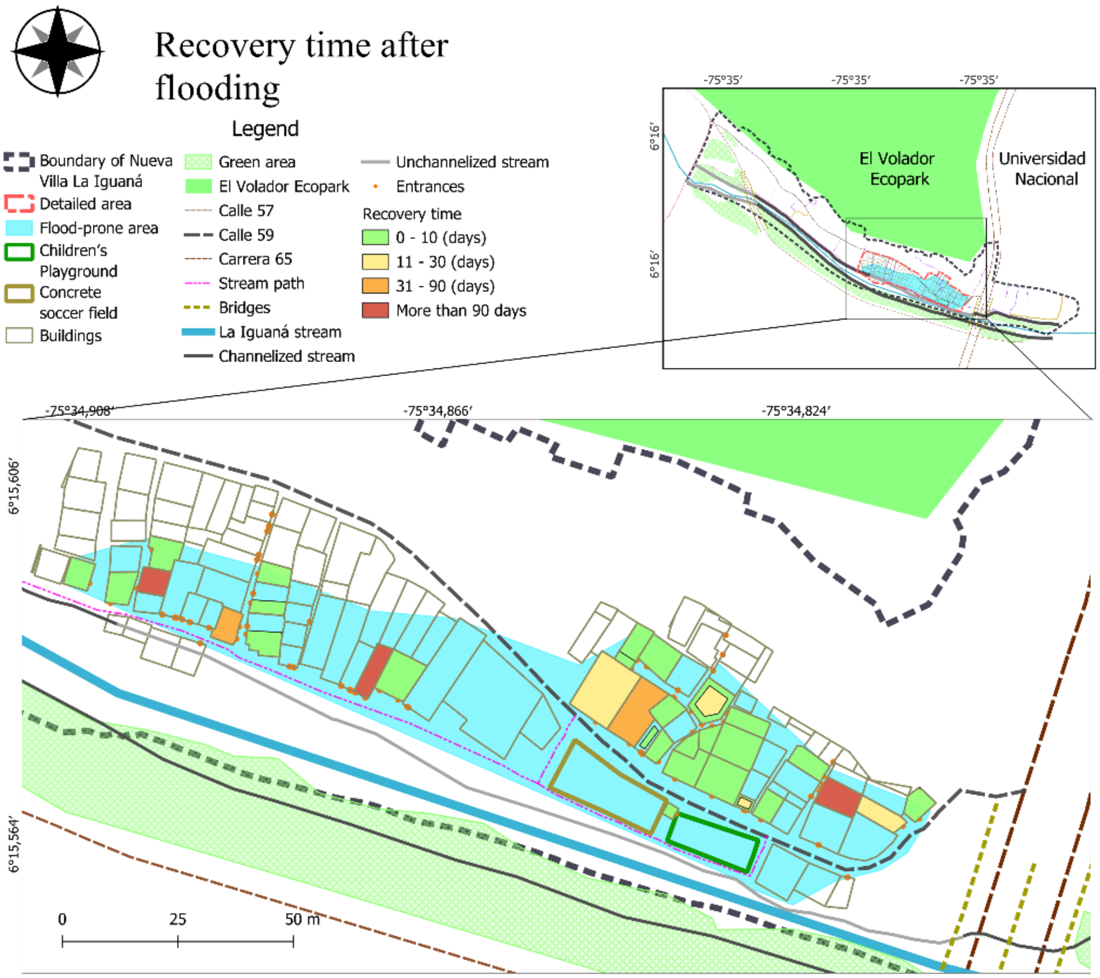


Figure 9. Map of recovery time after flooding

On the other hand, it appears that the highest level of overcrowding in the flood-exposed area is in the E2 zone (Figure 10). Azuma (2018) identified that, following flooding events, health problems can arise due to high moisture levels and the growth of indoor mold in homes. This was also observed in several homes while the surveys were doing. Based on these, it can be inferred that this also poses a public health risk, especially because the most vulnerable population is located in this area (as mentioned previously). Considering that this neighborhood is exposed to flooding from one of Medellín's most polluted rivers (Zuleta, 2024), it is important to implement measures to address flood mitigation with regard to its sanitary implications.

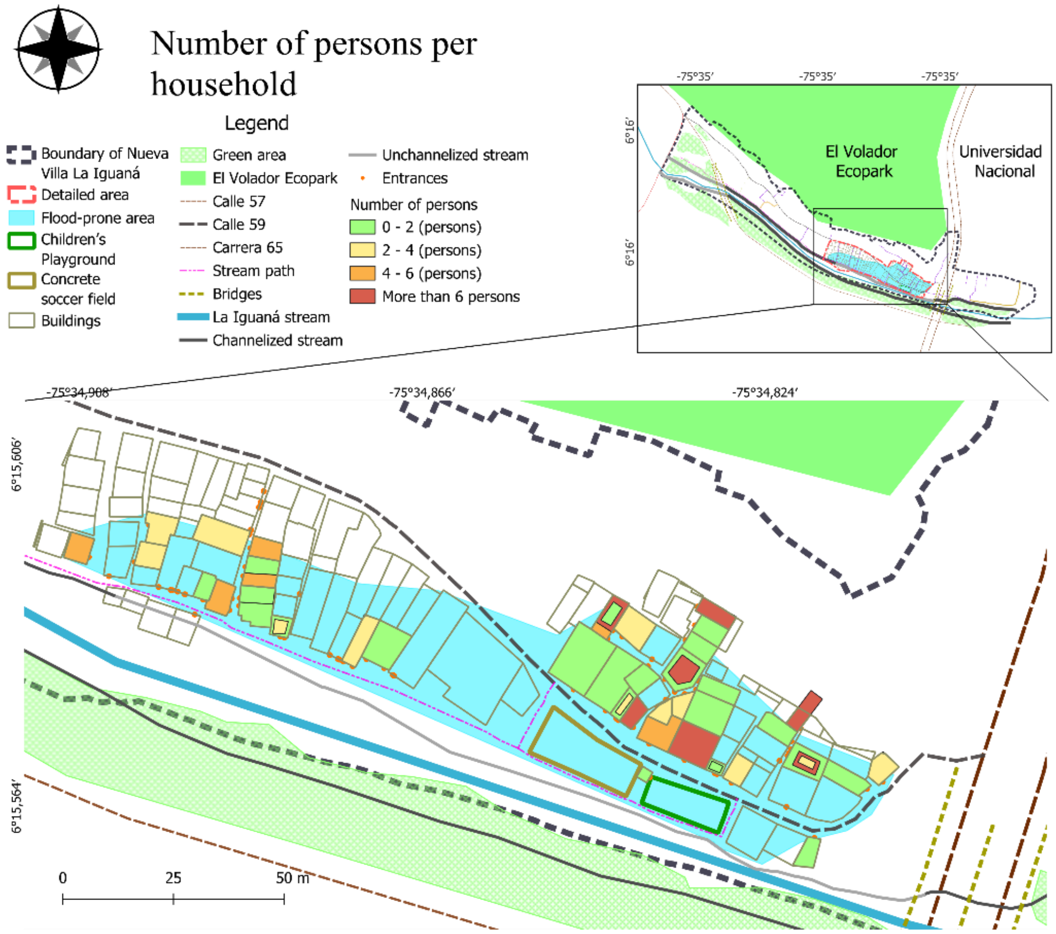


Figure 10. Map of the density of people per housing unit

The overcrowding in the neighborhood and its drainage infrastructure present significant challenges, as highlighted by this study. According to Proverbs and Lamond (2017), water prevention and exclusion technologies, such as adaptive landscaping, improved drainage systems, and standalone barriers, are crucial for managing flood risk and enhancing property resilience. The information provided in the maps is valuable for applying these technologies effectively, as it includes the locations of manholes, which can be integrated into drainage systems (see Figure 7A), and flood levels (see Figure 8), which are critical for identifying where standalone barriers can be implemented.

According to Buttler et al. (2018), drainage systems are composed of major and minor components. The minor system refers to the underground piping that drains water, while the major system consists of surfaces such as streets and roads that facilitate water flow. The interface between these two systems is the manholes, which connect water from the interior to the exterior. From this perspective, the neighborhood's major system comprises Street 59, which is the only street, and the alleyways. Both the minor and major drainage systems in the neighborhood appear to be insufficient for handling the water concentrated due to increased precipitation and the overflow of the creek.

According to residents, manholes frequently become uncovered, highlighting the excess water and the drainage system's inability to manage it.

These issues present significant challenges for this particular neighborhood, which, in addition to having a large portion of its surface being quite impermeable—a characteristic of urban "development"—has few green or natural areas for water infiltration and limited space for their development. However, this situation also represents an opportunity to invest in nature-based solutions and Sustainable Urban Drainage Systems (SUDs) as alternatives for flood mitigation, as proposed by several authors (Sagala et al., 2022; Mabrouk et al., 2023). Such interventions, rather than being quick fixes like grey infrastructure, which often proves ineffective in the long term, aim to replace the functions of natural systems for water retention and filtration. Depending on the specific characteristics of the location, these solutions can be effective in managing flood risk.

Challenges

Throughout the project, we faced numerous challenges, particularly in coordinating the team of university students involved and engaging with the community. Effective project management requires strong coordination skills, including task delegation, schedule management, and clear communication with both the community and the team. To enhance project development, we organized our work into packages and planned the delegation of tasks weekly. One of the key lessons we learned was the importance of maintaining clarity in our objectives, as it's easy to become distracted and lose focus on critical activities. Delegating tasks to students was also challenging; since they were not professionals, even with some technical knowledge, they needed more support and clearer instructions to complete tasks effectively, which required additional time investment.

Working with the community presented another set of challenges. From assembling the focal group to preparing workshops, each step was complex. Although we had support from community leaders, we needed participants with specific characteristics (e.g., strong ties to their neighborhood, familiarity with cellphones or technology, and availability). This required mapping the various groups within the neighborhood to identify individuals with these traits, and then planning a call that took into account the community's communication styles, preferred times, and locations. Before reaching out, we had to understand these dynamics thoroughly. Once we established the focal group, we had participation from individuals who were interested but faced technological limitations, which meant we had to accommodate different learning paces when teaching collaborative mapping.

To capture the community's interest and maintain active participation, we needed to plan creative workshops. Our focal group was diverse, with both young and older participants, making it challenging to design sessions that engaged everyone. We used a workshop structure recommended by the Humanitarian OpenStreetMap Team's social team, which included various phases: an icebreaker, concept development, an energizing activity, and a closing with conclusions. This structure allowed us to relate topics to dynamic activities that engaged participants. Coordinating this with the student volunteers, who lacked experience in such settings, was another challenge. We prepared the workshops together, and each student took turns leading two sessions.

These are some of the primary challenges we faced, and they are common in any project development. We believe that these aspects are what make projects real and should be shared, along with the methodology—not just the results. By sharing these experiences, other initiatives can learn from our management strategies or avoid making the same mistakes.

Achievements and Next Steps

In this project, SIATA (the organization responsible for implementing early warning systems in the metropolitan area of Medellín) was involved to initiate a process of engagement with the community and explore the use of this information for supporting and implementing an early warning system. This connection served as an opportunity to build a bridge between the institution and the community, ensuring continued collaboration beyond the project's duration in areas such as self-care and risk management.

The community (focus group) was trained in open geospatial tools for gathering cartographic information useful for flood risk management and planning. Initial actions were established to start strengthening flood resilience, focusing mainly on proper waste management, which is causing the river to be blocked.

One of the project's most valuable achievements was the creation of cartographic data, which was previously unavailable for the neighborhood and is now accessible to any interested institution or group (see products). This was done in an innovative and cost-effective manner, using open geospatial tools and collaborating with university research groups and international networks such as YouthMappers and the Humanitarian OpenStreetMap Team. This project provides a crucial geographic information base that can continue to be expanded for flood risk contribution and management.

Of course, the cooperation of all these partners does not replace the need for a multidisciplinary professional team that can address both the technical aspects (related to flood management) and the social/community aspects of operational resilience actions. To translate the installed capacity into operational resilience actions, ongoing support, time, a rigorous technical team, and substantial funding are required. However, this project establishes a methodology that can be replicated and institutionalized, involving and training communities to participate in risk management for any threat.

Products:

Videos en social media: We created videos in Spanish to document what was accomplished in each phase. list of videos in Geolab channel. video summary of the project

Web Resource to the community: Page for the community "*Iguaná mapping project tab*" with project information and a *toolkit* ("Caja de herramientas" on the page) so that the community has resources with which it can continue to gather information and improve its community planning, not only in terms of risk management, but also in terms of territorial planning. Link to the page

Cartographic information: The infrastructure information collected is available at:

Collaborative mapping guide for settlements: Based on this experience, the mapping methodology is also available in detail (in Spanish) for chapters and university groups that work with mapping, so that they can have a reference guide for the mapping of settlements in LATAM. (Link to the document)

Acknowledgments and thoughts

This project is a youth-led initiative that would not have been possible without the support of the Integrated Drought Management Program, Global Water Partnership, and the World Meteorological Organization. We are grateful for the financial support, patience with our schedule, and willingness to assist in the development of this idea. The execution of this project provided an invaluable opportunity to ground and refine the scope of what can be achieved with tools such as open mapping and risk management, particularly at a time when our socio-environmental systems are beginning to face significant challenges. We extend our sincere thanks to everyone who contributed to the team, particularly Cristo Facundo Perez, for his readiness to assist whenever possible.

The development of this project represented a significant effort because we did something very useful with numerous challenges and a limited budget. This represented a substantial and demanding volunteer effort, and we take great pride in the results achieved with our efforts. We hope to have the opportunity to share all this with the different communities that support IDMP, showing the project as real as it was, with their difficulties and challenges because is there where improvement can arise.

We would like to mention that programs designed to support youth ideas must go beyond funding and we would like to suggest taking into account the need for comprehensive support throughout the entire process. This is important to ensure meaningful feedback that enhances project development and increases its potential. Additionally, we consider it is important to recommend that social media campaigns incorporate most information possible in every phase of the project. We are looking for visibility and it is important videos show and tell what was done. We think much more of the information that we sent could be used to fully reflect each phase.

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