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**Neglected Landscapes and Green Infrastructure:**

**The case of the Limas Creek in Bogotá, Colombia.**

The landscape of Bogotá's low-income informal settlements reveals intense and ongoing conflicts between political agendas, socio-environmental needs and everyday practices. This paper presents the results of an interdisciplinary research project that used semi-structured interviews with practitioners, academics and community leaders to critically investigate the interactions between people and landscape in Bogotá. The paper aims to deepen the understanding of the social and ecological processes that are constantly intertwined in the occupation and appropriation of the landscape. Using the Limas Creek as a case study, the paper explores the technological constraints, governance structures, cultural values and community agency around the restoration of rivers and the implementation of green infrastructure in low-income settlements in Bogotá. The research highlights the need to explore the demands of co-production and its relation to the challenges of sustainable development. The paper demonstrates that, in addition to sustainable solutions to water management, there is also a need to develop strategies around education, landscape attachment and environmental awareness. This is seen as a first step towards the re-articulation of the relationship between people and water in the urban realm to ultimately guarantee environmental justice.

Key words: green infrastructure, sustainable development, informal settlements, landscape, Bogotá.

## 1. Introduction

**Water** is a crosscutting element to achieve Sustainable Development (SD), a cornerstone of life on earth, and necessary to ensure healthy lives, promote wellbeing, restore ecosystems, sustain biodiversity, and produce food (World Water Council, 2015). However, it is becoming a shrinking and limited resource (Feyen & Shannon, 2008). It is estimated that 2.3 billion people live in water-stressed countries and billions of people still lack access to safe drinking water, sanitation and hygiene (Durosaiye & Hadjri, 2022). This demonstrates the slow rate of progress to achieve the Sustainable Development Goal (SDG) 6: “Ensuring availability and sustainable management of water and sanitation for all” by 2030 (United Nations, 2021). This is even more challenging for the people who live in informal settlements, estimated at about 113.4 million in Latin America and the Caribbean and 864 million globally (Niva et al., 2019; United Nations, 2017).

Informal settlements are usually built in fragile ecological areas that face natural hazards such as floods or landslides, which amplify their vulnerability to natural disasters (Adegun, 2018). In these areas, people construct self-built incremental housing, without proper infrastructure, public utilities or adequate public spaces (Wekesa et al., 2011). These conditions, especially the lack of water and sanitation services as well as the vulnerability to disasters, have a direct impact on quality of life and human health. Informal settlements dwellers rely on coping strategies to access clean water, such as water trucks, illegal pipes, or untreated water. Additionally, wastewater is usually discharged into water bodies, polluting rivers, streams and wetlands which further deteriorates water bodies (Narvaez Tafur, 2009; Swyngedouw, 2004; UN-Water, 2017).

Addressing the challenges associated with the provision of safe drinking water, adequate sanitation and climate change adaptation for growing urban populations, especially in the Global

South, is critical to guaranteeing SD in the long term. The first well-known definition of SD, presented in the Brundtland report in 1987, states that SD requires meeting “the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland & World Commission on Environment Development, 1987). The report also makes two clarifications, first that priority should be given to “the essential needs of the world’s poor”, and second, that acknowledging the ability to meet human needs depends on the “limitations imposed by the state of technology and social organisation on the environment” (Barkemeyer et al., 2014). Therefore, there is a need to develop integral solutions that tackle physical and social barriers to provide equitable access to healthy environments. Furthermore, there is an urgent need to increase protection against natural hazards and to build infrastructure for climate change adaptation (Diep et al., 2019). Nevertheless, Escobar (2014) points out that in order to respond to the current environmental and social crisis it is necessary to take a critical approach to the concept of development. The author proposes a shift in focus from unsustainable development to collective and individual wellbeing, decoupling human development from economic growth, and recognising that place and identity play an essential role in a person´s wellbeing

**Green Infrastructure** is a critical element of SD that can provide environmental and social benefits. Green infrastructure is defined as a network of natural and semi-natural open spaces of different scales that enhances the ecological performance of an ecosystem while providing a wide range of services to the local communities, among them the reduction of flood risk and adaptation to climate change (Benedict et al., 2006). However, Hanna & Comín (2021) acknowledge that while there is an increase in emphasis on research about the environmental aspects of green infrastructure in relation to SD, there is a lack of studies that also integrate environmental, social and economic dimensions. The authors also argue that most of the research about green infrastructure has been published by researchers in the Global North.

Therefore, there is a need to apply an integrative approach to research green infrastructure combining the three pillars of SD, as well as to evaluate its role in wellbeing.

Addressing the issues of implementing green infrastructure in informal settlements can provide an opportunity for a deep exploration of the social dimension of SD in relation to this approach. This task is extremely relevant in countries of the Global South, such as Colombia[1], where social inequality goes hand in hand with environmental degradation. This paper aims to contribute to filling this gap by exploring social, economic and technical challenges to the sustainability of green infrastructure in low-income settlements in Bogotá, using the Limas Creek as a case study. This creek has the potential to become the backbone of a network of natural and semi-natural spaces that could provide ecosystem services for low-income dwellers to become a green infrastructure.

This research, which examines the case study of the Limas Creek, is guided by the following questions:

- What is the role of water landscapes in the daily living of low-income dwellers of the Ciudad Bolívar settlements?

- What are the challenges to river restoration and public space improvement to guarantee equitable access to green infrastructure services and benefits in informal settlements?

- What are the interplays between top-down policies and bottom-up processes in the management and appropriation of the Limas Creek landscape?

[1] In Colombia the value for Gini index is 51.3, placing it as the fourth-most unequal country in Latin America, and the 13th most unequal country in the world (World Bank, 2019).

The article starts with a brief literature review exploring the emergence of green infrastructure and its relation to urbanism, the challenges to intervene in informal settlements and the social production of the informal settlement landscape. A description of the Limas Creek is presented followed by the results of interviews with stakeholders. Finally, the article discusses the conflicts between social and environmental needs and the possibilities for enabling access to healthy and safe environments in informal settlements.

## 2. Green Infrastructure and Urbanism

One of the first uses of the term 'Green Infrastructure' was by Paris Glendening in 1999 within the US President's Council of Sustainable Development (Mell, 2017). Glendening declared that there was a prevailing need to invest not only in human and capital infrastructure "but also in our environmental or green infrastructure — our forests, wetlands, stream and rivers" (Benedict & McMahon, 2002, p. 6). During the last decade, there has been a growing interest in green infrastructure, because of its potential to reduce the impacts of climate emergencies resulting from flooding, heatwaves, droughts and air pollution (Satterthwaite et al., 2010). Furthermore, Nieuwenhuijsen (2021) suggests that green infrastructure may provide many health benefits because there is large number of studies that prove the positive impact of green spaces on health. However, Nieuwenhuijsen acknowledges that more research is needed to corroborate these findings since green infrastructure is a larger network composed of green spaces and other elements. The next sections will discuss water and cities, the challenges of intervention in informal settlements and the social construction of landscape in informal settlements, in order to establish the relation between green infrastructure, water and urbanism as well as the socio-spatial characteristics of neighbourhoods of informal origin.

### 2.1 Water and cities

The emergence of the term green infrastructure in the Global North was aligned with a transition to a new paradigm in the management of water. Fletcher et al., (2015) state that, although the term green infrastructure includes more than sustainable water management, its use in stormwater literature has grown significantly in recent years. Sustainable water management requires a divergence from traditional, highly engineered approaches to flood control, to an ecologically 'engineered' solution that addresses multiple purposes, such as reducing flood risks, increasing ecological biodiversity, improving air and water quality, and providing open public spaces for recreation and physical activity (Novotny, 2008). This potential as a multifunctional infrastructure has stimulated governments to promote the soft or green engineering approach to water management as a sustainable form of investment (Mell, 2017).

In parallel, during the last three decades, urbanism has been concerned with how water systems can provide structure for urban interventions and afford resilient solutions to current urban and environmental challenges (Margolis & Chaouni, 2014; Mathur & Cunha, 2014; Rojas Bernal et al., 2020; Shannon, 2008; Shannon & de Meulder, 2013). This approach, named Water Urbanism, aims to bring water back into the public realm by reverting modern pipeline engineering practices that appeared in response to public health concerns such as cholera, dysentery, and typhoid. These practices placed water 'out of mind', transforming rivers into underground pipes, riverbanks into artificial concrete canals and partly erasing water from the collective imaginary of citizens (Shannon et al., 2008). To find solutions to these urban and environmental challenges Water Urbanism explore context-specific design investigations based on the understanding of landscape logics. These logics refer not only to the physical aspects of landscape but also to the recognition of landscape as active systems intertwined with the practices of the communities that inhabit them (Rivera, 2018).

### 2.2 The challenges of intervention in informal settlements

In most countries in the Global South, governments' approaches to tackling the challenges of informal settlements have changed over time. These approaches range from eradication, eviction and re-settlement, housing subsidies, and public housing, to urban upgrading (Wekesa et al., 2011). One of the major challenges to address these issues is related to land tenure regularisation. Payne (2001) affirms that there is a gradient of tenure categories that result from the informal urbanisation process which he calls the 'tenure continuum'. Consequently, he states that legalisation should be an incremental process instead of an abrupt change between the formal and informal, or legal and illegal, categories. This is because regularisation of tenancy can have unintended negative effects, such as an increase in land prices, which can stimulate the emergence of new informal settlements, as well as distort the land market and increase rent prices for the poorest inhabitants. Therefore, instead of stopping the process of informal expansion, regularisation may perpetuate the problem of illegal occupation (Payne, 2001).

Torres-Tovar (2011) explains the different approaches to informal settlements in Bogotá that range from forced eviction to urban upgrading. Forced eviction was implemented through the first slum eradication programme from 1957 to 1970. From 1963 to 1990, the government promoted urban upgrading through the legalisation of tenure, construction of basic infrastructure, and house improvement. The current Program for Neighbourhood Integral Improvement, PMIB (Programa de Mejoramiento Integral de Barrios), which started on 2000, seeks a comprehensive approach to intervene in informal settlements. This includes intervention in public spaces, social facilities and mobility infrastructure. However, it is important to note that in Bogotá "…illegal development rarely took the form of land invasions. Rather, 'pirate' developers sub-divided land at the edge of the city, sold it without planning permission and offered settlers a minimal supply of infrastructure" (Gilbert, 2009, p. 427).

Despite all efforts, spatial inequality continues to be one of the country's major problems. In Bogotá, access to environmental assets, adequate public spaces and healthy environments still

show a huge gap between the more affluent areas of the city and the poorest. Roa (2016) estimates that approximately 40% of Bogotá's urban areas had an informal origin. Though most of these neighbourhoods had been legalised, spatial characteristics such as morphology and location as well as an unequal public investment in infrastructure remain problematic. An equitable distribution of green infrastructure could decrease territorial imbalances through an equitable access to public space and nature which in turn would improve territorial cohesion. This approach requires not only spatial interventions, but also good territorial governance, which would "promote balanced development, reduce existing territorial disparities and imbalances, and promote economic and social cohesion processes, as well as environmental sustainability" (Sánchez-Zamora et al., 2017, p. 51). This is necessary to guarantee access to societal benefits and reduce the risks from natural disasters and climate change (Wolch et al., 2014).

### 2.3 Social construction of landscape in informal settlements

Despite the infrastructure shortcomings and environmental risks in informal settlements, inhabitants' agency in the production of space has positive socio-economic and physical contributions to the built environment. For instance, in Bogotá, residents have designed, self-built and managed public spaces and community gardens for food production (Hernández García & Sierra Moncada, 2019; Hernández-García & Caquimbo-Salazar, 2018). The urban morphology of informal settlements also contributes to increasing the vitality of public space. The narrow streets, commercial uses on the ground floors and high densities create vibrant streets and public spaces that offer spaces for exchanges, gathering and performance of social and cultural practices (Hernández-García & Yunda, 2018).

Through everyday practices, communities manage to overcome the different physical and socio-economical shortcomings that result from their 'informal' condition. These include the

intervention of their built environment, the organisation of community groups and the development of informal economies, amongst others. These practices can be understood through the concept of 'people as infrastructure', which means as a platform "for and reproducing life in the city" that "depended on the ability of residents to engage complex combinations of objects, spaces, persons, and practices" (Simone, 2004, p. 408). They can also be understood as 'tactic movements' (de Certeau et al., 1980) that allow residents to adapt to the precariousness of their environments (Lobosco, 2009) and to build resilience when living in informal settlements.

Bottom-up participation and grassroots movements can also be understood using the concept of people as infrastructure. In Bogotá, new modalities of public participation have emerged during the last decades, many of which are related to modes of 'social environmentalism' that aim to defend the natural areas, such as wetlands, rivers and forest. (Hernández, 2010). The substantial increase in participatory mechanisms, between 1991 and 2007, has facilitated the emergence of these practices. Besides, environmental projects such as Eco-neighbourhoods (Eco-barrios), as well as the School Network initiative by the Hills Foundation together with local and public schools, are also an example of grassroots movements that promote environmental awareness and collective action as the first steps to renewing the relationship between people and nature (Herzog et al., 2021).

Despite the large offer of participatory mechanisms, these instruments fall short in responding to the spatial, environmental and political inequalities, because they have been unable to generate democratization processes and mobilize citizen commitment to the public sphere and the city. Furthermore, the valuable contribution of the grassroots movements is still modest considering the scale and complexity of informal settlements. Removing these barriers, through adequate interventions and agreements between communities and local institutions, could promote new relations between society and the environment. As such, the study of water and green

infrastructure in informal settlements provides insights into the extent to which sustainable planning concepts developed in the Global North could contribute to creating healthy environments in the Global South, where limited resources intersect with social needs.

## 3. Data and Methods

This paper is informed by qualitative research methods, using the Limas Creek as a case study. A case study is a research approach that conducts an empirical investigation of a particular contemporary phenomenon in its real-life context, using multiple sources of evidence (Walliman, 2011). Gomm et al., (2000) argue that a case study research strategy is a useful means to answer the 'how' or 'why' question, whereby the researcher tries to study real-world situations, without the necessity to influence the event under study. The intention is to collect qualitative research data from multiple sources, which can be triangulated in order to answer the research questions. To achieve this objective, a literature review was undertaken, followed by interviews with the stakeholders, practitioners working on projects related to green infrastructure and community leaders of the case study area.

The initial stages of the research entailed the examination of technical reports, policy documents, grey literature, and other non-published work. The objective was to gather information about the physical conditions, the existing planning instruments and ongoing projects for the environmental restoration of the Limas Creek. The relevant documents were identified by searching databases with keywords. The databases of governmental institutions such as the Biblioteca Distrital IDIGER, Observatorio Ambiental de Bogotá, SDP, as well as databases from Google scholar, local universities and research centres such as, Universidad Nacional, Universidad de Los Andes, Universidad Distrital, Instituto de Estudios Urbanos and Instituto Humboldt, were consulted. Then, following an initial thematic review, 49 documents were selected for further examination.

The interviewees (stakeholders) were selected using purposive sampling. In this type of sample, the researcher selects the interviewees who are most likely to provide accurate and in-depth information on the research topic. This strategy assumes that “specific kinds of people may hold different and important views about the ideas and issues at question and therefore need to be included in the sample” (Campbell et al., 2020, p. 654). The aim was to collect information about stakeholders’ perceptions of the technical challenges, social problems and participatory process in projects related to water management, green infrastructure and public space, in the Limas Creek watershed and/or the Tunjuelo River. Therefore, we selected fifteen interviewees whose knowledge of the case study in relation to these key themes would provide proficient and well-informed information.

Interviewees were recruited using the existing network of contacts of the partner institutions, which included public institutions, practitioners and community leaders. The 15 interviewees included eight practitioners working in institutions in charge of the management of public and green space or water management in Bogotá; three academics with expertise in sustainable water management and/or public participation; two community leaders of the case study area; and two practitioners working in consultancy and design projects for green infrastructure and public space (see Table 1).

The interview consisted of 13 questions that address the specific questions of this research on the following themes: Experience on participatory projects, knowledge of the physical conditions of the Limas Creek and/or the Tunjuelo River watershed, experience in developing projects related to the case study area, and potential strategies for improvement of public space and environmental conditions. The interviews were transcribed and analysed using inductive content analysis as described by Elo et al., (2008). This approach to qualitative data analysis is employed when the objective of a study is to explore a phenomenon, and by allowing themes and categories to emerge from textual data in order to create new knowledge, insights, or representation. The

intention is to allow the data to define the contexts of the study, rather than the researchers prescribing a priori the themes.

| **Practitioners working in public institutions** | |
|---|---|
| P1 | Architect and Urbanist |
| P2 | Civil Engineer |
| P3 | Environmental Engineer. |
| P4 | Architect. Specialist in Urban Law |
| P5 | Cadastral Engineer. Master in Urban Planning |
| P6 | Architect |
| P7 | Sociologist |
| P8 | Architect |
| **Academics** | |
| P9 | Professor of Environmental and Civic Engineering |
| P10 | Professor of Environmental Engineering |
| P11 | Professor. PhD in Geography. Master in Economics |
| **Community leaders** | |
| P12 | Community leader |
| P13 | Community leader |
| **Practitioners from the private sector** | |
| P14 | Architect. Master in Landscape Architecture |
| P15 | Architect. |

Table 1. List of the interviewees.

## 4. Case study: The Limas Creek

The Limas Creek was selected because It is part of a system of creeks, located in the oriental mountain range of Bogotá, that face similar problems such as the large rate of informal urbanisation and environmental degradation. The Limas Creek, which is the largest tributary of the Tunjuelo River, is located in Ciudad Bolívar, the poorest administrative area of Bogotá (see Fig. 1) (Herrera Molina, 2017). As a green infrastructure, this creek has the potential to become the backbone of a network of natural and semi-natural spaces that could provide ecosystem services for low-income dwellers. This could reduce the deficit of public space and improve environmental quality and public health.

FIGURE 1 ABOUT HERE

The Limas Creek watershed has an area of 1,748 hectares, of which 626 hectares are located in rural land (Secretaria Distrital de Ambiente, 2009). The creek begins at 3,100 meters above sea level, in the rural area of Vereda Quiba Alto, where it preserves most of its environmental qualities. It flows into the Tunjuelo River at 2,550 meters above sea level (Departamento Técnico Administrativo del Medio Ambiente, 2004) (see Fig. 2). The physical landscape of the Limas Creek watershed is characterised by high slopes and unstable soils, which in turn pose high landslide risks (Rogelis, 2009). In the urban area, the loss of vegetation cover, erosion and quarry exploitation activities increase sedimentation and flood risk (Delgado Tobón, 2010; Secretaria Distrital de Ambiente, 2013). In addition, discharges from illegally connected sewer pipes, leachates, and poor waste management have resulted in the proliferation of pests and a decline in air quality, which have negative impacts on public health (Departamento Técnico Administrativo del Medio Ambiente, 2004).

FIGURE 2 ABOUT HERE

In the Limas Creek watershed, social and environmental inequality is reflected in the lack of public space, the degradation of the ecosystems, the low-quality housing and the proximity of residential areas to quarries. For instance, the average per capita of public parks, squares and green areas is between 1.65 sq. m. to 1.95 sq. m., which is much lower than the 4.62 sq. m. median for Bogotá (Observatorio del Espacio Público de Bogotá, 2020). Furthermore, the density of trees is less than seven trees per 100 inhabitants, while the median in Bogotá is 17 trees per 100 inhabitants (Observatorio del Espacio Público de Bogotá, 2017). In addition, social inequality is evident in the average household income, estimated at 493.167 Colombian Pesos (114 euros) for Ciudad

Bolívar which is significantly lower than the average for Bogotá 1.063.144 Colombian Pesos (247 euros) (Secretaría Distrital de Planeación, 2017).

According to the land-use regulations, in the urban area, the Limas Creek and its riverbanks are environmental corridors that are part of Bogotá's Ecological Main Structure (EMS). EMS was introduced in the official legislation, namely Bogotá's Land Use Plan (POT: Plan de Ordenamiento Territorial) of 2000, as a series of components that preserve biodiversity, guide ecological processes and provide environmental services (Andrade et al., 2013). According to the urban norm, environmental corridors, such as the Limas Creek, include two zones: (1) a strip for hydraulic control and (2) an area for Environmental Management and Preservation Zone (EMPZ) (Zona de Manejo y Preservación Ambiental ZMPA) (see Fig. 3) (Decreto 190 de 2004, 2004)[2]. To address flood impacts and water pollution, the government has implemented a series of projects that are compiled in Table 2.

FIGURE 3 ABOUT HERE

| Project | Reasons | Actions |
|---|---|---|
| Ecological restoration of the Limas Creek 2004 | Formulated after the declaration of emergency due the floods of 2004 that affected the neighbourhoods located in the | Cleaning, reforestation and socialization activities |

[2] The two zones are defined by the Decree 469/03 as follows: (1) Strip for hydraulic control: non-buildable public area for environmental and hydraulic protection, it consists of a strip parallel or around the bodies of water, measured from the maximum tide line (maximum flood line), up to 30 meters wide intended primarily to hydraulic management and ecological restoration. (2) Environmental Management and Preservation Zone (EMPZ): it is a strip of publicly or privately owned land adjacent to the hydraulic control strip. It has the following aims: promoting the adequate transition between the built environment and the ecological structure, ecological restoration and construction of infrastructure for the public use related to the defence and control of the water system.

| | | |
|---|---|---|
| | lower basin (Decreto No. 383 of 2004) | |
| Wastewater Interceptor. 2018- ongoing | Wastewater pollution. Infrastructure project included in POT 2001. | Six kilometres long interceptor. Includes cleaning, construction of dykes and sewerage system (see Fig. 5). |
| Design and works for river embankment | Flood risk management | Open hydraulic structure and transversal works in the neighbourhood Villas del Diamante. |

Table 2. Summary of the projects developed to reduce flood impacts and water pollution along the Limas Creek.

Aerial photographs show the continuous expansion of informal urbanisation in the Limas Creek watershed (see Fig. 4). This, together with the lack of adequate wastewater infrastructure, the exploitation of quarries and the loss of vegetation cover, have seriously decreased the environmental qualities of the watershed, which in turn exacerbates flood and landslide risk and negatively affected people's health. In legal terms, the Limas Creek is part of Bogotá's EMS. Nevertheless, the river system is designed as an engineered canal with the main purpose of floodwater control. Furthermore, the parallel strip along the river course (hydraulic control), is not accessible, lacks arborisation and ignores the variations in ecosystem conditions (see Fig. 5).

FIGURE 4 ABOUT HERE

FIGURE 5 ABOUT HERE

## 5. Interview analysis.

Fifteen stakeholders were asked about their experiences in participatory projects, their knowledge

of the physical conditions of the area, the challenges they have faced in the development of projects, and their recommendations for the improvement of environmental conditions and public space in the area.

Content analysis of the interviews revealed three key themes: 1) Challenges regarding the implementation of green infrastructure projects; 2) Relationship between water and people; and 3) Participatory process and community agency. Each theme is explored through several sub-themes that emerged from the content analysis as indicated in Fig. 6.

FIGURE 6 ABOUT HERE

### 5.1 Challenges to implement green infrastructure and urban river corridors

#### *5.1.1 Technical challenges*

Bogotá's city planning administration has made important progress to legalise informal neighbourhoods since the 1960s (Torres-Tovar, 2011). However, priority has been given to the most pressing issues, such as the provision of drinkable water and the management of wastewater at the scale of the neighbourhood. In order to obtain these services, the city administration requires that the community legalise the neighbourhood, for which neighbourhoods had to fulfil four conditions: 1) the plots should be intended for Social Interest Housing (SHI) (Vivienda de Interés Social VIS); 2) the built environment should have a high degree of urban consolidation (access roads, built plots, inhabited dwellings); 3) the neighbourhood should not be located in an area where it is not possible to manage risk; and 4) there should be a community representative to carry out the process (Estupiñan, 2018).

According to an interviewee who has been involved in the design and construction of water infrastructure in the Limas watershed, the neighbourhoods along the creek started to be legalised

in the 1990s. The construction of the Limas sewer interceptor started in 2008, but in 2020 there were sections still awaiting construction, mainly because this requires the acquisition of private land by Bogotá's Water Company (EAB-ESP). For this process, the company must deal with long negotiations to solve land property issues, and in some cases demolish houses and resettle the population (see Fig. 7).

> "… the construction of the Limas sewer interceptor began more than 10 years ago, and why has it not been advanced…? due to problems with property titles, because when we want to build the pipe or the design tells us the pipe must pass through here, there are houses built there, so what do we have to start doing? to buy the houses, moreover, to set laws to tell people: you have to leave..." P2

FIGURE 7 ABOUT HERE

In addition to the physical condition of the built environment, the continuous expansion of informal urbanisation hinders the planning of infrastructure for future informal growth. This is because the sewage system and storm water networks are designed according to the existing conditions without foreseeing future informal dynamics. This results in an incomplete sewer system that is never able to respond to the expanding urbanisation on the ground.

### *5.1.2 Management issues*

Most of the interviewees emphasised the influence of political will in the implementation and the allocation of investment for public space or green infrastructure projects. The lack of autonomy between the implementation of urban projects and the definition of a political agenda results in the lack of continuity of projects. Public investment is decided by each administration in the

'Development Plan' (*Plan de Desarrollo*) through the formulation of aims or quantifiable goals. The plan is negotiated and approved by the district council, assigning not only financial resources but also institutional responsibilities. If a project is not included in the plan, the government needs to allocate additional funds, which can take a long time. A participant stated:

> "…strong institutional coordination is not always necessary because if there is a political will, the projects are really developed because the mayor gives a line/direction so that these are a priority within the Land Use Plans, (continuity) will depend on future mayors and their development plans. I understand that ... all (politicians) have realised the importance of the water and geographic watershed management…". P14.

Another major challenge in the implementation of any infrastructure project appears to be administrative fragmentation. An interviewee stated that only strong political will can foster the consolidation of projects in face of the management fragmentation. However, the importance of a project in a city mayor's agenda can rapidly vanish and lead to the abandonment of a project. This lack of continuity in the definition of priorities and long-term projects results in the multiplication of studies and project proposals. The interviewees also mentioned numerous projects and diagnosis reports that did not result in any actual implementation. Such a proliferation of technical knowledge without implementation is often perceived as a 'lack of action'. A participant stated:

> "…we have a very fragmented administration because there are 12 sectors in the district, each sector has its responsibilities, plus the decentralised sectors, plus the local mayor offices, plus other entities and other institutions that work in the territory, so we have a very dispersed management, and we do not sit down and come to an agreement on what we want and where we are going, the only ones that can help with this are the communities that inhabit that territory…". P4.

### *5.1.3 Time and resources constraints*

An interviewee states that the challenges of funding not only apply to the projects that are unexpectedly prioritised in political agendas, but also to environmental infrastructure works that are inscribed in the POT (Bogotá's Land Use Plan), because funding for environmental projects is considered of lesser importance by planning authorities than other types of interventions such as water supply and wastewater disposal. The limited economic resources often result in incomplete projects. The overlap of responsibilities in the management of water systems[3] also hinders the allocation of resources. A participant commented:

> "... we (the water company) prioritise water supply and wastewater collection, but environmental matters are not part of the fee, when you look at your water bill, we charge you (only) water supply and wastewater collection, the issue of investing in water bodies is not clear, therefore for the company it is an expense, and when we go to the Secretary of Environment, that is administratively responsible for this, it has no resources…". P2.

[3] In Bogotá, water management is divided between different players. The regional autonomous corporation CAR (Corporación Autónoma Regional de Cundinamarca) is responsible for the management of the Bogotá River watershed. The secretary of environment SDA (Secretaría Distrital de Ambiente de Bogotá) is responsible for the management of the sub-watersheds: Torca, Salitre, Jaboque, El Tintal and Tunjuelo, within Bogotá's administrative perimeter, as well as the management of vegetation in green public areas. The Bogotá's water company EAB-ESP (Empresa de acueducto y alcantarillado de Bogotá) is responsible for the infrastructure networks for water and sanitation and the protection and maintenance of rivers, canals, creeks within Bogotá's administrative perimeter.

There was a strong consensus amongst the interviewees that to sustain projects in the long-term these should be initiated and embraced by local communities. Interviewees saw this as a way to counter the challenges resulting from the changes in the government, fragmented administration and socio-spatial urban conditions. Interviewees also mentioned that communities have led actions to protect the water bodies and promoted actions to guarantee flood-risk protection as a result of the lack of effectiveness of the State and its inefficiency to guarantee their rights. An interviewee stressed that:

> "… it is essential that there is first an inter-institutional articulation and secondly a process of appropriation by the community because the institutions can carry out actions in the surroundings of the river, but if those actions are not sustained, because there is not a proper link with the community, the problems of the river will persist...". P7.

### 5.2 Relationship between water and people

#### *5.2.1 Socio-cultural issues. Conflicts between livelihoods and environmental quality*

After 2008 the Bogotá's water company EAB-ESP started to delimitate the boundaries of the Environmental Management and Preservation Zone (EMPZ) by means of boundary markers as mandated by the Decree 386 of 2008 (see Fig. 8). These markers make evident, on the ground, contestations between the environmental risks and housing. In many cases, the boundary markers are located in already built areas, houses or roads. An engineer working in a public institution commented:

> "…before that (the decree 386), there was a delimitation, but I think it was on paper, people did not know what the delimitation was, so today this is done, today there is

delimitation. Therefore, one goes to the creek, although it is still vandalized, and finds the boundary markers defining the site…". P2.

FIGURE 8 ABOUT HERE

The possible activities allowed in the (EMPZ) strip are also defined by the POT, being mainly passive recreational activities. On-site observations reveal that space is also used for grazing, urban farming and waste disposal. The interviewees had opposing views regarding the possible public uses of these spaces and how they could contribute to strengthening the interaction between citizens and nature. For instance, the final result of the ongoing project for the environmental restoration of the Limas Creek has been the construction of fences along the (EMPZ) (see Fig. 5), as a measure to control the proliferation of negative actions, such as vandalism, or illegal occupation of the floodplain. This has created a physical barrier that further disconnects the inhabitants from the water body. A community leader stated:

> "At this moment, what the water company did for the intervention of the riverbanks was to enclose all the area with wire mesh, demarking the area as a property of water company, while the imaginary of the community was a linear park layout where (we) the inhabitants could enjoy the space, at least for passive recreation. We cannot access these spaces, these have again been privatised in the hands of a public entity." P13.

The water quality objectives are another instrument to improve the environmental quality, these aim to reduce the contamination of water bodies through the ordering and regulation of the uses of this resource as well as the monitoring, follow-up and evaluation of its quality. To achieve this, the objectives define achievable and measurable goals for water quality in a five-year term. The definition of these objectives implies a process of negotiating between an ideal scenario and the

possibilities of the existing context. Challenges such as the location of small-scale tannery industries along the riverbanks of the Tunjuelo River evidence the difficulties of dealing with high levels of pollution while guaranteeing economic sources for local inhabitants. An interviewee argued:

> "… (in the water there is) mercury, lead or other metals, (caused) by the tanneries that are located along the Tunjuelo River... If one were to apply the law, then simply rubber stamp the entire procedure and close down production… but the people who work there are mostly local residents. If you close the company, all you are doing is taking away their livelihoods and their only economic activity…". P15.

### *5.2.2 Socio-cultural issues. Landscape Detachment*

In Bogotá's informal settlements, rivers are left as waste spaces after the demarcation of the plots by informal developers who aim to maximise profit. At the beginning of the occupation, the rivers provided services for inhabitants, such as water for laundry and freshwater supply, but the quality of the water declined rapidly as the river started to function as a sewage collector. In the Limas Creek, on-site observations reveal that environmental degradation led to the rupture of the physical connections between the built and the natural environment, which materialised in blind walls, absence of pedestrian pathways and lack of activities in the public space (see Fig. 9). This lack of connection resulted in cultural detachment, the river area became insecure and was turned into a forgotten space, used for drug consumption and waste disposal. A participant stated:

> "People turn their backs on (the rivers), in doing so… insecurity becomes an issue, and along with security, a lot of other matters. This leads to a powerful negative spiral… the fact that it (the river) could be cleaned, just cleaning it could generate an impressive level of appropriation at community level." P10.

FIGURE 9 ABOUT HERE

### *5.2.3 Social and environmental benefits of green infrastructure*

Most of the interviewees are aware of the multiple benefits of public spaces and ecological areas, however, the relevance attributed to these benefits varies across the group, depending on the specific expertise and experience of the interviewee. For some, the integration of the river system as a public space is the final stage in the process of urban intervention and corresponds to landscaping interventions, for others the construction of a sense of belonging, and the promotion of use is a fundamental step in the process. An architect working in a public institution stated:

> "…while sanitation infrastructure (is built), the idea is for people to appropriate, to change the culture, at least to build a nice park along the river and activate it, it doesn't always smell bad, it can be used, in fact, the Fucha river has enough parks along it and people can culturally get used to using the river…". P1

It can be seen therefore that the loss of the services that rivers provide to the community, such as drinking or washing, together with the high levels of pollution, leads to cultural detachment. Furthermore, the existing technical and legal instruments to improve environmental quality and reduce natural hazards, such as land-use zoning or water quality objectives, create conflicts between regulations and landscape use. The reactivation of the river as a public space and its integration with the urban environment could be a first step towards the transformation of the river into green infrastructure. Nevertheless, there is a need to explore how to design and manage green infrastructure in such a way that facilitates recreational uses, controls insecurity problems and avoids deterioration caused by lack of appropriation,

### 5.3 Participatory process and community agency

#### *5.3.1 Collective actions of resistance*

Despite the conflictive relationship between nature and the people, local environmental groups such as 'The Limas Creek Environmental Committee' (CQL. Comité ecológico de la Quebrada Limas) have played a critical role in developing actions to promote the recovery of the river, these include the organisation of environmental protests, the construction of community gardens, art performances, neighbourhood clean-up days and community meetings (see Fig. 10 and Fig. 11). For instance, after the flooding event of October 2003, in which two people died and many families lost material possessions, the group mobilised the community to demand the intervention of the authorities. Interviewees highlighted that emergency situations, such as the floods of 2003, or that other critical conditions have commonly been a catalyst for community action. To exert pressure, the communities have gained knowledge of their rights as well as of global environmental agendas and have demanded that the government took action. A participant stated:

> "…it is precisely because an incident, a situation that has affected and affects these communities, has forced them to organise themselves, to create a group, to raise questions and make demands… it is not even the state through its respective entities that plan to act but now it is the courts, it is the ruling of the state council that plans the territory ... it is from those problems that the community... has come to understand what planning is, the definition of design as well as green and blue infrastructure …". P15.

FIGURE 10 ABOUT HERE

FIGURE 11 ABOUT HERE

### *5.3.2 Limits and benefits of participation*

Most of the interviewees have worked in projects that involved different stances of participation, nevertheless, different opinions emerged regarding the definition of participation. The experiences are related to the complexity and scale of this process, ranging from public enquiry/questionnaires, co-design with the community, interinstitutional co-production, to community-led decision-making processes. Specifically, regarding the process of involvement of the community in participation projects, the interviewees agreed on highlighting benefits such as the definition of priority needs and the creation of appropriate channels for communication, but also the challenges such as lack of consensus, lack of trust and loss of empowerment. This was commented by a participant who stated:

> "Participation and trust are fundamental. If there are proper participatory processes and the communities feel that their knowledge of the territory… or their ideas are included in the plans of the local institutions, that will generate confidence in the community to continue participating; and if, on the contrary, they are not represented within these processes, they will move away, they will retreat and they will not want to know anything about the activities." P7

It is evident that the community's action has been motivated by an environmental emergency, the critical environmental state of the area, and the government's limited capacity to improve the physical conditions of the built environment. The community demands and actions have contributed to advance the development of plans for the Limas Creek watershed. Nevertheless, community-driven processes, as well as top-down participation mechanisms, have had limited reach in the improvement of the inhabitant's living conditions.

## 6. Discussion

Green infrastructure can contribute to achieving sustainable development, however, there are various challenges that hinder its implementation. The analysis of the interviews demonstrates that the socio-environmental conflicts and economic restrictions of informal settlements make the implementation of green infrastructure even more challenging. In this section, some of these conflicts are discussed and some recommendations are presented to address them. The discussion is organised around three issues. The first, 'Infrastructure, landscape and people', discusses the technical and administrative aspects to implement green infrastructure as well as the socio-economic and environmental trade-offs. The second, 'From practices of neglect to the practices of care', focuses on the interdependence between the physical characteristics of the landscape and the appropriation by citizens. The third, 'Enabling healthy environments', discusses how knowledge and education can create synergies between investment, public health and landscape conservation.

### 6.1 Infrastructure, landscape and people

The interviews conducted in this research expose the multiple conflicts between infrastructures in informal settlements and the uses and meanings that people give to landscapes and water bodies. Multifunctionality, which is one of the main principles of green infrastructure, offers a solution to resolve some of these conflicts (Diep et al., 2019). Nevertheless, in Bogotá's informal settlements there are different barriers to promoting multifunctionality: firstly, the fragmented organisation of the institutions associated with the management of green infrastructure and public space; secondly, the restricted public access to the urban natural spaces that have environmental value; and thirdly, the persistence of a modern approach to water management based on hard engineered monofunctional structures, dissociated from ecosystems.

The research also highlights the difficulties to overcome the struggles between environmental and socio-economic needs of the inhabitants of informal settlements (de Risi et al., 2013; Huchzermeyer & Karam, 2006). In the Limas Creek, such as in other informal settlements in the Global South, populations inhabiting flood-prone or landslide risk areas are relocated through long administrative processes. In this case, there is a need to design mechanisms that guarantee relocation on-site. In addition, there is a need to produce affordable housing that counters the construction of informal settlements in high-risk areas. Furthermore, there is a need to settle existing conflicts between extractive and polluting activities, such as quarrying and tanning, and landscape conservation. To address this, it is necessary to find alternative economic activities for the people working on small-scale polluting activities, to improve the livelihoods of informal dwellers (Cherunya et al., 2021), as well as to establish environmental and economic compensation for the large-scale economic activities that have significant impacts on the landscape.

### 6.2 From practices of neglect to practices of care

Place attachment is strongly related to environmental care (Bailey et al., 2012). In this study, it was seen that while local inhabitants complain about being disenfranchised, often due to poor sanitation, environmental degradation might also be due to a lack of place attachment. In the case of the Limas Rives, the physical characteristics of the built environment constitute a barrier to the relationship between people and nature. Everyday practices that are a response to insecurity, such as avoiding walking along the creek or building blind walls along the riverbanks, reinforce the neglect of the creek (Furtado & Renski, 2021). Thus, the area becomes a space of drug consumption, waste dumping, and robbery. These tactical movements of avoidance and indifference are ways in which society deals with the complex socio-spatial conditions of informal settlements.

By contrast, grassroots movements have demonstrated other types of approaches that combine long-term actions with emergency responses. These approaches aim to strengthen the role of the river as the structuring element of the territory and promote ecological conservation and community attachment (Hernández, 2010). Other inhabitants use the area for urban farming or grazing, due to the proximity of the urban-rural border, though are also restricted by the urban regulations. Despite their limited results, these tactics are an example of the potential of local communities to take part in co-production processes and preserve the values of nature. Thus, communities need to be considered not only in socio-economic surveys, or as participants in top-down participatory processes, but as central actors in the design, management and maintenance of their environments (Dias et al., 2018; Ostrom, 1996).

A shift from practices of neglect to practices of care can be supported by a reconceptualisation of sustainable development (SD). The concept of Sustainable Territorial Life (STL) offers a framework to build this new interpretation. STL is not only a theoretical concept but a way of acting, living and relating to ecosystems that is linked to communities and their culture (Gutierrez, 2015). In other words, it starts from local knowledge and culture to promote wellbeing, instead of promoting a view of development based on western values and focussed mostly on economic growth (Gutierrez 2015). The formulation of this concept emerged from the need to respond to the multiple contradictions and challenges in the SD concept. One of these critiques is the lack of connection with territorial realities and local cultures because the SD standards are based on western ideals (Escobar, 2007).

STL is aligned with notions such as ‘Buen Vivir’ that emerged in Latin América. Escobar (2017) refers to the notion of ‘Buen Vivir’ as an alternative to development because it goes beyond dualistic positions, embracing multiple knowledges and realities which allows a ‘deeply relational

understanding of life' (Escobar 2016:22). Furthermore, 'Buen Vivir' conceptualises sustainable development, not as the replacement of a previous state by a later one, but as achieving a balance in which the needs of power groups do not take precedence over other groups (Gutierrez 2015). Ordoñez (2022) maintains that 'Buen Vivir' offers an opportunity to design interventions that harmonised the relations between human settlements and ecosystems. Nevertheless, Ordoñez (2022) states that there are still many challenges when using concepts such as 'Buen Vivir' as a framework for spatial interventions. The case of the implementation of Guayaquil Ecológico project, conceived under the vision of Buen Vivir, offers an example of this risk. In this case the preservation and rights of nature took precedence over social needs, causing relocations and evictions (Ordoñez, 2022).

Although the adoption of the 17 sustainable development goals has made it possible to advance an agenda to improve health and education and reduce inequality, they have been insufficient to reduce the social gap. Furthermore, the preponderance of economic growth over the preservation of nature and social equality continues to push society dangerously close to climate tipping points. Therefore, new interpretations like STL or projects that materialise the notion of Buen Vivir, can address the needs of communities and promote equality and social and environmental justice (Gutierrez 2015).

### 6.3 Enabling healthy environments

Design also plays a critical role in supporting and promoting healthy environments. In the Limas Creek the disconnection between the river and the built environment is a result of the unplanned process of urban growth. Recent research in the field of Water Urbanism in Latin America can offer insights about how to design spatial interventions that respond appropriately to the specific socio-ecological dynamics of a place. For example, using the case of the Andalien river in Chile,

Espinosa (2021) proposes a series of principles whereby the urban fabric adapts to the natural dynamics of the fluvial territory, thus allowing the rivers to be alive. These principles resulted from a collaboration between architects, urbanists and geomorphologists and were tested in the international design competition 'Concepción Living at (in) the Edge'. On the other hand, through the study of the Cuenca territory, Rivera (2018) points to the need to ground any design intervention in extensive fieldwork. This departing point offers an understanding to the interactions between social and spatial practices and could be the basis for starting a dialogue between local knowledge and technical knowledge. Furthermore, interaction with other disciplines, such as Geography, could contribute to deepening an understanding of the territory in order to improve territorial cohesion (Gutierrez, 2012). These approaches demonstrate that landscape intervention and the construction of green infrastructure requires a dialogue between different disciplines and knowledges.

Furthermore, the planning of green infrastructure spaces should focus more on designing and guiding the socio-ecological processes that take place in the watershed, from community engagement activities to biodiversity monitoring and infrastructure maintenance, rather than reaching an end product or project (Carmona, 2014). In this way, projects could overcome the lack of continuity that results from changes in political agendas and adequately respond to long administrative processes. Co-production processes also allow the creation of new relations between institutions and communities that could create trust and empower local communities (Ostrom, 1996).

Coupled with the new ways of designing and managing green infrastructure, there is a need to find funding mechanisms for its construction. The underlying reason for a lack of investment in green infrastructure is the difficulty to measure its benefits, such as physical and mental wellbeing, risk reduction or biodiversity preservation (Wilker et al., 2016). This might explain the lack of

continuity in project initiatives across successive governments regarding the Limas Creek. More research is needed to define a set of indicators to monitor and measure these benefits. This knowledge could facilitate the allocation of public financial resources for its construction (Gordon et al., 2018; Vandermeulen et al., 2011). Furthermore, investment in green infrastructure could support the development of climate adaptation measures that might in turn reduce landscape associated risks (Demuzere et al., 2014; Gill et al., 2007).

Furthermore, to solve the territorial imbalances related to the equitable access to healthy environments, it is also necessary to implement education strategies that create socio-ecological relations based on the knowledge of its benefits in terms of risk reduction, climate change mitigation and biodiversity preservation (Ahern, 2014). This would help communities to protect and restore their landscapes because environmental education increases biological diversity knowledge and the capacity of communities to self-organise (Krasny & Tidball, 2009). In addition, a better understanding of socio-ecological processes amongst the professionals working in public spaces, water management and the environment would build institutional capacity to create more equitable and inclusive green infrastructure that is accessible to all while being economically viable and environmentally sustainable (Matthews et al., 2015).

Finally, there are two major limitations in this study that could be addressed in future research. First, the study focused mostly on the environmental corridor along the creek and the risk associated with floods and landslides. However, the environmental impacts and the socio-economics dynamics of the quarries were scarcely explored, as well as their potential ecological restoration. Second, the interviewee group had a limited representation of community leaders, though there were practitioners with significant experience in participatory projects. Nevertheless, further research could include focus groups with local inhabitants, community groups, and other

local organizations to explore how to coproduce spatial interventions for strengthening the relationship between the inhabitants and the creek.

## 7. Conclusion

This article contributes to the growing body of research on green infrastructure by exploring the challenges of its implementation in the specific context of informal settlements in the Global South, a context that has, hitherto, been barely addressed. The Limas Creek, in Bogotá, was selected as a case study because it has the potential to be the backbone of a network of natural and semi-natural spaces that could provide ecosystem services for Ciudad Bolívar, the poorest administrative area of Bogotá. Furthermore, upstream creeks in Bogotá face similar challenges to the Limas Creek regarding lack of infrastructure and environmental risks coupled with socio-economic problems. Despite the efforts of the local government to address these issues, findings of this study illustrate that there remain critical challenges to guaranteeing equitable access to green infrastructure in Bogotá. This is the result not only of informal urbanisation, but also of fragmented governance, political shifts and limited economic resources. This demands that policymakers should understand the potential for green infrastructure to play a strategic role in permeating and supporting all aspects of a community's daily living.

Findings of this study reveal how everyday practices constitute a form of dealing with the shortcomings of informal settlements' landscapes. Two types of practices have been identified around the Limas Creek. On the one hand, there are practices that reinforce the neglect of the creek through avoidance and disregard. These practices result from the characteristics of the built environment. Physical barriers, such as blind walls and wire meshes, coupled with social barriers such as insecurity, and increasing environmental risks, go hand in hand with the neglect of the landscape. On the other hand, there are practices that mobilise the community to care for the

creek through access and environmental awareness. Landscape care has the potential to be sustained in the long-term and empower the community to negotiate the barriers that undermine the values of natural spaces. Furthermore, landscape intervention could contribute to the building of identity and place attachment, factors strongly related to wellbeing.

This research, based on a content analysis of interviews with fifteen stakeholders, uncovered the different conflicts between landscape conservation, water management, governance and society. It established that the interviewees have different understandings of what constitutes green infrastructure, though the concept of Ecological Main Structure (EMS) is included in the official legislation. Therefore, green infrastructure as a multifunctional network of natural and semi-natural spaces and its potential to address climate change needs to be integrated into planning. Furthermore, the existing technical knowledge of public administration should be complemented with the understanding and implementation of landscape-based solutions to water management that are context based, address socio-environmental purposes and provide open public spaces for recreation and physical activity. Likewise, more research is needed to quantify the multiple benefits of green infrastructure in the local context to support public investment.

There is also a wide range of approaches regarding participation, but the agency of communities in the improvement of the built environment is often undervalued or ignored. Therefore, there is a need to transition from top-down participation towards co-production. Such transition should value the empirical knowledge of local communities and be complemented by environmental education programmes that engage more inhabitants in conservation processes. More research is needed to systematise the experiences of bottom-up and top-down public participation and to formulate strategies that facilitate co-production processes. In addition, there is a need to investigate how the ongoing actions of environmental groups could be harmonised with institutional programmes and the activities of other community groups and the private sector.

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**FIGURE CAPTIONS**

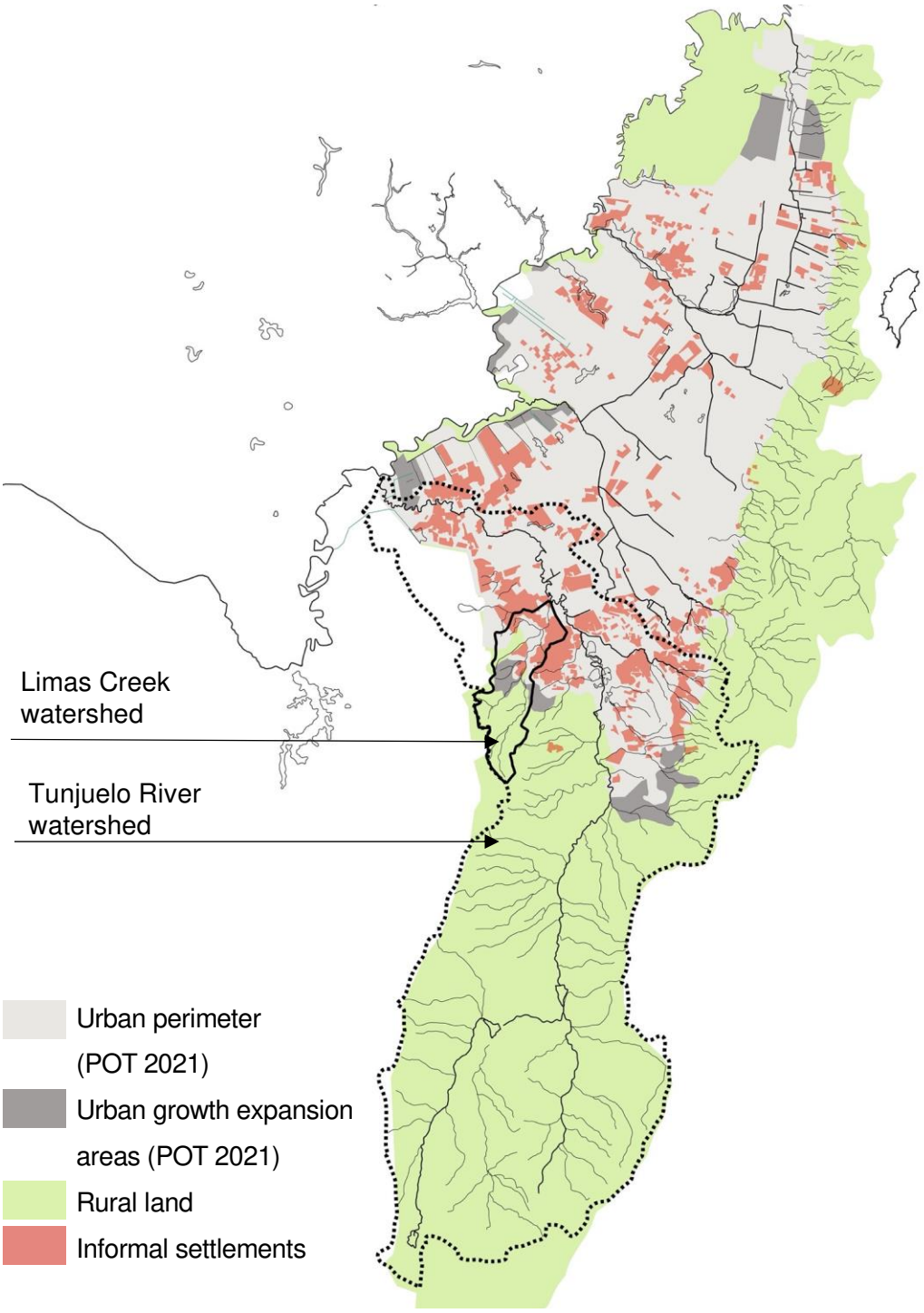


Fig. 1. Location of informal settlements in Bogotá in relation to the system of creeks and the urban perimeter. (IDECA, 2018).

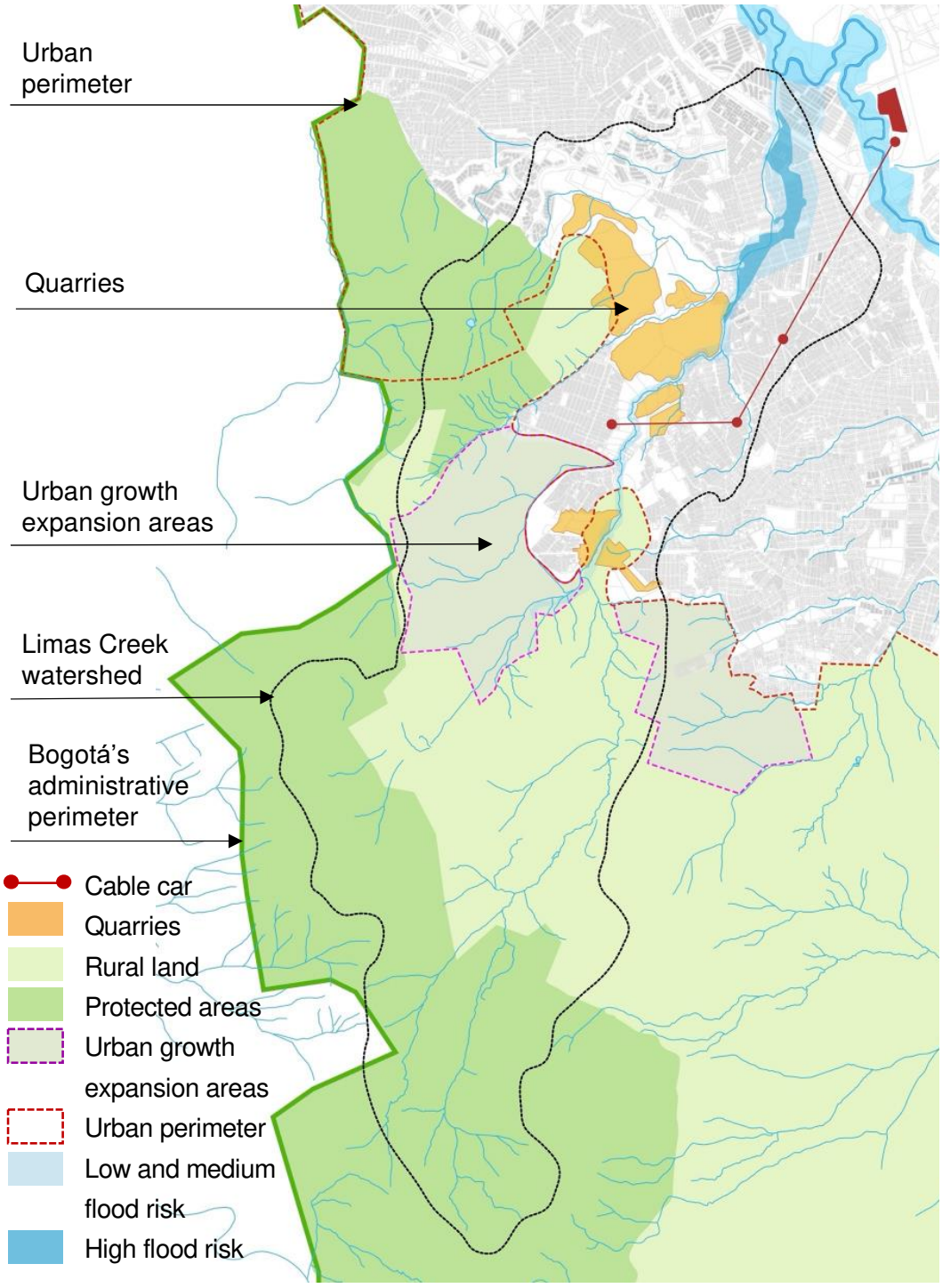


Fig. 2. The Limas Creek watershed. The map illustrates the transition between the urban and rural areas, the flooding risks and the location of active quarries. Base map based on IDECA

(2018). Urban and rural perimeters based on Secretaría Distrital de Planeación (2021). Flooding risks were taken from Rogelis (2009). Quarries areas based on Google Earth Pro (2020).

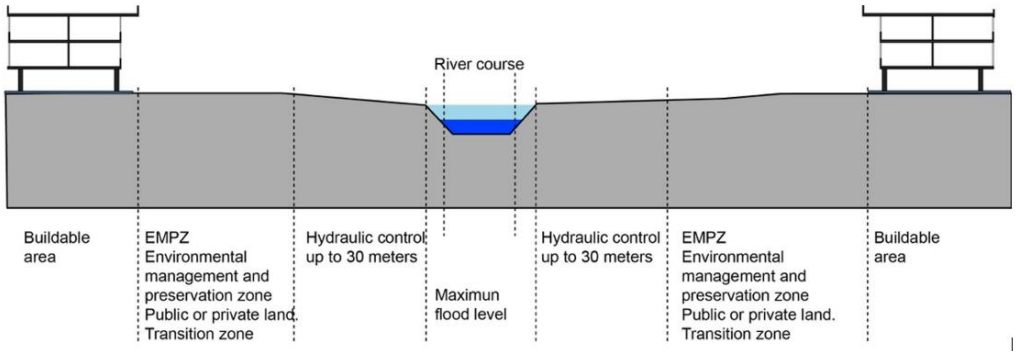


Fig. 3. Cross section of a river corridor. Drawn by the authors according to Decree 469/03.

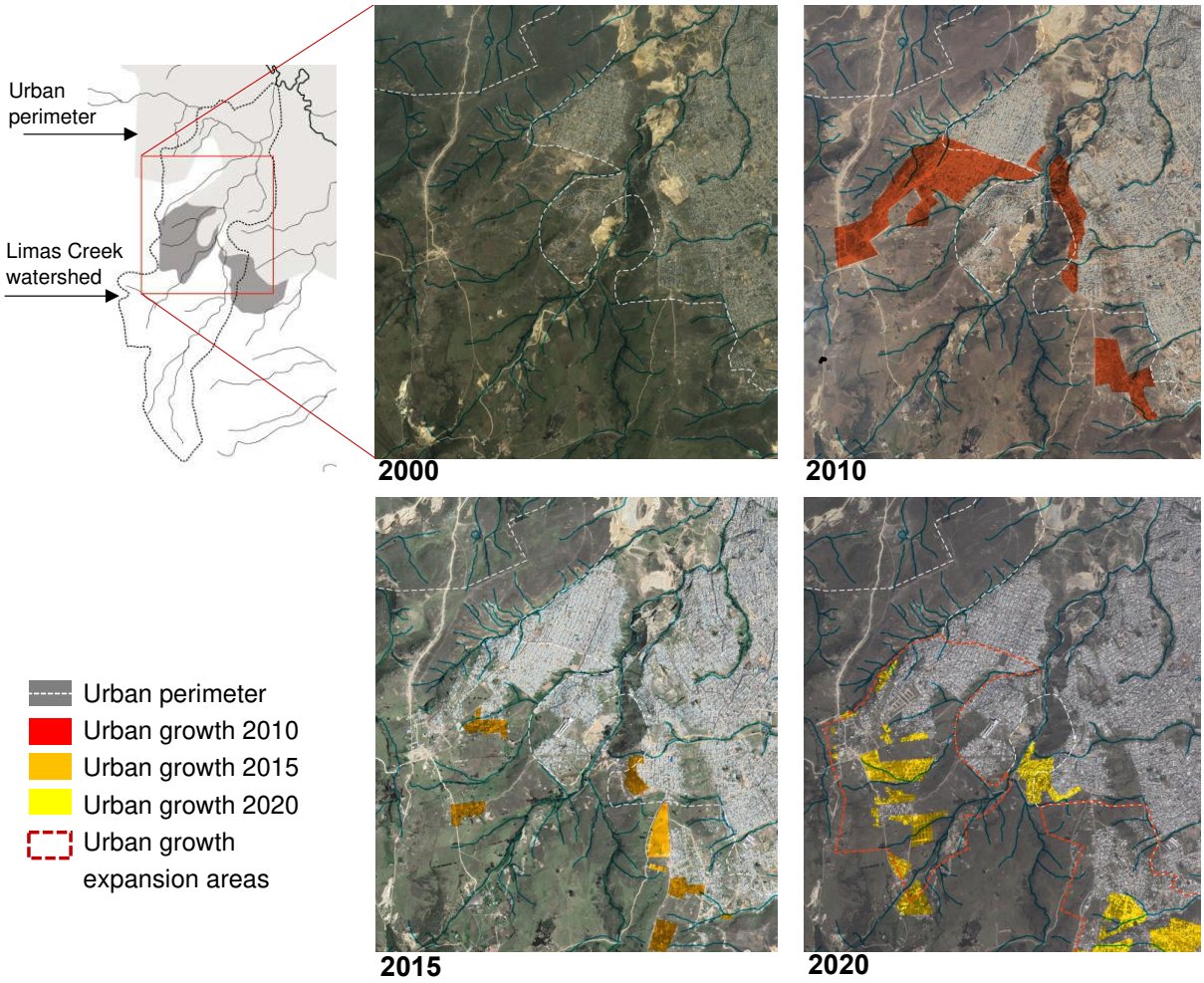


Fig. 4. Comparison of the growth of informal settlements beyond the urban perimeter of Bogotá, based on Google Earth Pro (2020). In 2021, the new POT included this growth within the new perimeter for urban growth expansion. Urban perimeter and expansion areas are based on Secretaría Distrital de Planeación (2021).

Fig. 5. A view of the lower section of the Limas Creek.

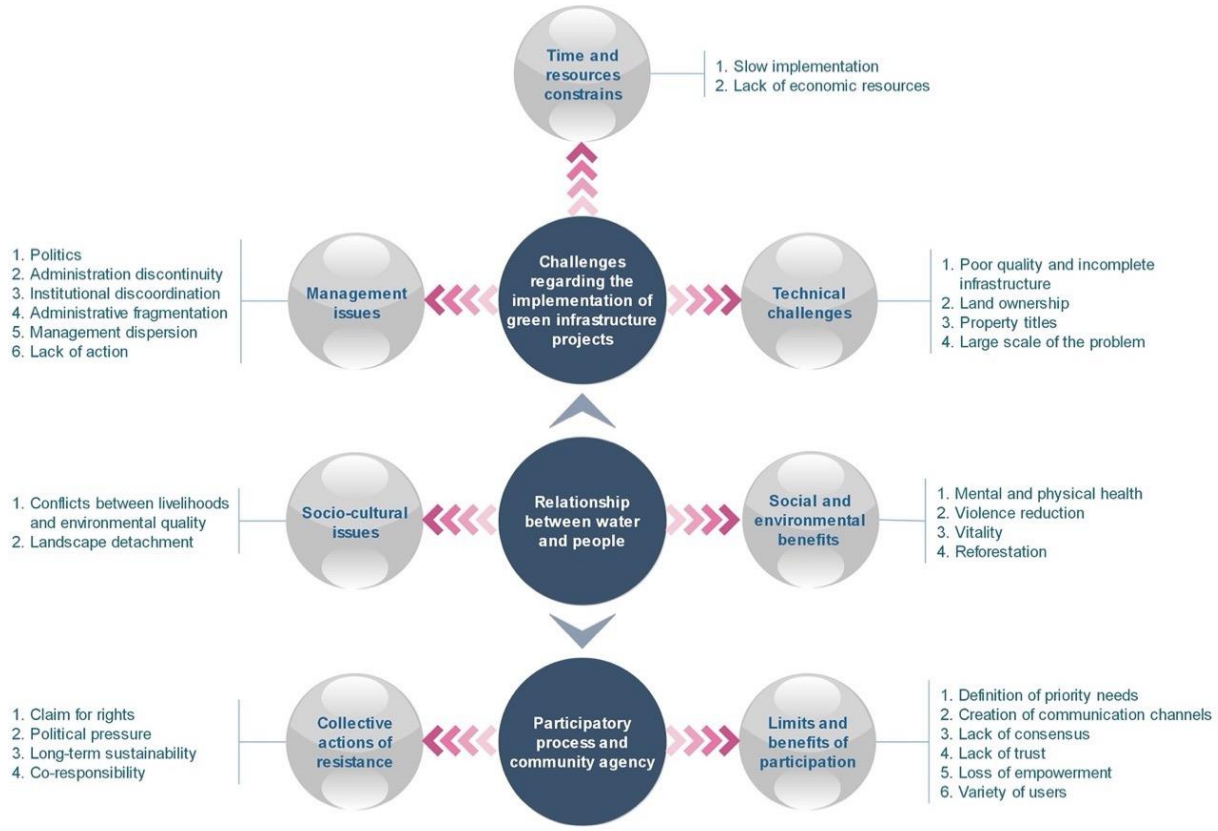


Fig. 6. Key themes that emerged from the content analysis of the 15 interviews with stakeholders.


Fig. 7. Land management by Bogotá's Water Company in 2019. The company buys private land and demolishes houses to build the Limas sewer interceptor.

Fig. 8. Boundary markers that delimitate the official limit of Environmental Management and Preservation Zone of the Limas creek.

Fig. 9. Landscape in the upper section of the Limas Creek (within urban perimeter).

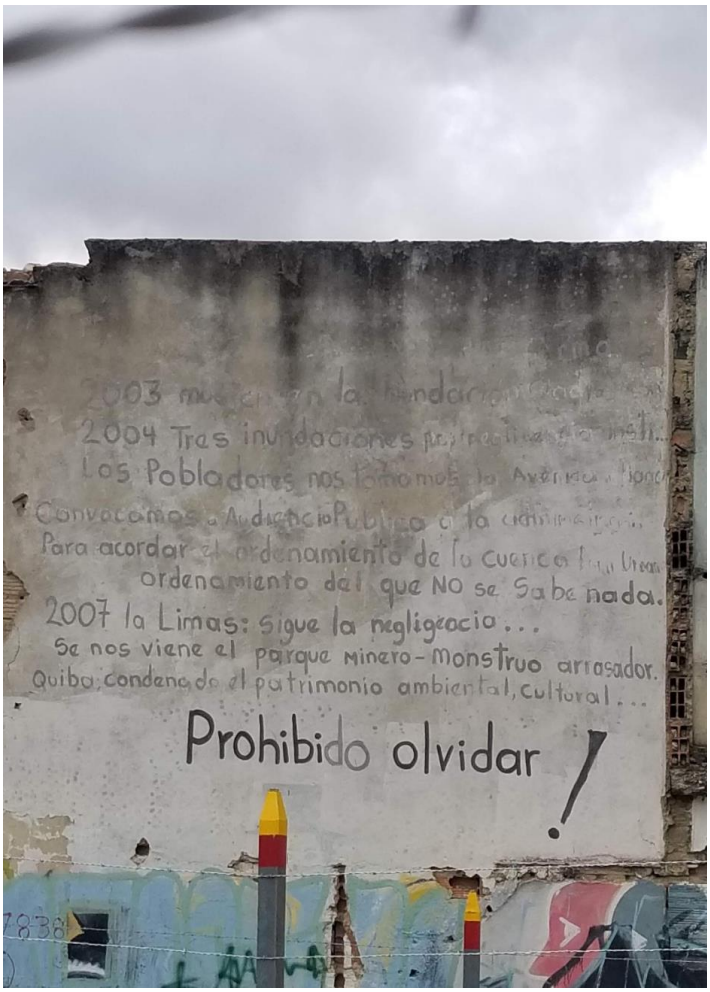


Fig. 10. Community mural to preserve the historical memory of the disasters along the creek. It contains a chronological list of floods and other risks, such as the opening of new quarries. The mural is titled ‘Forgetting is not allowed’.

Fig. 11. Self-build intervention along the Limas Creek.