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Seeing the city for the trees: Exploring naturescapes in present and future urban landscapes

A Case Study of Bogotá: Understanding imaginaries for how systems of nature-based solutions contribution to healthy, biodiverse, and resilient cities in urban landscapes

Hedda THOMSON EK

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Hedda THOMSON EK

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ABSTRACT OF THESIS submitted by:

Hedda THOMSON EK

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Nature-based solutions (NbS) are increasingly recognized in urban planning for their multifunctional roles in addressing urban challenges, promoting human well-being, supporting biodiversity and enhancing climate adaptation. To increase NbS transformative potential, it is essential to systematically upscale their implementation, and understand how they are interlinked as systems. However, there is a limited understanding of how NbS are linked across urban landscapes, and how imaginaries of transformative change can be considered in urban planning. This thesis explores how interconnected systems of NbS can be understood through the concept of "naturescapes", and how they are perceived to enhance human well-being, biodiversity, and climate adaptation over three time horizons in the case study of Bogotá. This is explored through 20 interviews with 14 actors, 5 documents, and a novel interactive visualisation exercise using an AI-moderated survey tool. The study identifies seven naturescapes: (1) main ecological structures, (2) wetlands, (3) urban forests and trees, (4) ecosystem connectors and green corridors, (5) urban agriculture, (6) sustainable urban drainage systems (SUDS), and (7) green roofs and vertical gardens. Based on lessons from the city-wide implementation of SUDS, the thesis discusses the potential for including futures-thinking into an early planning stage of naturescapes in cities. Findings highlight that community engagement, ecological connectivity, and flood mitigation, are amongst the most desired ecosystem services (ES) in the long-term future (2100). The thesis concludes by discussing considerations that should be made for implementing naturescapes in an urban landscape, emphasizing the importance of integrating future-oriented thinking into urban planning processes.

Keywords: Nature-based solutions, Naturescapes, Ecosystem services, Urban planning, Imaginaries, Futures-thinking, Transformative Change

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List of Abbreviations

ES: Ecosystem Services

NbS: Nature-based Solutions

MES: Main Ecological Structures

SUDS: Sustainable Urban Drainage Systems

ZIBO: Industrial Zone of Bogota (Zona Industrial de Bogotá)

POT: Bogota Land Use Plan (Plan de Ordenamiento Territorial)

1. Introduction

1.1 Background to research and problem definition

The rapid urbanisation occurring globally comes with a variety of urban challenges related to environmental degradation, biodiversity loss, and heightened vulnerability to climate change impacts, such as extreme weather events and urban heat islands. The increasing pressure on natural ecosystems and biodiversity conservation reduces nature's capacity to provide ecosystem services to urban inhabitants. The pressures of urban expansion are expected to continue growing in the future. over the coming decades, it is expected that 40% of ecoregions globally may fail to achieve the 2050 Biodiversity Conservation Goal, as a result of urban expansion (Ren et al. 2023). Biodiversity decline is a particularly pressing issue in countries with a lower level or governance, where low political stability reduces the effect of the conservation of key habitats. (Huang et al., 2018). The low access to open public spaces is particularly low in urban regions located in the global south, which is negatively impacting the quality of urban life (UN 2023). The Sustainable Development Goals stress the importance of conserving and restoring ecosystems, and the access to safe, resilient, and sustainable cities and settlements in the face of climate change. Furthermore, the Post-2020 Global Biodiversity Framework, adopted in 2022 in the Convention on Biological Diversity (CBD), sets out a 2050 vision, *"whereby 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people."* (CBD, 2022, page 7). To achieve these objectives and visions for the future, many actors call for a transformative change in the way we organise our societies, and recognise the need to better include natural elements in urban landscapes to make use of their many ecosystem services (IPBES 2019; E. Cohen-Shacham et al. 2016; Fedele et al. 2019). Rather than making small and incremental changes, transformative changes aim to fundamentally reorganise society on a system-wide level, through transforming paradigms, goals and values needed for the sustainable use of biodiversity and sustainable development (IPBES 2019; IPCC 2023).

Nature-based solutions (NbS) have received growing attention in both academia, politically and in practical urban planning due to their potential to address societal challenges while simultaneously strengthening biodiversity and improving ecosystems (Pineda-Pinto, Frantzeskaki, and Nygaard 2022; Bush and Doyon 2019). Through managing existing, modified or constructed ecosystems, NbS have a practical impact on urban systems, and facilitate transformative change which benefits both humans and biodiversity (Fedele 2019; Kabisch et al. 2016). However, while the transformative contribution of individual cases of NbS has gained more attention (Palomo et al.

2021; Gillard et al. 2016; Fedele et al. 2019), there is yet little understanding of the synergies and trade-offs of systems of NbS on a landscape level, here referred to as naturescapes. Furthermore, while literature emphasises the challenges with upscaling NbS (Emmanuelle Cohen-Shacham et al. 2019; Jeuken et al. 2023), there is a need to better understand how the concept of naturescapes can be applied to functionally linked systems of NbS, and how actors envision the socio-ecological transformative change that these systems can contribute to.

To address this research gap, this thesis will explore the NbS and naturescapes' potential for facilitating transformative change from a socio-ecological perspective, regarding three key urban themes: well-being and access to ecosystem services (ES), biodiversity and ecosystems, and climate adaptation. This will be explored by researching different actors' imaginaries of how NbS are functionally structured in systems in the current urban landscapes, and how they can contribute to the three urban themes, now and in the future.

This thesis will therefore explore the newly developing concept of "naturescapes" by exploring how actors perceive systems of functionally linked NbS now and in the future. This is done through exploring imaginaries of how NbS are perceived currently, and what role they can have in the future in facilitating socio-ecological challenges in the case study Bogotá, capital of Colombia. These perceptions are understood through exploring "imaginaries", which are commonly held values and visions, of naturescapes and their contribution to three major urban themes. The three urban challenges in focus of this study are: (1) contribution to the well-being and access to (cultural and provisioning) ecosystem services, (2) support of biodiversity and healthy ecosystems, and (3) resilience and climate adaptation. These imaginaries are explored through analysing policy documents, interviews and through using a novel survey approach using an AI-moderated survey tool, imaginaries for naturescapes in urban and peri-urban landscapes are identified and their contribution to the three major urban challenges, are analysed over three time-horizons, present, short-term and long-term future.

The outcome of this thesis will contribute to the academic understanding of how naturescapes can be applied in an urban context, and an understanding of how imaginaries can be applied in various time horizons. The research also contributes to the current understanding of future studies by applying a new conceptual framework and testing a novel methodological approach to research imaginaries by using interactive AI-moderated surveys. Finally, the results of this study can inform policymakers and practitioners on how futures-thinking and imaginaries potentially can be included in the design of naturescapes to benefit socio-ecological values in future urban development.

1.2 Research aim and objectives

The aim of this thesis is to deepen the understanding of how assemblages of nature-based solutions (NbS), referred to as naturescapes, can contribute to a transformative change of public urban and peri-urban spaces in a Latin American Context. The central objective of this thesis is to research contemporary and future imaginaries of naturescapes in an urban and peri-urban landscape to understand through an exploratory approach in Bogotá as a case study. As such, the study explores how contemporary naturescapes are formed and governed, and what barriers and opportunities various actors perceive regarding the current planning and implementation of NbS concerning three key themes: 1) well-being and access to ecosystem services (ES), 2) high status of biodiversity and ecosystems, and 3) climate adaptation. Furthermore, the thesis sets an objective to explore how actors perceive the role of these naturescapes to contribute to a transformative change of the three main themes in the context of Bogotá. Finally, the sets an objective to test a novel approach to understanding naturescapes and transformative through both conceptualising naturescapes within the realm of transformative change, and through a piloting methodology of using an AI-moderated survey tool to explore personal imaginaries.

RQ1 Present Bogota: How are naturescapes imagined to facilitate well-being, biodiversity, and climate adaptation, in present Bogota?

- **How can the concept of naturescapes be applied in Bogota, and what factors are considered in their application?**
- **How are naturescapes in Bogota perceived to contribute to well-being, biodiversity and climate adaptation imaginaries?**

RQ2. Future Bogota: How are naturescapes imagined to facilitate transformative change for well-being, biodiversity and climate adaptation envisioned, in future Bogota?

1.3 Thesis outline

This thesis is divided into eight chapters, in which the first and second give an introduction and overview of the literature on the urban development of nature-based solutions. The third chapter presents a conceptual framework based on naturescapes, futures-thinking and transformative change. The fourth chapter presents the research design, methodology and limitations of this study. The results are presented in the fifth chapter, divided into three subsections, each presenting the imaginaries for a different time horizon. Finally, the significance and practical implications of the results are discussed in the seventh chapter followed by conclusions and recommendations in the eighth chapter.

2. Literature review

2.1 Introduction review

To understand the context in which this thesis is set, there are many fields and realms of knowledge to consider. Firstly, the long-spanning understanding of the human-nature interaction is central to the understanding of NbS and naturescapes. Nature's contribution to humans is by no means a new understanding but has been recognised in traditional knowledge systems for much longer than the conservation concepts which have developed over the last century (Selin and Kalland 2003). The understanding of humans dependency on nature has contributed to conservation practices all over the world (Uprety et al. 2012; Kimmerer 2011). Learning from many traditional perspectives, the socio-ecological field in academia has over the last two decades increasingly begun to question the human-nature dualism, which is still a prominent worldview where nature and humans are viewed as separate systems (Haila 2000) and instead recognise the entanglement of humans and nature (Misiune, Depellegrin, and Egarter Vigl 2022).

Nature-based solutions have, on the other hand, developed, not as a value system or worldview, but as a response to thee need to simultaneously address societal issues and conserve nature. While now being applied globally, the concept of nature-based solutions emerged in the late 2000s, and was widely spread by the International Union for Conservation of Nature (IUCN), primarily to address societal issues linked to urban landscapes (E. Cohen-Shacham et al. 2016).

As the concept of NbS is getting increasing attention globally, it is therefore important to critically reflect over how the concept fits in to an arena of conservation which has in many parts of the global south been based on colonial structures. Many structures have been discussed to "decolonize nature" (Adams and Mulligan 2012), and to promote inclusive regenerative conservation in the global south (Kashwan et al. 2021; Choudry 2013). Arturo Escobar, a Colombian-American anthropologist, has over the last decades contributed valuable insights into the discussions of the field through his views on decolonising through discussing whose knowledge is considered in nature conservation (Escobar 1998). This becomes particularly important in the Colombian context, which not only has a wide diversity of ecosystems and biodiversity, but also of culture and ethnicities. The conservation efforts in Colombia are not only influenced not by local and regional actors, but are also highly influenced by international agendas, which makes it highly relevant to understand different views and discourses on conservation and resource management (Escobar 1998). Furthermore, Escobar points out that many of the current structures and practices in the global south are highly influenced by the historical Western-centred discourse of "development". Therefore, it is important to critically reflect on the implementation of

development practices and understand the current discourse of involved stakeholders, as well as understand "alternative visions for a postdevelopment era" (Escobar 2012). This thesis aims to contribute to this ongoing dialogue by understanding the current imaginaries of stakeholders involved in NbS development in Colombia now and in the future, and how naturescapes fit into this discussion. The focus of NbS solutions, a concept developed in a western-oriented worldview of nature, makes it critical to bear in mind the alternative world-views on nature, which does not easily fit into the application of NbS, but which still can contribute to its implementation through inclusive design processes. Furthermore, the developing concept of naturescapes can learn from the experiences of the implementation of NbS in different contexts, and recognise structures and knowledge systems which are more widespread in the global south by considering its context when the terminology is developed. The selection of Bogota as a case study thus attempts to understand how naturescapes can be applied in a metropolitan in the global south and to understand the dynamics which impact its implementation. As this chapter reviews the development of NbS-related concepts, the ongoing academic discussions of varying world views of the human-nature relationship, as well as colonial conservation structures, are critical to bear in mind.

2.2 Nature-based solutions potential in addressing urban challenges

Cities constitute the world's fastest-growing ecosystem, consisting where the hardening of surfaces, densification of residential and commercial buildings, and concentration of people have adverse impacts on the environment (IUCN 2020). The rapid expansion of urban areas is one of the most urgent stressors that have proven to negatively impact biodiversity worldwide (Fenoglio et al. 2021; Concepción et al. 2015; Elmqvist et al. 2015). As urban regions continue to expand the need to understand how ecosystem services are applied in urban context is a growing research focus. Several studies worldwide find multiple benefits restoring ecosystems in urban areas can provide both social, ecological and economic benefits (Elmqvist et al. 2015; De Bell, Graham, and White 2020). IUCN identifies three crises to which NbS can contribute: namely, the biodiversity crisis, the climate crisis and the inclusivity crisis. The biodiversity crisis emphasises the urgent need to protect biodiversity and ecosystems. With one million species of plants and animals being categorised as threatened or extinct globally, ecosystems provided by nature are rapidly declining. The loss of biodiversity and species not only compromises the heritage of nature but also its contribution to human well-being and quality of life (IPBES 2019). For an action to be classified as a NbS it must contribute to the maintenance or enhancement of biodiversity according to the IUCN standards. The second crisis recognised by IUCN is the climate crisis which is predicted to have devastating effects globally as the global temperatures continue to rise, and is recognised as

one of the main drivers for biodiversity loss in the future (IUCN 2020). The multifunctionality is considered critical to NbS actions, where social challenges such as the need for food security and climate mitigation, can be addressed while simultaneously increasing climate adaptation in vulnerable areas (IUCN 2020) Finally, IUCN points out an ongoing inclusivity crisis, noting that there is currently a lack of inclusivity in the design of actions addressing societal challenges. Further, the IUCN notes that conservation intervention success depends on the inclusion of various knowledge systems and actors, including indigenous people, local communities, women and youth. Therefore a diversity of stakeholders must be considered to achieve an inclusive process for NbS, and minimise "cultural bias and elitist perspectives" (IUCN 2020). While coming from vastly different disciplines, the Western-developed conservation discourse and traditional understandings of nature are converging in the interest of creating an inclusive process for conserving natural values, while simultaneously addressing societal challenges (IUCN 2020). This thesis recognises these crises and continues the discussion of the current debate forward through contributing to the understanding of how systems of NbS can mitigate these challenges. The three urban themes in the focus of this thesis, (1) Human well-being and equal access to ecosystem services (2) biodiversity and healthy ecosystems, and (3) resilience and climate adaptation, all connect to the three crises recognised by IUCN. While these topics crisis can be approached in different ways, it is important to recognise their interlinkage, and that addressing one of these challenges, will positively impact the others.

2.3 Ecosystem services & nature-based solutions in an urban context

2.3.1 Ecosystem services development and typologies

Nature's contribution to people is widely recognised as ecosystem services (ES). While the idea that natural systems support human welfare is an ancient understanding, the concept of ecosystem services emerged in the 1970s when humans' increasing impact on natural systems started to be discussed at a higher degree (Gómez-Baggethun et al. 2010; Johnston 2024). Despite there being several limitations to the concept of ES, such as how it can be used for the economic evaluation of nature, the concept has been used widely to increase the recognition of nature's contribution to humans, aiming at increasing the economic and social valuation of nature (Lele et al. 2013). A typology of ecosystem services which has been widely accepted is the four categories suggested by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005):

1) Provisioning services: Goods which ecosystems provide for human consumption and use, such as food and fresh water.

2) Regulatory services: Services which moderate or control conditions or processes, such as flood regulation, erosion regulation and temperature regulation.

3) Cultural services: intangible benefits supporting the health and well-being of people, such as aesthetic enjoyment or religious inspiration.

4) Supporting services: basic processes and functions which support the other three typologies, such as soil formation and nutrient cycling.

As urban areas continue to expand, there is growing literature addressing the need to sustainably manage urban landscapes to ensure the longevity of ES in urban environments, through supporting biodiversity while simultaneously creating resilient cities and promoting wellbeing. When applying ecosystem services in an urban context, research particularly finds challenges related to 1) spatial conflicts 2) fragmentation and altering of ecosystems, 3) environmental injustices, 4) path dependency in planning legacies and 4) misconceptions of urban disconnection from nature (Kabisch, Frantzeskaki, and Hansen 2022).

2.3.2 Nature-based solutions development and typologies

i. Development

Over the last decades, many typologies and concepts have developed, for actions which promote ES to address societal challenges in an urban context. To address urban challenges and deficiencies in natural structures, there is an increasing focus on how Nature-based Solutions (NbS) can contribute to ecosystem services in urban contexts. Nature-based Solutions (NbS) are defined by IUCN as *"actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"* (E. Cohen-Shacham et al. 2016). As such criteria for NbS, is that it provides benefits for biodiversity and well-being simultaneously (IUCN 2020). The concept focuses on the multifunctionality of nature to address multiple social, economic and environmental challenges and functions as an umbrella term for concepts related concepts of ecological conservation and management practices, including urban greening and ecosystem-based management (Dorst et al. 2019). As such NbS gathers an interdisciplinary perspective to address societal challenges. For example, the term can be conceived as an umbrella term for concepts such as green engineering (Vallero and Brasier 2008), natural solutions (Dudley 2010), green infrastructure, (Hanna and Comín 2021), Ecosystem-based Disaster Risk Reduction (Eco-DRR) (Wickramasinghe 2021) and Ecosystem-based Adaptation (EbA). Some of these concepts have a more specific focus on societal challenges, such as EbA, which aims to reduce vulnerability to climate change and increase the general resilience in society, through sustainable management, conservation and restoration of ecosystems (Colls, Ash, and Ikkala 2009). Much of the research on EbA in an urban context focuses on their ability to

reduce the impacts of heat and flooding through ecological structures such as green space, wetlands, trees and parks (Brink et al. 2016). There are however many constraints concerning the urban development of EbA, implementation and evaluation of EbA structures, including lack of funding, legal disadvantages and challenges with monitoring and managing the systems (Nalau, Becken, and Mackey 2018).

The wide arrange of concepts included in NbS has resulted in varying definitions and applications usage of the term (Sarabi et al. 2019; Dorst et al. 2019). Even so, research has pointed out many benefits of NbS, including urban health (Van Den Bosch and Ode Sang 2017), improve ecosystems and biodiversity (Marselle et al. 2019), and climate adaptation (Kabisch et al. 2016). Literature, however, also shows many barriers to the implementation of NBS such as lack of financial resources, path dependency in planning, institutional fragmentation, inadequate regulations, availability of land, and uncertainties regarding implementation processes (Sarabi et al. 2019). Kabisch et al. (2022) bring up a set of challenges for urban areas, including spatial conflicts, fragmentation of urban biodiversity, alteration of environments, multifactor interdependencies, environmental justice, path dependencies of planning, and disconnection of nature. To address these challenges, the authors developed five Mains to push the NbS discourse towards more sustainable, resilient urban planning, design, and development (Kabisch, Frantzeskaki, and Hansen 2022). These Mains build on multiple disciplines, including ecology, sociology, urban design, and governance, and interplay with each other:

(1) consider the need for a systemic understanding

(2) contribute to benefiting people and biodiversity

(3) contribute to inclusive solutions for the long-term

(4) consider context conditions

(5) foster communication and learning

These Mains can be equally important when assessing how NBS interact with each other in naturescapes and can help understand what elements of naturescapes can contribute to a transformative change.

ii. Typologies

To ensure that the increasingly used concept of NbS is used in similar ways, IUCN has developed a global standard for NbS, including 8 criteria. These criteria aims to ensure that NbS simultaneously contribute to both conservation and restoration actions to halt biodiversity loss, and that they simultaneously address societal challenges (IUCN 2020). Furthermore, the implementation of the standard aims to achieve a common understanding of the term which allow increased implementation of NbS in a systematic and coordinated manner across multiple sectors,

users, and geographies (IUCN 2020). Through these standards becoming an integral part in planning and implementation in the response to societal challenges, IUCN argues that NbS can contribute to transformative change. The criteria are:

1: NbS effectively address societal challenges

2: The design of NbS is informed by scale

3: NbS result in a net gain to biodiversity and ecosystem integrity

4: NbS are economically viable

5: NbS are based on inclusive, transparent and empowering governance processes

6: NbS equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits

7: NbS are managed adaptively, based on evidence

8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context

While not all NbS will fulfil all criteria on equal terms, balancing these criteria can provide insights into viable NbS options which can be upscaled, and as such have more impact (IUCN 2020). While it is not the only framework to assess NbS, scholars have found it to serve as a useful tool for multiple stakeholders (Berg et al. 2024). Others, however, note that the proposed NbS framework does not sufficiently address adaptive management, effectiveness, uncertainty, multi-stakeholder participation and temporal scale to the same degree as other ecosystem-based approaches (Emmanuelle Cohen-Shacham et al. 2019).

To distinguish between different typologies of NbS, Eggermont et al., (2015) have developed three typologies for NBS based on the level of modification of the ecosystem, and the amount of ecosystem services it provides. These are: 1) protection of existing ecosystems; 2) management and design of multifunctional landscapes, and 3) management and design of new ecosystems. The first type includes *better use of natural and protected ecosystems,* where no or minimal changes are made to the ecosystems. Instead, the objective is to maintain or improve the delivery of ecosystem services to extend beyond the preserved ecosystems (Eggermont et al. 2015). The second type includes *management approaches designed for the sustainability and multifunctionality of managed ecosystems and landscapes*, where the delivery of ecosystem services is improved in relation to conventional practices. This type includes, for example, the enhancement of tree species and agricultural crops' genetics and diversity to be more climate-resilient in the face of a changing climate (Eggermont et al., 2015). The third type involves the *design and management of new ecosystems*, where either ecosystems are managed intrusively, or new and artificial ecosystems are created (Eggermont et al., 2015). Examples include green roofs and walls, which contribute to biodiversity and carbon storage while regulating temperatures and cleaning polluted air (Eggermont et al., 2015).

The boundaries between the types are fluid, and recognizing hybrids of the types is important, especially on a wider scale. For example, Eggermont et al. (2015) note that mixing protected areas (type 1) and managed areas (types 2 and 3) may be necessary to provide multifunctionality and achieve sustainability. Furthermore, the development of type 3 NBS, such as an artificial wetland, may be managed and preserved as a type 1 NBS once they are established (Eggermont et al., 2015). Eggermont et al. (2015) note that synergies and trade-offs exist between ecosystem services and the expectations of actors when designing an NbS. Similarly, synergies and trade-offs must be considered on a city scale or landscape scale, which could be researched with naturescapes. This includes not only trade-offs between NbS but also between other types of spatial development, including technical solutions (Turkelboom et al., 2018). This leaves room for further research on how NbS can be systematically upscaled, and how they are considered as interconnected systems within cities and urban units of cities.

2.4 Scaling up Nature-based solutions

The need for a transformative change in urban and peri-urban areas has caused academic debate across multiple disciplines on how NbS can be upscaled feasibly. IUCN notes that NbS which are more aligned with the criteria of the standard have strong potential in scaling up the usage of NbS and identifying gaps to improve the NbS structures (IUCN 2020). When evaluating these standards, Cohen-Shacham et al., (2019) found that three of the suggested criteria are particularly important to consider as core for upscaling the implementation of NbS. These are: that NbS should be applied at a landscape scale, that NbS can implemented alone or in an integrated manner with other solutions, and that NbS are integral to the overall design of policies, measures and actions to address societal change (Emmanuelle Cohen-Shacham et al. 2019). The research in upscaling NbS ranges from understanding what typologies of NbS have the best potential for scaling up in various contexts (Cortinovis et al. 2022b) and understanding future scenarios which simulate full-scale implementation of different NbS strategies (Cortinovis et al. 2022a), to financial and governmental implications of upscaling NbS (Seddon et al. 2020; Tye, Pool, and Gallardo Lomeli 2022). To understand how NbS can be applied on a landscape level, landscape planning has become an increasing focus on how NbS can be widely implemented in urban landscapes as well as how landscape benefits from NbS (Tayefi Nasrabadi 2022; Albert et al. 2019). Despite the urgency of upscaling NbS, there is however little understanding about how NbS can be functionally linked and linked by governance across urban landscapes, and what synergies and trade-offs they bring when implemented as systems. Thus, there is a need to understand how NbS functions as a system across different scales. The term naturescapes is a newly introduced terminology which aims to address how assemblages of NbS generate synergies and trade-offs in defined geographical spaces.

Furthermore, the systematic upscaling of NbS calls for a need to discuss what areas should be prioritised, what criteria the selection of NbS should be selected on, and how we should take into consideration future challenges and visions in the planning for systems of NbS.

2.5 Contextual background of Bogotá

Bogotá is the capital of Colombia, the third most biodiverse country in the world, located at over 2600 meters above sea level, in the Tropical Andes Hotspot. The city has experienced rapid growth to its today over 8 million people, a population that where the population of the city has almost doubled over the last 30 years, whereas the surrounding areas of the city have almost tripled (Guzman, Oviedo, and Bocarejo 2017). Much of this growth has occurred with a lack of regional urban management, where, rather than being systematically planned with connectivity in mind, much of the city's infrastructure, housing and services have over the decades sprawled, many of which were informal, without sufficient involvement of the public sector, resulting in an expansion of informal settlements with low-cost housing without connectivity to electricity, water and other public services and infrastructure (Guzman, Oviedo, and Bocarejo 2017). The rapid growth has resulted in a number of environmental, social and economic challenges for the city, transforming natural ecosystems, polluting rivers and loss of extensive wetlands and forests that make out the region, compromising ecosystem services such as the provision of drinking water, climate regulation, as well as cultural ecosystems services related to recreation and well-being.

In the last decades, the importance of public space has been increasingly recognised in the local governance of Bogotá. As such Berney notes that local politicians and local planning and design units play a key role in shaping the urban public environment of the city (Berney 2010).

The land use plan for Bogotá (POT – from Spanish abbreviation) recognises multiple challenges with the continued planning for the Bogotá region (City Hall of Bogotá 2021). Firstly, the plan recognises the challenge of consolidating an efficient and responsible governance of the region that facilitates socially, economically and ecologically sustainable development. In a socio-ecological context, the plan stresses the need to respond to climatic emergencies and the loss of biodiversity and ecosystem services, and the urgent need to take action to promote the health and well-being of the region's inhabitants and *"all forms of life that share the districts territory"* (City Hall of Bogotá 2021). Furthermore, the plan recognises the challenge of providing sustainable living spaces, public services and public spaces which support the balanced development of the territory, while promoting economic competitiveness in the city by creating more jobs and income for its inhabitants and reducing poverty and inequity. Finally, the plan notes the challenges of governance and local administration, and a need to organise territories with better co-responsibility between

the institutions, particularly between authorities and inhabitants and relation between urban and rural space (City Hall of Bogotá 2021).

In recent years, much of the development of the implementation of Nature-based solutions in Bogotá focuses on Sustainable Urban Drainage Systems (SUDS), which are currently implemented at a wide scale in the city. The methodology for selecting areas of priority and sites for implementation of SUDS, considering both physical restrictions and the need for urban interventions (Jiménez Ariza et al. 2019). The development of SUDS in Bogotá is a response to the need to handle large quantities of run-off water to mitigate the risk of flood, as well as to improve the water quality (Jiménez Ariza et al. 2019). When looking at perceptions from key actors in a case study of Bogotá, Ortegtega, Rodríguez, and Bharati (2023) found that there are many both technical and institutional barriers to the implementation of SUDS systems in Bogotá, such as the operation and maintenance of the NbS structures, and unclear institutional responsibilities. However, the authors also show the potential of SUDS as a systematically implemented NbS, which goes beyond the key priority of storm-water management, such as the benefits of harvesting rainwater, improved health and well-being, and biodiversity augmentation (Ortega, Rodríguez, and Bharati 2023). Furthermore, Bogotá has been used as a case study for interdisciplinary research where spatial analysis and landscape design are combined to develop a methodology for selecting NbS for stormwater management based on needs and opportunities for providing ES.

Developing this framework further, researchers at Universidad de los Andes, are currently developing a methodology for recommendations on the selection of NbS in local urban scales to address key needs of ES in the planning units, which will contribute to valuable insights on how NbS can be systematically upscaled.[1] While there is increasing focus on NbS solutions in both academic and political agendas in Bogotá, as well as in Colombia, there is yet a limited understanding of how different actors perceive the synergies and trade-offs provided by ecological structures and NbS in Bogotá. In the context of Bogotá, the city would benefit from a better understanding of how their ecological structures apply as NbS, in the understanding of actors who are involved in developing solutions for NbS. There is also a limited understanding of how well the official guidelines for the city's urban development, align with personal imaginaries of the urban development that NbS and systems of NbS can facilitate.

[1] Personal correspondence with author.

2.6 Conclusion of literature and research gaps and justification

This thesis is situated in the nexus of the future-oriented development of nature-based structures and their capacity to facilitate transformative change of societal structures, and the recognition of historic colonial development-oriented structures' impact on the current structures of the global south. The need for urban transformation and the recognition of nature's contribution to humans has been discussed by an array of actors both in academia and by practitioners, which has increased the need for standards and frameworks for both nature's contribution to humans, such as the widely recognised concept of ecosystem services, and the development of nature-based solution as an umbrella term for a variety of ecosystem-based solutions. Nature-based solutions are increasingly recognised as a structure which can facilitate transformative change, however, there is less understanding of how this can be done systematically through systems of NbS. Furthermore, while the understanding of how NbS can be upscaled is approached from many disciplines, the concept of naturescapes is a newly developed concept, which therefore has not been applied to a metropolitan area. While there is an increasing interest in planning for NbS from a landscape perspective, and robust methodologies developed for scaling the implementation of NbS, particularly concerning SUDS, there is yet a need to understand how different actors identify and value different systems and structures of NbS in Bogotá. Finally, while there is a growing consensus from the conservation society and academics that a socio-ecological transformation is needed, there is yet little understanding of how imaginaries can be used to envision such change over different time horizons. This thesis aims to address these gaps by exploring how the concept of naturescapes can be applied in an urban landscape in Latin America. This will be done through, firstly, exploring imaginaries for the current understanding of how NbS can be functionally linked, and secondly exploring imaginaries for how naturescapes can facilitate transformative change in three urban themes now and in the future.

3. Theoretical Framework

The conceptual framework for this thesis draws on several theoretical frameworks which are established in various research. Through combining aspects of these frameworks, this thesis contributes to originality by trying to understand the transformative potential of using nature-based thinking in urban planning processes, and how it evolves in official and everyday imaginaries.

3.1 Naturescapes

While nature-based solutions are an ever more researched topic, they are usually looked at in isolation. Naturescapes is a developing concept to understand systems of NbS in any given geographical boundary. The term is proposed by a research project *Naturescapes*, defining it as *"the assemblage of NbS within a landscape whose character is the result of the action and interaction of natural and societal factors"* (Voytenko Palgan 2023).[2] The project recognises that there is a lack of understanding of the synergies and trade-offs that multiple NbS bring, and emphasises the need to understand who benefits from naturescapes and under which conditions. Taking a perspective on naturescapes, rather than individual NbS, allows an understanding of the role of collaboration and partnership in the successful implementation and upscaling of NbS and their impact (Voytenko Palgan 2023). The role of Naturescapes does not only relate to the individual installations of NBS structures but addresses the pressing issue of transforming to sustainable practices for land management, thinking of land as systems rather than individual entities. Understanding naturescapes' role in land management is important, not only to address pressing challenges that land use change and degradation have on biodiversity conservation, climate change, and livelihoods, but also to allow a just and inclusive management of socio-ecological systems.

This thesis approaches Naturescapes predominantly from a city-wide scale, to understand how different actors perceive major networks of NbS in Bogotá, and how they are, and potentially can be further, interconnected. The theory contributes to the framework through the conceptualisation of understanding the physical and social formation of naturescapes as systems of NbS structures, rather than looking at individual NbS structures. The focus of this thesis is identifying NbS structures which are

Figure 1. Visualisation of naturescapes in an urban landscape. Designed by author.

[2] Retrieved from project document in Naturescapes Project through personal e-mail correspondence.

functionally linked with various typologies of NbS where trade-offs and synergies of these typologies apply within the Naturescape. NbS is in this thesis recognised as actions and structures which are actively managed to simultaneously contribute to biodiversity or ecosystem processes while addressing societal challenges. Functionally linked naturescapes are considered systems of NbS which have similar typologies of NbS, or similar functions within one or within combinations of the types of NbS (type 1-3).

3.2 Transformative change

To address urban challenges many actors, call for actions which go beyond the incremental adjustment of society, and instead generate society-wide transformations. As such many disciplines gather in the quest to understand how transformative change can be framed in the context of sustainability, taking a central role in the global sustainability discussion. A variety of conceptual and theoretical frameworks have developed in an attempt to analyse transformative change and social transitions, such as socio-technical transitions, social-ecological systems, and transformative adaptation (Patterson et al. 2017; Gillard et al. 2016).

In the socio-ecological sphere, transformative change refers to systematic and fundamental changes in society and socio-ecological interactions that support biophysical systems while meeting human needs (Palomo et al. 2021; Patterson et al. 2017; Gillard et al. 2016). Recent research has explored the potential of NbS for transformative change in different contexts. For example, Palomo et al., (2021) found that NbS generally contribute to transformation through their combined ecological and social elements (Palomo et al. 2021). Frantzeskaki et al. (2021), for example, stress the importance of deep transformation to achieve urban sustainability, calling for systems thinking. Exploring how specific NbS interact in functional areas of naturescapes, and how they are governed, envisioned, and valued can provide a more systemic understanding of how transformative change for urban areas can be achieved.

To understand how transformative change can be assessed, Fedele et al. (2019) use six indicators of transformative adaptation to assess how socio-ecological systems have fundamentally changed (Fedele 2019). These indicators are: *1) Restructuring, 2) Path-shifting, 3) Multiscale, 4) Innovative, 5) System-wide, 6) Persistent.* When applying these indicators tob, Palomo (2021) found that NBS could achieve all these factors in various ways. For example, they bring up cases where *path-dependencies* shifted, where innovations were made in funding through supporting eco-tourism. *Multi-scale governance* has been applied, involving stakeholders at various levels in the design and governance of NbS, and system-wide thinking and landscape perspectives were applied to watershed restoration (Palomo, 2021). The last indicator, *persistence*, is difficult to evaluate for short-term projects. However, if NbS are embedded in the Mains of urban NbS, including co-design for long-

term application, context consideration, and communication and learning, it will provide a solid foundation for persistent solutions. Scaling up to the naturescapes perspective, adding the importance of robust and flexible structures, responsive to change in their surroundings becomes a particularly important factor.

3.3 Futures Thinking, Three Horizons Framework and Imaginaries

To understand the alternative pathways to transformative change, and what type of change we are working towards, it is important to understand how key actors perceive such a change. There are many frameworks which adopt various ways of visualising the future, four of which will be considered more closely in this thesis futures-thinking, imaginaries, Three Horizons framework and backcasting. Futures-thinking, takes into account a wide array of futures, distinguishing between possible, plausible, probable and preferable futures.

Imaginaries refer to a set of values, visions and beliefs, in which people imagine a concept or an alternative future. They are shaped by shared backgrounds through which we experience ourselves and our surroundings, as well as expectations regarding certain topics. While the concept of social imaginaries can be traced back many decades in sociology and psychology (Sartre 2010) it is a relatively new concept to understand topics related to sustainability and transformative change, and it is becoming a popular tool for understanding the shared values of our society, both now and in the future. In the context of environmental science, imaginaries have been used to understand both present ways to structure society and to visualise alternatives for responses to environmental challenges such as climate change and urbanisation (Levy and Spicer 2013; Paprocki 2020). There are many types of imaginaries, focusing on social imaginaries, sociotechnical imaginaries, and urban imaginaries (Hasenkamp and Sun 2023; Kaika and Swyngedouw 2014). Imaginaries are in this thesis understood as visions, values and ideas which are collectively held among separate actors or groups of actors about present and future societies. Here imaginaries will be used to explore contemporary and future values and visions of NbS and naturescapes in urban and peri-urban public spaces.

Another framework which aims at visualising rather than predicting is the Three Horizon framework, which is a pathway approach used to guide actors and practices with complex problems and handle uncertain futures. The framework aims to help develop future consciousness distinguish between incremental and transformative change, and explore how to manage transitions (Sharpe et al. 2016). The framework takes into account three Horizons. The first Horizon (short-term) represent the current context and conditions – focusing on maintaining stability – and representing the "business as usual" scenario. The second Horizon is the result of actions taken in the present to adapt to change and build change, resulting in a turbulent domain with transitional activities and innovations in a landscape facilitating a test-bed for the preferred future. The third

Horizon, constitutes transformative changes, or emerging transformative changes, entailing ideas about possible and preferred futures with a visionary mindset (Sharpe et al. 2016). The framework has been adopted in various contexts to co-create positive transformed futures in Anthropocene, and how these can be approached (Pereira et al. 2018; Fazey et al. 2020). Finally, backcasting is a planning approach, typically used to understand policy implications by defining a desirable future and working backwards to identify policies and programs which connect the preferred future to the present. The concept is useful for complex problems over long time horizons, impacting multiple sectors and levels of society, and where there is a need for major change as incremental changes are not sufficient (Dreborg 1996).

3.4 Conceptual framework

This thesis explores how imaginaries can be used to understand the potential of naturescapes in facilitating transformative change. This will be used through exploring the naturescape's contribution to three urban themes which are from here on shortened as: (1) Well-being and access to ES (2) Biodiversity and Ecosystems (3) Climate Adaptation. While the theoretical framework discussed above all contribute with valuable components none of them bring in all aspects of futures-thinking, transformative change and naturescapes. Therefore, this thesis applies its own conceptual framework to analyse and discuss the data for this thesis drawing on the theoretical frameworks of naturescapes, imaginaries, transformative change and three horizons approach.

Firstly, the conceptual framework takes off from the understanding of imaginaries as collectively held visions and values among multiple actors. These imaginaries can be both personally held (by individuals) or officially held (as expressed in official sources and processes). These imaginaries constitute a collective understanding of the world, as it is today, in the past or in the future. In this conceptual framework imaginaries are the glasses through which both naturescapes and their values are understood, as illustrated in Figure 3. In this thesis personal imaginaries of the present and future will be explored using interviews and an interactive visualisation exercise, further explained in Appendix B, while official imaginaries will be explored through document analysis. These imaginaries shape what makes a naturescape, as a social construct, and how they can benefit society, now and in the future, and facilitate a desirable transformative change. Thus imaginaries are at the core of this thesis, looking through the frame of naturescapes, to visualise a

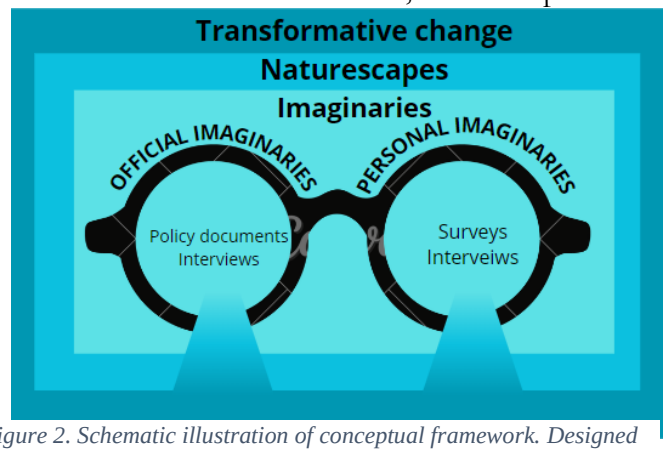

Figure 2. Schematic illustration of conceptual framework. Designed by author.

desired transformed future, as illustrated in Figure 3. In this study, such imaginaries will be explored as widely collectively held imaginaries for naturescapes across the three horizons, rather than trying to distinguish between imaginaries held by different actors.

Secondly, the conceptual framework recognises that actions and interventions, such as the implementation of naturescapes, can contribute to a transformative change in society, which goes beyond small and incremental changes. NbS's contribution to transformative change can be understood through the seven criteria applied Fedele et al., (2019) *1) Restructuring, 2) Path-shifting, 3) Multiscale, 4) Innovative, 5) System-wide, 6) Persistent* (Fedele et al. 2019). Furthermore, naturescapes specific contribution to transformative change in the socio-ecological sphere is in this thesis understood through its contribution to three urban challenges, which are hereon called "urban themes". The naturescape's contribution to these three themes is indicated through ecosystem services (ES) based on a modified version of the Millennium Ecosystem Assessment assessments typologies for ES as presented in Table 1. The ES are distributed within the three urban themes, where the first theme: well-being, and access to ES are linked to cultural and provisioning ES. The second theme, biodiversity and healthy ecosystems is linked to supporting ES and additional services for ecosystem connectivity, with additional categories for biodiversity (see table 1). The third theme, climate adaptation is addressed by regulatory services.

Table 1. Framework for urban themes based on ecosystem service indicators.

Urban Theme	Ecosystem Services address
Well-being and access to ecosystem services	• Food supply • Water supply • Raw materials, natural medicines and biomass • Recreation and physical activity • Aesthetics and inspiration • Education • Community engagement • Cultural heritage and spiritual values
Biodiversity and healthy ecosystems	• Water cycling purification and bioremediation • Air purification & photosynthesis • Disease & natural pest control and pollination • Well-connected green and blue corridors and connectivity for biodiversity • Ecosystems supporting native and endangered species • Ecosystems adapted and resilient to a changing climate • Soil formation, purification and nutrient cycling
Resilience and Climate Adaptation	• Temperature & humidity regulation • Green & blue carbon capture • Erosion & landslide prevention • Windbreak & wave break • Flood regulation and mitigation • Water cycling and drought prevention

Linking these concepts together, the conceptual framework uses imaginaries, as collectively held visions and values to understand 1) how naturescapes are perceived as functionally inked systems of NbS, and 2) how these naturescapes contribute to socio-ecological transformative change. The imaginaries thus look at how naturescapes contribute to three urban themes, now and in the future, and the transformation is the difference between those two imaginaries. Futures-thinking contributes to the notion that there are several possible futures which imaginaries can focus on. This thesis focuses on a desirable future, and thus a positive socio-ecological transformation.

To navigate the time perspectives, the conceptual framework adds a final element of a timeline on which stages of transformation are imagined. To understand the stages of transformation this framework takes in the perspective of the Three Horizon framework, which works with three-time horizons as demonstrated in Figure 4. The present time frame (1st horizon) constitutes of current understanding of NbS and naturescapes, and barriers and opportunities related to their current governance. The short-term future (2nd horizon) is applied to the near future, which falls within the current political and governing time horizon for which there exist plans to develop urban areas, such as (newly developed) land use plans spanning a decade into the future. The long-term future (3d horizon), looks into the future beyond what current political and institutional actions have

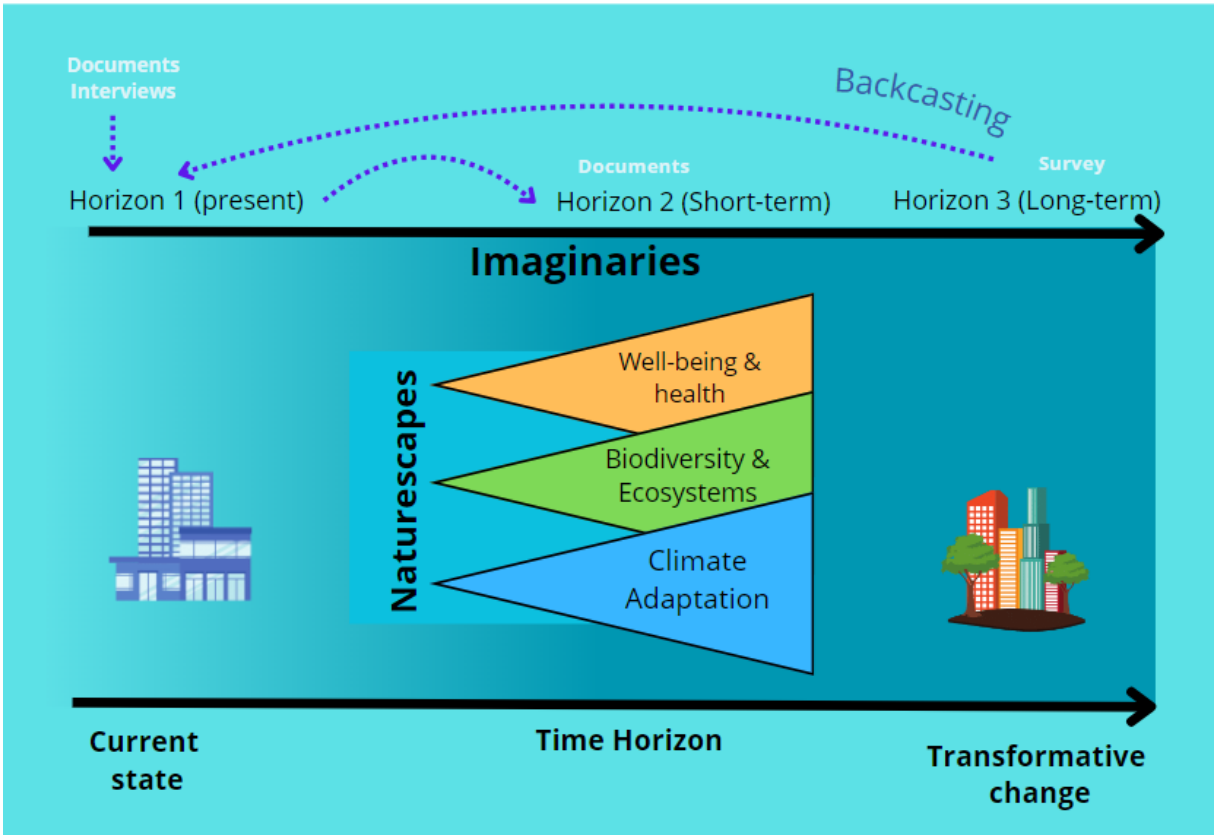

Figure 3. Schematic scheme of conceptual framework combining futures thinking, naturescapes and transformative change. Designed by author.

planned for, constituting a desired future of a socio-ecological transformative change. While the first horizon will be understood through current perceptions among people and plans, the second horizon is understood through future-looking plans. The third horizon is understood through backcasting, where a preferred future is presented, where NbS are effectively and plentifully providing ES accessible on equal terms. Through input from participants on how this was achieved through the lens of naturescapes, we can understand imaginaries for how naturescapes provides these services in the future, but also perceptions about how to get there.

4. Methods/approach

4.1 Research Design

This study investigates key actors involved with NbS in urban planning imagine systems of NbS, referred to as naturescapes, in urban and peri-urban areas, and how they can facilitate transformative change in three urban themes: well-being and access to ecosystem services, healthy biodiversity and ecosystems, and climate adaptation.

The study adopts a qualitative-method approach to capture participants' views through interviews and surveys. Qualitative research aims to explore and understand the meaning of individuals or groups to social or human problems through gathering data from participants, which is typically analysed inductively within set themes (Creswell and Creswell 2018). To contribute to the objective of this thesis, three main sets of qualitatively collected data; document analysis, interviews and surveys, to contribute to the triangulation of the data and improve the validity of the research (Creswell and Creswell 2018). In addition, field visits were conducted on-site to generate observational elements for the study. As such the definition of naturescapes, and the value it contributes with to humans in terms of ES now and in the future, is a subjective perception that may change over time, while the ecological contributions may remain more objective.

Furthermore, this research springs out of a social constructivist worldview, where an individual seeks to understand the world they live in and apply subjective meanings to their experience (Creswell and Creswell 2018). As such the research does not imply that there is a pre-decided "truth" to the aims of this research, but that the meaning of the topic is developed by the experience of groups and individuals participating in the study. The study also recognises that the conducted research impacts its surroundings through dialogues and cause for reflection, and therefore does not exist in isolation from the research topic. This is adopted through using the case study Bogotá, an approach which is commonly used to develop a theory, or test concepts, and to which understanding and analysing the context of the case is crucial (Perri and Bellamy 2011). To test the developed conceptual framework, the research takes on elements of grounded theory design, where interactions with participants contribute to the refinement of the categorised information (Corbin and Strauss 2015). Bogotá is used as a case to understand how the objectives of this thesis apply in a metropolitan area in the Andes.

4.2 Data collection and analysis

To achieve this objective, three sets of data are used to map current naturescapes and understand how public, private, and non-governmental actors perceive opportunities and barriers with their current structures, and how they imagine that they can facilitate transformative change in the future. This is done through three levels of analysis, for the three different time horizons.

4.2.1. First level of analysis: Horizon 1 (Present imaginaries)

In the first level of analysis, the current understanding and imaginaries of how naturescapes can be applied in Bogotá was established using two main sets of data: document analysis and interviews. Firstly, a rapid literature review was conducted of academic literature, reports and policy documents which could inform what types of NbS have developed in Bogotá. This resulted in the identification of 6 main policy documents, which were translated into English using the translation software DeepL, skimmed to see their focus on planning and implementation of NbS in Bogotá, where additional documents of interest were detected and translated. Out of 8 reviewed documents, 5 were selected for more in-depth analysis (Tables 2 and 4). The document analysis focused on the current presence of NbS in Bogotá, and how they were potentially functionally linked, along with what ES are recognised for the various naturescapes. The document analysis consisted of an inductive coding of themes within the deductive framework of the three urban themes: well-being, biodiversity and climate adaptation.

Table 2. Policy documents for the first level of analysis.

Policy Document (English title)	Policy Document (Spanish title)	Reference
Bogotá Land Use Plan	POT - Plan de Ordenamiento Territorial	City Hall of Bogotá. 2021.
Vegetated Infrastructure Technical Guide	Guía Tecnica Infraestructura Vegetada	Marcela Reyes, Diana 2019
Public Food and Nutrition Security Policy for Bogotá: Building Food Citizenship 2019-2031	Política Pública de Seguridad Alimentaria y Nutricional Para Bogotá: Construyendo Ciudadanía Alimentaria 2019-2031'	District Planning Secretariat.
A Multicriteria Planning Framework to Locate and Select Sustainable Urban Drainage Systems (SUDS) in Consolidated Urban Areas	-	Jiménez Ariza, Martínez et al., 2019

Secondly, a stakeholder analysis was conducted to identify key actors involved in the planning and implementation of identified NbS in Bogotá. Further contacts to interview were attained through the snowballing method where interviewees recommended specific persons to contact within previously identified institutions, or suggested new institutions. 20 interviews were conducted with 14 actors across 3 sectors, public institutions (6), academic institutions (including research institutions) (4), private institutions (including urban planners) (2), and non-governmental organisations (2), some of which were consulted multiple times for following up on previous

interviews as new material emerged (Table 3). The interviews ranged from 50 – 80 minutes and followed the general themes of an interview guide developed before the interviews attached in Appendix A. The interviews were transcribed using an online transcription software (TurboScribe) and analysed through inductive coding using the coding software NVIVO (version 14). The inductive themes were thereafter clustered into common themes participating into common themes. The identification of NbS and potential naturescapes and opportunities and barriers governing them. (Horizon 1) and perceptions about naturescapes potential contribution to transformative change among three urban themes (Horizon 2). Additionally, publicly available environmental data from the District Environment Secretariat was utilised to generate maps, to understand the geographical boundaries of the identified naturescapes and visualise them (references in 8.3). For each dataset, the naturescape's contribution to ES within the three main themes was determined. For each theme, the naturescape was given a weight depending on whether the objective of the naturescape was to contribute to one theme in particular, or if the benefits were fairly equally distributed. The results for the naturescapes were summarised in tables, presented in the results section and supported in the text.

Table 3. Interviewees for Bogotá Case Study: Academia (AC), Public Sector (PU), Private Sector (PR), Non-Governmental Organisation (NG), Urban Developer (UD)

Key Actor	**Sector**	**Interview Code**	**Department**
University of the Andes	Academia	AC1	Department of Civil and Environmental Engineering
University of the Andes	Academia	AC2	Department of Civil and Environmental Engineering
Universidad of the Andes	Academia	AC3	Department of Architectures
ICESI University	Academia	AC4	Sustainability Master's Program
Urban renewal and development companies in Bogotá (RenoBo)	Public institution	PU1	Planning Department
District Environment Secretariat	Public Institution	PU2	Eco-urbanism and environmental businesses
Urban Development Institute (IDU)	Public Institution	PU3	Planning Department
Botanical Garden of Bogotá	Public Institution	PU4	Biologist, Wetland and Native Species
National Business Association of Colombia (ANDI)	Private Institution	PR1	National Centre of Water and Biodiversity
World Resource Institute (WRI)	Research Institute	RI1	Cities4Forests
Humboldt Institute	Research Institute	RI2	Centre of Nature-Based Solutions
Conservation International (CI)	Non-Governmental Organisation	NG1	Water and Cities
World Wildlife Fund (WWF)	Non-Governmental Organisation	NG2	Cities Program
ZITA	Urban Developer	UD2	Architecture

4.2.2. Second level of analysis: Horizon 2 (Short-term imaginaries)

For the second level of analysis, 2 public documents containing visions of how identified NbS and naturescapes will be used in urban planning in the near future (2030-2035) were analysed. Two documents were consulted as official imaginaries for the planning for naturescapes contributing to transformative change in a short timeframe (until 2030-2035). This was done through analysing the future objectives of the POT (until 2035), and a case study of an urban renewal program (ZIBO) planned to be transformed until 2035. The understanding of documents was complemented by the interviewee's perspectives on how naturescapes are currently involved in urban planning for facilitating urban development in the time horizon until 2035.

Table 4. Policy documents second level of analysis.

Policy Document (English title)	**Policy Document (Spanish title)**	**Author**
Bogotá Land Use Plan	POT - Plan de Ordenamiento Territorial	City Hall of Bogotá. 2021.
Technical assessment of Strategic Action ZIBO, Bogotá Industrial Zone	Actuación estratégica ZIBO. Zona industrial de bogotá.	Bogota District Planning Secretariat. 2023

4.2.3. Third level of analysis (Horizon 3 – Long-term imaginaries)

Finally, the long-term imaginaries of the city were analysed by conducting an interactive visioning exercise. All participants who took part in interviews were offered to participate in the survey which was tested on four people with expertise on NbS and climate adaptation before being sent out to the 14 participants, out of which 10 responded to the survey. The survey was designed using an AI-moderated survey tool powered Wondering © which services were offered for free to test in a research approach. Here a backcasting approach was used where the participants were presented with scenarios of the future state of Bogotá (2100) where the city had been transformed to contribute to ES identified for each urban theme. The participants were asked to describe how NbS supported this vision, what actors had been involved, how it was financed, and what challenges had to be overcome. The survey focused on the case study of the renewal project in Bogotá, for which pictures were provided which the participants which the participants could anchor their imaginaries. The results from the survey were compiled through inductive coding, which were then deductively categorised for each theme. For more detail on the survey design and discussion of usage, see Appendix B.

4.3 Limitation and validation

4.3.1 Limitations in data collection

The data was collected through multiple means of analysis, each of which has limitations. Firstly, semi-structured interviews were collected on-site and online with a variety of actors, which typically lasted an hour. While providing extensive information, the time limitations do not allow exhaustive research of the actor's perception of the topic. Furthermore, most interviews were conducted in English, being both the researcher's and participant's second language. As such there are limitations to the freedom of expression and risk for misinterpretation. To limit these implications, the participants had the option to conduct the interview in their mother tongue (Spanish), for which a translator participated, and the transcript was translated, alternatively, the participants could access the interview questions in Spanish prior to the interview to allow them to look up any terminology they feel they might be lacking. As such the language barrier may have limited the possibility for participants to express themselves, however, it is not considered to have caused any major implications for the results. For the document analysis, most documents which were available in Spanish were translated by an AI software tool, where the software kept its original layout, and read and analysed in English. The translations therefore do not always capture all the nuances of the language, and expressions which are phrased in the original language. However, the reports were mostly informative rather than descriptive, and as the analysis focused more on the content rather than the discourse, this is considered to have limited implications for the results.

Finally, the survey was sent out to all participants of the interview of which 10 out of 14 completed the survey. The extent of the survey allows for a more detailed insight into the participant's perceptions, however, it also risks the participants to answer with less engagement towards the end of the survey. Furthermore, as the survey tool is a novel methodology which has not been tested in research before, the user experience and potential technical errors could compromise the results. To understand to what degree the user experience impacted the results, the participants filled in a user experience question in which they could comment on their experience using the survey. As all participants gave positive feedback (average X out of 10), the user experience is not considered a main limitation of this paper. The survey allowed participants to speak or write in their preferred language and was automatically translated to English, in which language it was analysed. The translation may loose some nuances, however, given the informal language, no major implications were observed.

4.3.2 Limitations in generalisation of results

The results of this study can give a unique insight into how the concept of naturescape can be adopted in an urban and peri-urban setting. Using a case-based approach, the research follows the concept implication in a Latin American context, specifically in the context of the Andean Metropolitan city of Bogotá. Furthermore, the research gives insights about how actors involved in the planning and development of NbS in Bogotá perceive their current and future role in the specific context. The results support barriers and opportunities found in literature both for the specific context and more general. However, both interviewees, surveys and document analysis are limited in scope due to time restrictions for this thesis, and thus, inherently contain limitations in the degree it can be generalised over the actor group, over the city, and over metropolitan areas of different contexts. Furthermore, it is important to note that the actors participating in this study does not represent the demography of Bogotá, nor does it necessarily represent the actor groups that are involved in this study. While the interviewees covered several actors, there are many more perspectives from both public, private, non-governmental and civil society which could have been valuable to the perspectives of this study. As such, the results can indicate the implications of adopting a naturescapes and imaginaries framework into a Latin American context, however, the geopolitical and cultural context differs in high degree between various contexts, and can not be expropriated directly into other Latin American contexts. While the results indicate that there are many common elements of how various actors, the representative sample is not wide enough to make out different imaginaries among different stakeholders, and as such only collectively held imaginaries are explored.

4.4 Research ethics

This thesis follows the form of ethics which has been approved by Central European University. While the participants of the study are kept anonymous, their participation is not considered to be harmful to them or their surroundings, nor are the implications of this thesis considered to impact them negatively. The participants were all informed of the aim of the study, and their voluntary participation and right to withdraw at any time. The participants all signed consent forms, which extent can be seen in Appendix A. This research included two months of fieldwork collecting data in Bogotá, Colombia which was funded by the Open Society University Network (OSUN) through their Graduate Research Mobility Funding Program and from the Environmental Department of Central European University.

5. Results and discussion

This section presents imaginaries for naturescapes current and future contributions to three themes in the urban and peri-urban landscape of Bogotá. This is understood through an analysis of how naturescapes are imagined to contribute three urban themes: (1) Well-being and access to ES (2) Biodiversity and Ecosystems (3) Climate Adaptation now and in the future. These imaginaries are explored through document analysis, interviews and surveys. The findings are presented in chapters divided by the three time horizons for which imaginaries are researched; present, short-term future and long-term future. The first section (5.1) addresses the first research question*: RQ1 How are naturescapes imagined to contribute to well-being, biodiversity, and climate adaptation, in* ***present*** *Bogota?* This is done by firstly identifying seven naturescapes in Bogota (5.1.1), and thereafter analysing their contribution to the three urban themes (5.1.2), and the considerations for implementing naturescapes (5.1.3-5.1.5). The following two sections address the second research question: *RQ2. How are naturescapes imagined to contribute to transformative change for well-being, biodiversity and climate adaptation envisioned in the* ***future****, in Bogota?* This is done by first analysing short-term imaginaries (5.2) and thereafter long-term imaginaries (5.3). Each chapter briefly discusses the main conclusions and the relevance and validity of the results.

5.1 Present imaginaries of Bogota (Horizon 1)

To understand what naturescapes are in the context of Bogotá, and what values they are imagined to bring to society in the future, we must first comprehend how the concept of naturescapes can be applied to Bogotá and what contributions are recognised in official and personal imaginaries. This section presents the results of the current understanding of functionally linked Nature-based Solutions (NbS) in Bogotá, here referred to as naturescapes, as derived from 20 interviews and an analysis of four policy and technical documents. The interviews include public, private, and non-governmental actors who have all been involved in the implementation, planning, and/or research on NbS in Bogotá. The primary document analysis includes the Bogotá Land Use Plan, which guides the development of urban planning in Bogotá from 2022 to 2035. Where there was insufficient information, additional sources were consulted through cross-referenced documents from the Land Use Plan and online data sources. To easily track the sources of data, the referenced articles are included with footnotes. In this section, the gathered imaginaries from the sources present seven naturescapes and their contributions to the three socio-ecological themes in focus in this study. The presentation of the naturescapes is complemented by an in-depth case study of the development of the naturescape of Sustainable Urban Drainage Systems (SUDS) in Bogotá. Finally, reflections on barriers and opportunities are discussed.

5.1.1 Identification of Naturescapes

While the understanding of ecosystem services and their benefits is well-established in Bogotá and Colombia, the concept of Nature-based Solutions (NbS) has only gained prominence in recent years. Consequently, one of the main challenges in implementing NbS in Bogotá is the varying definitions and interpretations of what constitutes an NbS. Here naturescapes are defined as systems of NbS which are functionally linked, through the individual NbS that they are made upon. This is based on how the individual NbS' are designed, how intrusively they are managed (type 1-3), and the specific characteristics of the typologies of the NbS. The NbS that were mentioned in interviews and documents were categorised according to their type as identified by (Eggermont et al. 2015).

Type 1: Natural structures with no or limited management, for example, include Main Ecological Structures (MES), which are protected natural ecological structures (both abiotic and biotic) around the region, such as mountains, and forests, as their ecosystem services are primarily linked to their natural characteristics. Type 2: Natural structures that are managed to provide multifunctional ecosystem services, include Urban forests and trees, as they are ecosystems managed to enhance certain services, such as recreation for city residents. Type 3: Intrusively managed and artificial ecosystems created to generate ecosystem services, including Sustainable Urban Drainage Systems (SUDS) are examples of type 3 naturescapes, as they are structures designed to provide specific services through the use of natural elements.

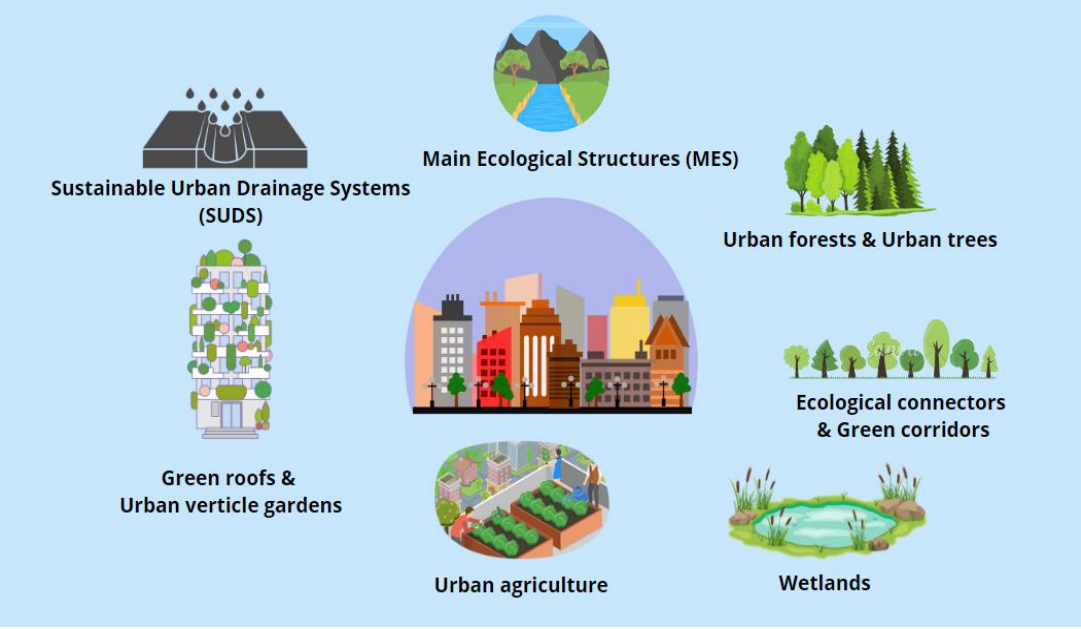

Figure 4. Seven functionally linked naturescapes identified in Bogota. Figure made by author.

Within the types, the NbS were separated based on their characteristics. For example, both SUDS, and Green roofs and vertical gardens, are made up of type 3 NbS, however, their typologies

and main contributions of ecosystem services differ from each other. Similarly, both wetlands and Main Ecological Structures (MES) are natural ecosystems (Type 1), but their natural characteristics and the scope of NbS differ, making them two separate systems. While the suggested naturescapes are arranged in systems, they also have overlapping sub-systems and can be considered in different hierarchical structures. For example, wetlands are NbS which are also included in the Main Ecological Structures (natural wetlands) in the peri-urban landscape of Bogota, as ecosystem connectors in the urban landscape of Bogota, and as SUDS (artificial wetlands). These naturescapes also differ in terms of governance, where some are linked by governance – such as the governance of Urban forests and urban trees are tied to specific institutions, whereas other naturescapes do not have a clear governance framework, such as Green roofs and Vertical gardens, which despite being included in greening policies, are implemented by both public and private actors.

5.1.2 Naturescapes description

i. Main Ecological Structures (MES)

The Main Ecological Structures (MES) are natural ecological structures around in Bogota region outside of the urban area, including both biotic and abiotic elements such as mountains, wetlands, rivers, parks and areas with high drainage capacity in protected areas.[3] The MES is recognised as a system in the Bogota land use plan (POT), and makes out the basis for environmental conservation and management of natural resources in the Bogotá capital district. Their preservation aims at sustainability preserving, conserving, restoring and managing renewable resources in the region which the plan recognises to support the socioeconomic development of the population.[4] The POT place a particular focus on improving the ecosystem connectivity between the elements of the MES, on a regional, district and local scale.[5] In particular, they are framed to have an important function in urban-rural borders, for example through the elements of edge parks in the peri-urban area. Through further improving the quality of, and connecting, urban, rural and regional ecological structures, the land use plan wants to achieve *"more harmonious and sustainable conditions between the city and its rural surroundings"* and improve the quality of life of its current and future inhabitants.[6] This connection emphasises a desire to distribute the benefits of the ecosystem services of the area equally, not only with a focus on the rural area where most of the services can be found but for all the people living in the region. For example, the MES provide provisioning service of the district's water supply, which is addressed as a focus of the MES on a regional level, which along with other

[3] See more information on what areas are included in Appendix C.
[4] POT. Article 41. Definition of the Principal Ecological Structure - PES. (p. 84).
[5] POT. Article 4. Guiding principles of territorial planning. (p. 48)
[6] POT. Article 5. Land use planning objectives. 1. (p. 51)

ecosystem services should benefit all inhabitants in the region.[7] The Main Ecological Areas can expand over time, for example through compensation projects generated in or adjacent to the MES, to compensate for urban renewal projects in Bogotá, with the purpose of increasing its area, connectivity, and improvement of ecosystem services.[8] The structures included in the MES are managed by both public and private entities. Most of the terrestrial areas are governed by The District Environmental Secretariat, whereas most water structures are governed and managed by the city's Water Company with technical assessments carried out by Bogotá's Water and Sewerage Company. Also, other institutions, such as the District Institute of Risk Management and Climate Change (IDIGER) are involved through carrying out ecological, social and hydrological studies in the area.[9] Most protected areas are regulated under an Environmental Management Plan,[10] and guided by the Environmental and Natural Resource Protection Policy which *"seeks to protect Bogotá's landscapes in order to improve the quality of life of its inhabitants as well as the quality of urban and rural ecosystems."*.

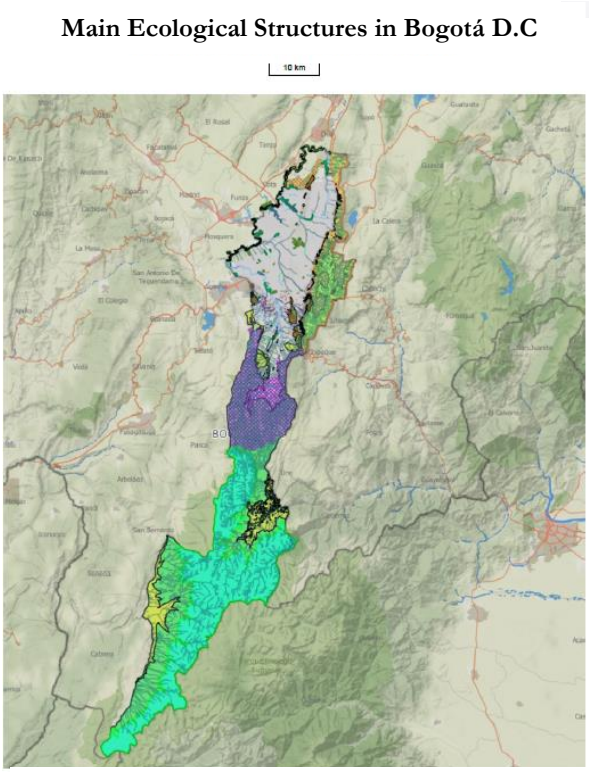

Figure 6. Geographical extension of Mian Ecological Structure (in colour). Map based on data from the District Environment Secretariat. 2024.

Figure 5. Highland wetlands, Paramos, (above) and the mountain landscape (bottom) Bogota, are two Main Ecological Structures. The author's own picture.

[7] POT. Article 7. Regional Elements of the Land Occupation Model. 2. (p.52)
[8] POT. Article 73. Public areas resulting from compensation or cession in areas of the Main Ecological Structure. (124)
[9] POT. Article 65. Criteria for the demarcation of water courses. (111)
[10] POT. Environmental Management Plan (Article 10 of Law 388 of 1997.)

Contribution to urban themes

Well-being and distribution of Ecosystem Services: The wide extent of MES offers abundant cultural and provisioning services to the region. Interviews particularly emphasise the importance of the ecological structures for provisioning and cultural services, with emphasis on the water supply to the region which is almost exclusively dependent on the highland wetlands, Paramos. Nature's contribution to human health and well-being is widely recognised both in the POT and among interviews. Furthermore, the natural areas around Bogota are invaluable areas for recreation, and physical activities, such as hiking, biking, learning activities and eco-tourism. The MES is recognised in the POT as both a tangible and intangible natural and cultural heritage which *"makes up the identify of the territory*", particularly naming ancestral trails and historic roads, border parks and rural nodes. [11]

Biodiversity and Ecosystems: The biodiversity and ecosystem connectivity that is generated through the MES supports the region with an array of ES. [12] The MES hosts biodiversity in the region through its varied and unique structures, making out habitats for several species which are endemic to the region, and supporting migrating species. The MES binds together a variety of ecosystems and allows for species to migrate and travel, finding food and refuge. Additionally, both documents and interviewees recognise their importance in providing many supporting ecosystem services such as air purification, nutrient recycling and clean retention and purification. The POT notes that *"conserving ecosystemic processes that hosts biodiversity in order to guarantee ecosystem services offered to the city."*[13] Biodiversity is recognised and its ecosystem services are addressed as a key measure to improve the resilience in the region, and its adaptive capacity.[14]

Climate adaptation: MES are recognised in the POT as natural buffer zones, which improve functions of ecosystems, they contribute as an ecosystem-based adaptation to risks of hazardous floods and mass movements, while contributing to the provision and regulation of water.[15] The permeable soils of the MES retain water and reduce flooding in and around the city. While some ecosystems are degraded and planted with exotic species, protects the soil from erosion and reduces the risk of landslides. Furthermore, the MES retinas water and promotes temperature regulation. The land management plan also recognises a need to further adapt the areas included in the MES to contribute to its preservation and manage further risks of forest fires and landslides. [16] The natural systems within the MES are also an important subject for mitigating the risk of forest fires. Interviewees note that the recent forest fires and drought in Bogota (as of spring 2024) have caused

[11] POT. Article 7. Regional Elements of the Land Occupation Model. 17. (p.52)
[12] POT. Article 4. Guiding principles of territorial planning. 2-10
[13] POT. Article 42. Strategies of the Principal Ecological Structure. 1. (p. 86)
[14] POT. Article 17. Territorial Measures for Climate Change Mitigation and Adaptation. 2. (p. 68)
[15] POT. Article 17. Territorial Measures for Climate Change Mitigation and Adaptation. 2. (p. 68)
[16] POT. Article 52. Sustainable Landscapes. (p. 95-98)

a lot of debate on the need for further climate adaptation measures in Bogota. The POT promotes the implementation of strategies which promote the preservation, restoration and management of protected areas, with a particular emphasis on the importance of consolidating a system of ecological connectivity in the region to promote climate adaptation. [17]

Table 5. The Main Ecological Structures (MES) contributions to three urban themes derived from document analysis and interviews.

Well-being and ES	• Quality of life • Natural and cultural identity of the territory. • Water supply • Food supply • Productive raw material (e.g. forestry products) • Improving human-nature relationships • Recreation, inspiration and learning • Ecotourism
Biodiversity & Ecosystems	• Ecological connectivity • Habitats and food sources for biodiversity • Ecosystems for native species. • Nutrient recycling • Water retention and purification • Air purification • Support biodiversity which contributes to climate adaptation.
Climate adaptation	• Flood reduction through soil permeability. • Reduced erosion and landslides through soil protection • Temperature regulation • Reduced risk of forest fire

ii. Wetlands

Wetlands are considered by both interviewees and the POT as an ecological system which contributes to ecosystem services such as climate adaptation, recreation and support of biodiversity. [18] Several interviews share that wetlands hold a particular value in Bogotá's conservation efforts, both due to its multiple ecosystem services and due to the notion that most of the area where Bogotá is located used to be a wetland. Out of the 17 recognised wetlands in Bogotá's Urban region, 12 make out an Urban Wetland Complex which is recognised in the Ramsar list of wetlands of international importance (Ramsar 2024). PU4 notes that the wetlands differ greatly in their construct and function. Whereas some wetlands remain with a natural structure and host many species, other are urbanised. *"They do a canalization and a little lake, an artificial lake that has the other type of concept of urbanism, all the wetland. And the others are very natural."*

[17] POT. Article 17. Territorial Measures for Climate Change Mitigation and Adaptation. 2. (p. 68)
[18] POT. Article 56. Regime of uses of the District Wetland Reserves. (p.102)

Currently, the management of wetlands focuses on monitoring, ecosystem restoration, recovery, and rehabilitation, which has a shared responsibility between Bogotá's Water and Sewage Company, District Environmental Authority and Bogotá's Botanical Garden. However, while many efforts have been made in the last two decades to conserve and restore the wetlands, many remain in poor conditions due to poor water conditions. Many wetlands are in poor conditions due to an overload of nutrients and sewage discharge, and features which are unfavourable for biodiversity, such as steep edges, and the spread of invasive species. The Botanical Garden of Bogotá is currently testing biofilters and "floating wetlands" to improve the water quality in the wetlands.

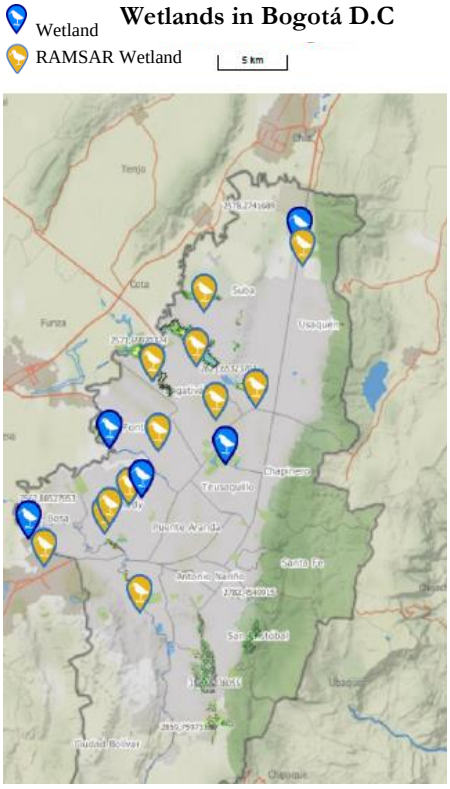

Figure 7 Wetland in Bogota (Ramsar and non -ramsar). Data for map retrieved from District Environmental Secretariat. 2024.

Many interviewees note that there is a strong community engagement in wetlands, working for their improved water quality, and conservation through the implementation of biofilters and maintenance of nurseries. Many wetlands are, however, considered unsafe, and are therefore fenced off and closed times of the day. The POT strives to minimise the amount of enclosures to increase the connectivity of wetlands, for both ecological and human benefits.

Many interviewees note that one of the most important actions for wetlands is to connect them, not only within the city but also with other NbS such as SUDS, and with other natural water systems such as the highland wetlands, Paramos. While several interviews note that there are a lot of community engagement and civil action in preserving Bogotá's wetlands, many note that there is less done for the highland wetlands: the Paramos ecosystems, but that they are equally important for providing ecosystem services to the city. PU4: *"For the Paramos, there exists a little information about that. So, I think that the government do some things, but it's necessary to do more and to maintain this type of program in the time. To have a better understanding of the process. Not only one point, but to understand how the system functions. The water from Bogotá and how the system functions."*

Due to the rapidly growing city, much wetland has been compromised and built on. This both compromises the ecological functions of the wetlands, as well as creates infrastructure in flood-prone areas. To address this development projects which overlap with wetland areas must be done in such a way that it does not alter the watercourse, and has sufficient flood prevention. Additionally, the infrastructure projects should compensate with the aim to recover the ecological

and functional connectivity of the ecosystem that was lost, considering its contribution to resilience, mitigation and adaptation to the effects of climate change.[19]

PU4 notes that apart from conserving the wetland, the most important action is to connect the wetlands, not only within the city but equally with water structures outside the city. To do this, there is a need for more information and knowledge on how different water systems are linked.

Contribution to urban themes

Well-being: Wetlands function as recreational spaces, with the potential for environmental education, research and learning. The POT promotes that more activities should be carried out in wetlands for education, research, and monitoring. activities in the area of environmental education, research and monitoring. In addition to this, the POT recognises wetland's potential for providing nurseries, ecotourism and contemplation along with conservation activities.

Biodiversity: Wetlands are recognised as one of the most important ecological structures for biodiversity, both flora, native species and migrating birds. To improve the state of wetlands for biodiversity, PU4 notes that it is important to not only think about the wetland structure, but also about the ecosystems surrounding the wetlands and connectivity with other ecosystems. For example, many birds in wetlands thrive when there are trees and urban forests surrounding the wetlands.

Climate regulation: Wetlands are recognised as important ecological structures for *"structural risk reduction measures"* which maintain and adapt to water flows and mitigate floodings in the city (Ramsar 2024). With increasing precipitation, several interviewees noted that wetlands are important to the city's resilience to climate change in the future. PU4: *"In the context of the change climatic, we are feeling the increase of raining in some periods and the decrease of raining in some periods here in Bogotá. So I think these spaces are important for regulating this type of volume of water that comes in this period."*

Table 6. Wetlands contributions to three urban themes derived from document analysis and interviews.

Well-being and ES	• Well-being and recreation • Education and knowledge
Biodiversity & ecosystems	• Support of native species (flora) • Resting spot for migratory birds • Endemic species • Improving water quality
Climate adaptation	• Flood prevention • Water cycling and regulation

[19] POT. Article 56. Regime of uses of the District Wetland Reserves.

iii. Urban forests and Urban trees

Urban forests are groups of trees (clustered or linear) with interlacing or overlapping crowns and differential plant composition, where native and natural species are intermixed in various sizes. [20] While the occurrence of Urban Forests are limited to a few spaces in Bogotá the occurrence of urban trees is widespread in the city (seen in Figure 8). The District Secretariat of the Environment and the Botanical Garden are in charge of the identification, and inventory of the Urban Forests and Urban trees. [21] The structure is included in the design for parks, green areas and playgrounds to provide multifunctional ecosystem services and provide public meeting spaces by both public and private actors.[22] For public spaces provided by private actors have less hard regulations in providing urban forests.[23] Furthermore, the entities are in charge of planning and conceptualisation of potential areas where urban forests can be suitable in the future, prioritising areas with deficits in cover and poor environmental quality which need improved access to ecosystem services.[24] This work should be paired with the development of management instruments in the areas, and guidelines, criteria and designs for what forest typologies are suitable in the area, and how they should be managed and monitored. This should be integrated with the current information in the Information System for Urban Tree Management (SIGAU), for identifying socio-ecological

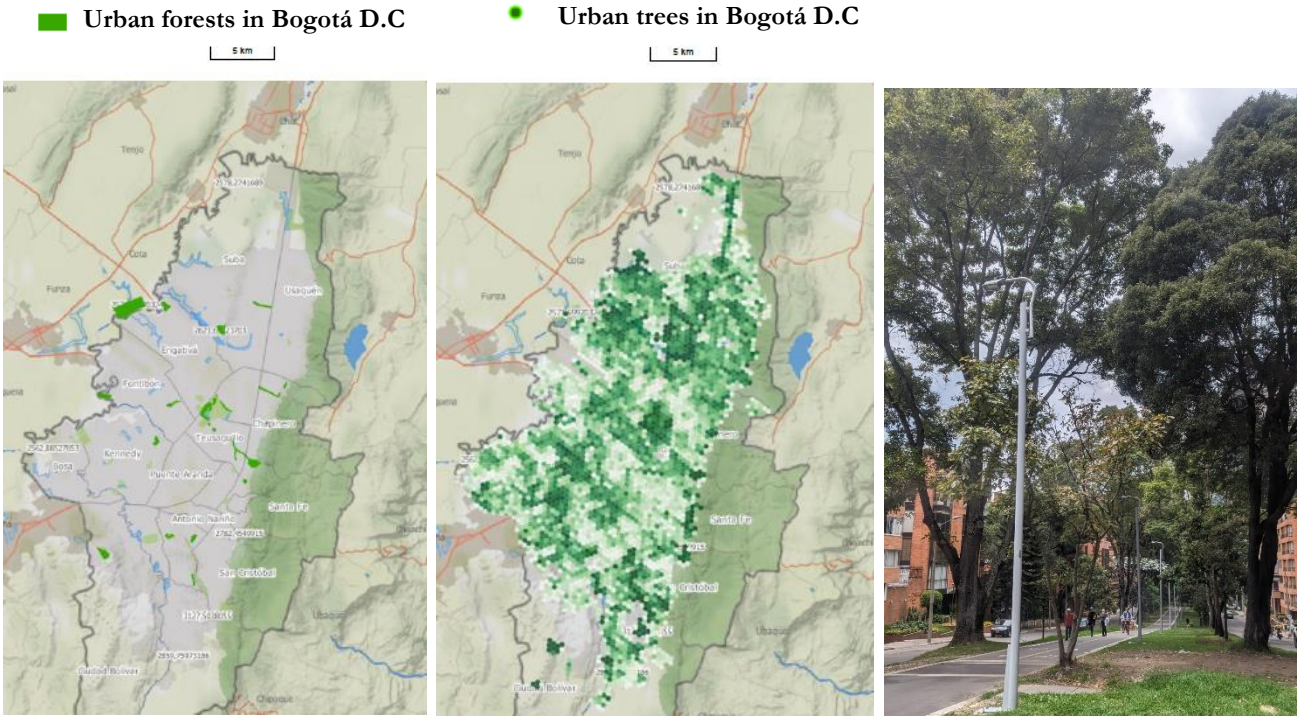

Figure 8. Map of the geographical distribution of urban forests (left) and urban trees (middle). Photo of an urban forest corridor in Chapinero district in central north of Bogota. Maps generated from data from District Environmental Secretariat and authors own ohoto. 2024.

[20] POT. Article 126. Design indexes for the elements of the public pedestrian and meeting space system. (p153)
[21] POT. Article 71. Areas of Climate - Resilience and risk protection. (p. 123)
[22] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[23] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[24] POT. Article 130. Consolidation of urban forests. (p. 157-158)

contributions of Urban Forests.[25] New instalments of infrastructure should be compatible with the presence of urban trees.[26]

Apart from increasing the quantity of Urban Forests and Urban Trees, and increasing their connectivity, Ac4 notes that the composition of the species used has to be shifted more towards native species, AC4: *"We think is that urbanization is reducing the diversity, especially in the introduced species compete and displace the native species."*. AC4 notes that native species, more than exotic ones, support interactions between species, increase carbon sequestration, and function as pest control. AC4: *"When you think about carbon sequestration, native species can provide better benefits in terms of carbon sequestration."*. Also, the diversity of species can help ensure natural pest control, AC4: "*We are disrupting interactions between, herbivores and their natural biocontrol or natural predators, the insect like parasitoids and predators insect interaction. So I would recommend in the cities, try to avoid planting trees of the same species close to each other."*. Pest control can also be reduced through better management of individual trees, by giving them more space on the streets, and not putting concrete around them, something which would increase permeability and reduce the stress for the trees. AC4: *"Bogotá and Latin America cities are full of concrete. But what happened with that? Well, the runoff increased, we have a lot of flooding in the cities. But then also, you are reducing health for those trees. So you can see how trees on sidewalks are more vulnerable to pests. Why? Because they are growing under stress conditions."*

Contribution to urban themes

Well-being: Urban forests provide recreation and well-being to people's mental and physical health, support natural and cultural heritage, and improve the air quality and quality of the landscape.[27] POT promotes to "*make nature visible in the city"*, and thereby contributes to meeting spaces in public spaces, and climate mitigation.[28]

Biodiversity: Urban forests are aimed to be managed both in current Main Ecological Systems, as well as restored in in other areas to promote high biodiversity, favouring native species which are integrated to the "socio-ecological dynamics of the city".[29] Public spaces should promote increased vegetation cover with support for native species of varying ages, incorporating both fast and slow-growing species for a varying dynamic.[30] Some interviews note that the Urban forests are especially practised around wetlands and water bodies, where they are considered extra important for supporting biodiversity. The POT strives for Urban Forests to increasingly contribute to

[25] POT. Article 71. Areas of Climate - Resilience and risk protection. (p. 123)
[26] POT. Article 153. General guidelines for intervention in public space for mobility. (178)
[27] POT. Article 126. Design indexes for the elements of the public pedestrian and meeting space system. CI. (p 153)
[28] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[29] POT. Article 130. Consolidation of urban forests. (p. 157-158)
[30] POT. Article 128. Guidelines for the management of private spaces for public use. 2c-f. (p.156)

multiple benefits for biodiversity such as nesting for birds, and wildlife rescue.[31] It also contributes to air quality improvement.[32]

Climate adaptation: Urban Forests are brought up as a climate adaptation measure by providing shade[33] and through their ability to protect and bind soils [34]. , and climate adaptation and regulation, through providing shade. The POT and the CAP aim to increase the presence of green cover and urban trees to increase urban environmental quality and soil permeability to regulate the hydrological cycle, reduce surface runoff and regulate heat island effects in some sectors of the city.[35] [36]

Table 7. Urban forest's and urban tree's contributions to three urban themes derived from document analysis and interviews.

Well-being and ES	• Well-being and recreation • Sports and recreation (mental and physical health) • Quality of landscape
Biodiversity	• Support of native species (flora) • Nesting for birds • Wild-life rescue • Improve air-quality • Strengthening of ecological connectivity • Natural pest regulation
Climate adaptation	• Temperature regulation (shade) • Erosion control • Flood regulation

iv. Urban Agriculture

The POT promotes the development of urban agriculture and agroecological food production models in urban spaces, using a range of technologies, which should not disrupt interactions with ecosystems. Urban and peri-urban agriculture is included in the guidelines for the Principle Ecological Structures, where agroecological activities should be used as a model of food, allowing organisations and neighbouring communities to implement agricultural systems towards food sovereignty. These practices should take advantage of waste and optimise resource use, while not disrupting interactions with ecosystems.[37]

As examples of agricultural systems which can be used in urban and peri-urban spaces, the POT brings up vertical agriculture, biointensive systems, floating root systems, raised bed production, regenerative agriculture and family agriculture. The management of these production methods should consider the use of biological fertilizers, and bio-controllers.[38] It's use is seen particularly

[31] POT. Article 126. Design indexes for the elements of the public pedestrian and meeting space system. CI. (p 153)
[32] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[33] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[34] POT. Article 71. Areas of Climate - Resilience and risk protection. (p. 123)
[35] POT. Article 17. Territorial Measures for Climate Change Mitigation and Adaptation. 2.5 (p-69)
[36] POT. Article 71. Areas of Climate Resilience and risk protection. (p.123)
[37] POT. Article 125. Related services and activities in the public pedestrian and meeting space system. 8. (150)
[38] POT. Article 42. Strategies of the Principal Ecological Structure. (p.86)

compatible with public parks, in "zones for enjoyment" which focus on restoration and rehabilitation of ecosystem recovery, while providing enjoyment, recreation and learning experiences to the public.[39] The use of urban and peri-urban agriculture can also be conditioned in conservation and restoration areas of parks, whose main focus is to restore, rehabilitate and recover ecosystems.[40] and in protected areas around water bodies[41]

Figure 9. Botanical Garden has an urban farm which contributes to both food and learning activities. Authors own photo.

The activities of the urban and peri-urban agriculture and agroecology are carried out by the District Environmental Secretariat under the coordination of the District Secretariat of Economic Development.[42] The coordination of urban agriculture should follow the Public Policy on *Food and Nutrition Security in Bogotá: Building Food Citizenship 2019-2031.*[43] The policy promotes food citizenship, described as the practice of engaging in food-related activities and behaviours which support a democratic, socially and economically just and environmentally sustainable food system. The policy aims to engage all inhabitants of Bogotá and "overcome" the limits of a dualistic view on producer-consumer relationships with food by involving multiple actors. The policy not only frames it as the consumer's right to be involved, but also as their duty to create a co-responsibility among the region's inhabitants to take individual, family, and collective action to contribute to a more sustainable food supply in the region.[44]

Contribution to urban themes

Well-being: The practice of urban agriculture promotes community engagement to implement agricultural systems which take advantage of waste, optimise resource use, as well as contribute to the enjoyment of public spaces. [45] Several interviewees note that urban agriculture contributes to learning, recreation and enjoyment.

[39] POT. Article 69. Zoning of edge parks.
[40] POT. Article 69. Zoning of edge parks.
[41] POT. Article 62. Natural Water Bodies.
[42] POT. Article 73. Public areas resulting from compensation or cession in areas of the Main Ecological Structure.
[43] POT. Article 125. Related services and activities in the public pedestrian and meeting space system. 8. Urban Agriculture (151)
[44] District Planning Secretariat. 2019. 'Política Pública de Seguridad Alimentaria y Nutricional Para Bogotá: Construyendo Ciudadanía Alimentaria 2019-2031'. 2019.
[45] POT. Article 125. Related services and activities in the public pedestrian and meeting space system. 8. Urban Agriculture (151)

Biodiversity: Urban agriculture can contribute to increased greening and connectivity of ecosystems.[46]

Climate adaptation: Urban agriculture can be used as a measure to increase soil permeability to regulate hydrological cycles in the city. [47]

Table 8. Urban agriculture's contributions to three urban themes were identified in interviews and in documents.

Well-being and ES	• Community engagement • Food security • Learning • Recreation and enjoyment
Biodiversity	• Improving ecosystem connectivity
Climate adaptation	• Improving soil permeability • Regulate hydrological cycles in the city

v. Green Roofs and Urban Vertical Gardens

Bogotá has a vast network of green roofs and vertical gardens. Guided by the policy for Eco urbanism and Sustainable construction, the District Secretariats for Planning, Environment and Habitat monitor and develop regulations for promoting green infrastructure in the city. [48] This includes urban greening through vegetated infrastructure on roofs and facades.[49] The District Environmental Secretariat provides training and consultation to public and private constructions. Several interviews think that the interest in green infrastructure will increase in the future, both for recreational purposes and for its climate adaptation benefits, such as regulating urban temperature. Also private actors are promoted to take green infrastructure, into consideration through design guidelines which promote green roofs, facades and terraces which contribute to recreation, good environmental quality and mitigate climate effects.[50] An example of a private actor is the building: Edifício Santalaia, which has been recognised by the District Environmental Secretariat as one of the greenest buildings in Bogotá. Green roofs and vertical gardens are particularly apparent in the eastern side of Bogotá, which in general is a more high-income area. Interviewees note that these types of infrastructure not only are an architectural feature but also potentially increase the property value. However, PU2 notes that one of the main challenges with these structures is maintenance: *"Maintaining a garden is not the same as cutting a grass or a lawn. In other words, here you do need a significant budget to maintain."*

[46] POT. Article 121. Coverage d e public space. 4. Environmental connectivity. (p.146)
[47] POT. Article 121. Coverage of public space. 4. Environmental connectivity. (p.146)
[48] POT. Article 117. District Policy on Ecourbanism and Sustainable Construction. (p. 136)
[49] POT. Article 117. District Policy on Ecourbanism and Sustainable Construction.
[50] POT. Article 128. Guidelines for the management of private spaces for public use. a3. (p. 154)

Figure 10. Green roofs and vertical gardens. District Environmental Secretariat. 2024. (map to the left), such as private buildings in the Chapinero district in central north of Bogota (middle and right picture). Authors own photos.

Contribution to urban themes

Well-being: Green roofs and vertical gardens contribute to the reduction of stress through reducing noise pollution both inside and outside buildings, and improve thermal comfort through regulating temperature in both warm and cold climates.[51] The green structures also increase the recreational value and improve the quality of life, and are brought up as an opportunity to compensate for green areas that are lost in construction. Additionally, economic and social values are brought up, as they contribute to the renewal of the city improving the quality of leisure, and increasing the commercial value of properties. [52]

Biodiversity and healthy ecosystems: The practical guide notes that green infrastructures such as green roofs and vertical gardens contribute to better air quality through decreasing suspended particular matter in the air, and acts as a carbon sink. [53] Furthermore, the guide notes that bird and insect species can find nesting and resting spots, and contribute to the conservation of endangered plants and support pollinators. [54]

[51] Vegetated Infrastructure Technical Guide (p. 11)
[52] Vegetated Infrastructure Technical Guide (p. 12-13)
[53] Vegetated Infrastructure Technical Guide (p. 12)
[54] Vegetated Infrastructure Technical Guide (p. 13)

Climate: The vertical gardens and green roofs, provide shade and can regulate temperature both inside and outside the buildings, which reduces the effect of urban heat islands. [55] The green structure is also promoted for its ability to retain water during rainfall, gradual infiltration and mitigate the risk of overloading sewage systems. [56]

Table 9. Green roofs & vertical gardens' contributions to three urban themes were identified in interviews and in documents.

Well-being and ES	• Noise pollution reduction • Increased green space per inhabitant • Urban renewal • Increase in the value of urban project
Biodiversity	• Improved air quality (decreased suspension) • Biodiversity recovery in urban areas
Climate adaptation	• Reduction of Urban Heat Island Effect • Improved thermal comfort in buildings. • Recovery of natural water cycles (flood mitigation)

vi. Sustainable Urban Drainage Systems

Sustainable Urban Drainage Systems (SUDS) are a type of storm drainage system implemented in the city to sustainably manage stormwater, reduce risks of torrential flooding recover hydrological cycle, and increase permeability in the city. [57] To deal with the risks related to intense rainfall, the city's land use plan promotes *"naturalization, green infrastructure and the use of bioengineering",* which makes room for further implementation of SUDS in the future. [58] The SUDS are technical systems based on natural elements that are designed to manage stormwater in the city through natural processes. [59] The SUDS supports and complements the conventional storm sewer systems in managing drainage, collection and management of water in the city, and contributes to improving the quality of Bogotá's river basins.[60] There are several different typologies of SUDS, which for example include constructed wetlands and infiltration basins.[61]

Thus, SUDS is the only naturescapes which is implemented as a utility system in the city and is provided to the region's inhabitant as a public utility service.[62] This includes permeable areas connected to drainage systems and storm drainage infrastructure. [63] To make public spaces more resilient to flooding events and more adapted to climate change, SUDS are particularly promoted in public spaces and in road infrastructure. Implementing SUDS in these public spaces is a strategy

[55] Vegetated Infrastructure Technical Guide (p. 11)
[56] Vegetated Infrastructure Technical Guide (p. 13)
[57] POT. Article 184. Sustainable storm drainage system. (p. 225)
[58] POT. Article 184. Sustainable storm drainage system.1-6 (p. 225)
[59] POT. Article 98. Public Service Systems. 1.c. (p. 162)
[60] POT. Article 185. Sustainable Urban Drainage Systems - SUDS. (p. 226-228)
[61] POT. Article 98. Public Service Systems. 1.c. (p. 162)
[62] POT. Article 98. Public Service Systems. (p. 162)
[63] POT. Article 98. Public Service Systems. 1.c. (p. 162)

to *"efficiently managing the process of infiltration, storage, transport and treatment of rainwater drainage"*. [64] For example, the public sector must incorporate SUDS in at least 10% of any public space and transport project. [65] They are promoted in the design of public pedestrian and meeting spaces to manage and treat rainwater,[66] such as parks.[67] The Various standards are adopted by EAAB Technical Standard NS166. [68]

Governance

Bogotá has over the last decade planned for and implemented SUDS as a network of NbS with the objective to reduce stormwater and improve water quality of the run-off water in the city. Academia has played a large role in researching sites where SUDS can suitably be implemented and formulating a methodology for the selection basis of SUDS typologies depending on the local context. The planning and implementation of SUDS in Bogotá has been a process involving multiple stakeholders in academia, urban planning entities and governmental authorities. Since 2018, there have been several entities and public authorities have been working with the implementation of SUDS including the Urban Development Institute, District Environment

Figure 11 Three typologies of SUDS implemented in Bogotá. Authors own photos.

[64] POT. Article 184. Sustainable storm drainage system.1-6 (p. 225)
[65] POT. Article 185. Sustainable Urban Drainage Systems - SUDS. 1-2. (p. 226-228)
[66] POT. Article 122. Design criteria for the public pedestrian and meeting space system. 4.a-b (p 146)
[67] POT. Article 126. Design indexes for the elements of the public pedestrian and meeting space system. S2. (p. 153)
[68] POT. Article 185. Sustainable Urban Drainage Systems - SUDS. 1-2. (p. 226-228)

Secretariat, the Botanical Garden of Bogotá, District Institute of Risk Management and Climate Change - IDIGER, Bogotá's Water and Sewer Company. Also, other entities are involved in the maintenance of SUDS. For example, SUDS which have vegetation cover and are located in public spaces, should be maintained by the Botanical Garden of Bogotá, and the District Institute for Recreation and Sports. [69] SUDS in private or public properties also must follow guidelines from the Environmental Secretariat, and are reviewed as a part of *"designs of the hydro-sanitary network of urban and architectural projects"*. These are maintained by the owners of the land or the entity in charge of the public space (if applicable). [70]

SUDS have a good legal and regulatory basis in Bogotá, as they are on the political agenda and in various policy documents. Nature-based solutions are regulated and addressed in the territorial land use plan (POT). On a national level, there are several policy documents which regulate climate adaptation measures, such as Politica Nacional Cambio Climatico, E2050 and RAS. On a local level in Bogotá the two most important documents regulating implementations of nature-based solutions, and specifically SUDS, is Bogotá's Land use plan (POT) (City Hall of Bogotá 2021), and the technical standard for SUDS (EAAB 2018). *T*he city's guidelines for the usage of SUDS are specified in the Land Use Plan, Article 185[71] and article 186[72] in POT, which gives instructions of who has to maintain each of the types of SUDS. The technical standard provides guidelines for how seven selected typologies of SUDS should be designed and maintained(EAAB 2018).

Both the size and the typology of the SUDS impact who is ultimately responsible for its planning, implementation and maintenance. For example, large SUDS typologies (typically which can manage more than 200m3 stormwater per rainfall event), are mostly managed by Bogotá's Water and Sewerage Company. These include dry dams, artificial wetlands, reservoirs, and canals. The governance of smaller typologies of SUDS, including permeable vegetation coverage such as green ditches, extended dry basins, flooded corridors and bioretention zones, depends on where they are implemented. In public spaces, it differs who is in charge of the SUDS depending on what type they are. For minor typologies, it is the entity that constructs the SUDS which are responsible for their design and construction, and their linkage to the sewerage network (approved by the sewerage service provider).[73] It is however the entity which is administrating the public space that is in charge of maintenance.

All typologies of SUDS must be connected to the storm sewer system or a natural drainage system which must guarantee good retention and treatment conditions of the water. SUDS are

[69] POT. Article 186. Powers related to elements that make up the Sustainable Urban Drainage Systems - SUDS. 1-5. (p. 228)
[70] POT. Article 186. Powers related to elements that make up the Sustainable Urban Drainage Systems - SUDS. 1-5. (p. 228)
[71] POT. Article 185. Sustainable Urban Drainage Systems - SUDS.
[72] POT. Article 186. Powers related to elements that make up the Sustainable Urban Drainage Systems - SUDS. – Implementation
[73] POT. Article 186. Powers related to elements that make up the Sustainable Urban Drainage Systems - SUDS. 1-5. (p. 228)

mandatory to implement in partial plans and/or urban development plans which fall under a development license to various extents.[74] As the SUDS systems connect to the conventional storm sewer systems, their approval is managed by entities providing partial plans and urban licences and is in charge of rainwater management (in compliance with technical standards).[75]

Apart from the local governance, many actors who are involved in the implementation of SUDS are involved in an international knowledge-sharing network about SUDS called "redSUDS", a group born in Spain, which has grown into an international network.

Contribution to urban themes

Well-being: SUDS can increase the availability of natural public space, to benefit the inhabitants of the city.[76] The vegetation

Biodiversity: The drainage systems should also promote increased connectivity with Main Ecological Structures.[77] These Sustainable Storm Systems should be integrated with other elements of the city's water systems to enhance water quality, biodiversity, and public space.[78] The systems also contribute to biodiversity by using both native and exotic plants in their structures.[79]

Climate Adaptation: SUDS are primarily in place for addressing water management in the city. The structures contribute to water resource management for adaptation and resilience to climate change in the POT.[80] The plan wants to strengthen the current structure of SUDS and adapt them to extreme precipitation events[81]. Guidelines to incorporate SUDS in public spaces suggest that SUDS should be promoted as a climate adaptation strategy to increase the city's resilience to flood risks.[82]

Table 10. SUDS' contributions to three urban themes identified in interviews and documents.

Well-being and ES	• Aesthetically pleasing
Biodiversity	• Increase connectivity to main ecological structures • Improving water quality
Climate adaptation	• Flood mitigation • Water recycling

[74] POT. Article 185. Sustainable Urban Drainage Systems - SUDS. 1-2. (p. 226-228)
[75] POT. Article 185. Sustainable Urban Drainage Systems - SUDS. 1-2. (p. 226-228)
[76] POT. Article 184. Sustainable storm drainage system. (p. 225)
[77] POT. Article 184. Sustainable storm drainage system. (p. 225)
[78] POT. Article 184. Sustainable storm drainage system.1-6 (p. 225)
[79] Information retrieved during field visist.
[80] POT. Article 17. Territorial Measures for Climate Change Mitigation and Adaptation. 2.4. (p. 66-67)
[81] POT. Article 17. Territorial Measures for Climate Change Mitigation and Adaptation. 2.4. (p. 66-67)
[82] POT. Article 184. Sustainable storm drainage system. 1-4. (p. 225)

vii. Ecosystem connectors & green corridors

Ecosystem connectors is a network of green and blue corridors and areas which are important for connecting ecosystems outside of the city, including more fragmented areas which are of natural, socio-cultural and environmental importance.[83] While the MES are areas identified for their ecological functions, the Ecosystem Connectors have an emphasis on their ability to *connect* ecological attributes of the urban and rural areas in the region. This includes areas which are also covered by the MES, but also protection of other areas with ecosystems of importance for water connectivity, the structural and functional ecological connectivity. For example, the ecosystem connectors connect elements of the sub-basins of an important river, the Fucha River in the east, and green corridors connecting to the mountains in the west.

Ecosystem Connectors in Bogotá D.C

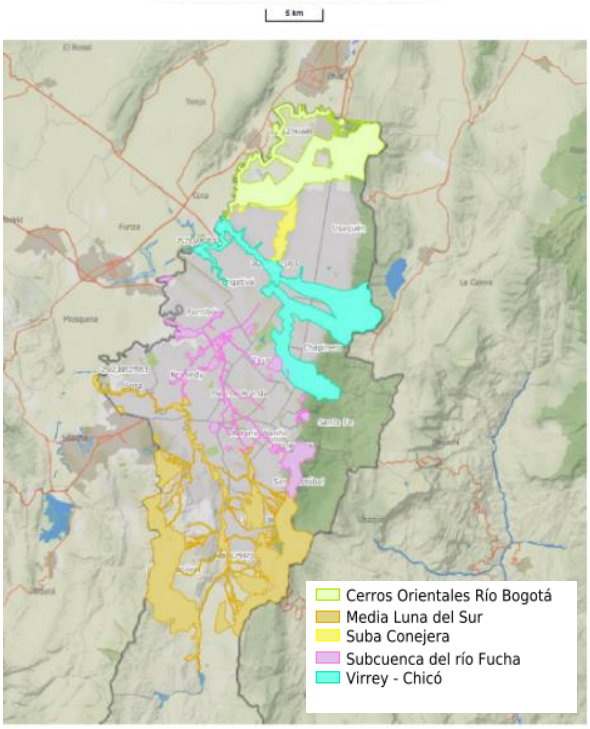

Figure 12. Geographical extension of Ecosystem Connectors including in Bogotá D.C. Map data retrieved from. Data retrieved from District Environment Secretariat. 2024.

Contribution to urban themes

Well-being: The ecosystem connectors contribute to the availability of public space for recreation and enjoyment.

Figure 13. Economic connectors, sub-basin of the Fuca river. Authors own picture.

[83] POT. Article 8. District Elements of the Land Use Model. 5. (p. 54)

Biodiversity: However, the purpose of the Ecosystem Connectors is to improve the management and consolidation of biodiversity and ecological processes and increase connectivity of ecosystems, landscapes as well as the permeability and green vegetation cover of the city. This should strengthen the socio-ecological governance and community-based governance among these structures, and *"strengthen socio-environmental management."*[84] The connectors include projects associated with increasing vegetation cover with ecological processes and protection and recovery of soil permeability of hardened areas while maintaining their current uses. [85] In addition, green corridors are particularly addressed as green structures developed along mobility infrastructure which improve the ecosystemic connection along transport nodes.[86]

Climate adaptation: Ecosystem connectors contribute to increased permeability, which increases soil retention and mitigates the risk of flooding. Furthermore, the green coverage of the green corridor contains moisture and reduces heat stress and heat island effects.

Table 11. Ecological connectors and green corridors contribute to three urban themes identified in interviews and in documents.

Well-being and ES	• Recreation
Biodiversity & Ecosystems	• Improve connectivity between ecosystems • Strengthen the eco-systemic function of rural-urban borders. • Ecosystems for native species. • Support biodiversity which contributes to climate adaptation.
Climate adaptation	• Water retention through soil permeability • Flood mitigation • Reduction of the heat island effect

5.1.3 Multifunctionality of Naturescpaes

To understand how the identified naturescapes currently contribute to the three urban themes: Well-being and equal access to ES, Biodiversity and healthy ecosystems and Climate adaptation in Bogotá, the values and ecosystem services expressed for each theme were analysed for the different naturescapes based on their multi-functionality. If the services of a naturescape had a clear focus on one of the themes, it was weighed as a (P) for that theme (primary contribution) for that theme. The other themes which were not priority were marked with an (S) for secondary priority. If the presumed contributions of the naturescape were fairly equally distributed over the three themes, it was weighed with an (E) for all themes (equal contribution). It is important to note that this weighing is based on how the naturescapes perceived contribution based on the imaginaries gathered from the data and does not automatically translate to the objective contribution.

[84] POT. Article 11. Ecosystemic connectors. (p-56)
[85] POT. Article 11. Ecosystemic connectors. (p-58)
[86] POT. Article 160. Conditions to form and consolidate Green Corridors.

All naturescapes contributed to the urban themes in various ways, however some had a clearer objective with their implementation and management than others. In general, natural ecosystems, such as the MES and natural wetlands were valued for their multiple contribution within the three themes contributing fairly equally to contribution to well-being, biodiversity and climate adaptation. On the other hand, more artificial systems such as SUDS and Urban Agriculture, were managed with primarily one of the urban themes in mind. While all naturescapes contribute to all urban themes, the general contributions to human well-being and access to ES were assessed higher, taking all naturescapes into consideration, while the contribution to biodiversity was considered more secondary, based on the assessment. As such, the stated contribution of these naturescapes to a high degree depends on how they are governed and managed. For example, the management of MES focuses on preserving existing ecosystems and their wide range of benefits, while SUDS were specifically implemented with climate adaptation as a primary objective.

Table 12 The assessed multifunctionality of naturescapes in Bogota.

Naturescapes	Type of NbS	Well-being & ES	Biodiversity & Ecosystems	Climate Adaptation
Main Ecological Structures (MES)	Type 1	*E*	*E*	*E*
Wetlands (natural)	Type 1	*E*	*E*	*E*
Ecosystem Connectors & Green corridors	Type 2	*S*	***P***	*S*
Urban Forests	Type 2	***P***	*S*	*S*
Green Roofs & Vertical Gardens	Type 3	*E*	*E*	*E*
SUDS	Type 3	*S*	*S*	***P***
Urban Agriculture	Type 3	***P***	*E*	*E*

Some naturescapes were brought up in a larger extent in documents and among interviewees than others, indicating that they had a more recognised status as an NbS and were more important to link as a system. For example, Main Ecological Structures are recognised as territorial structures within the POT, which is a prioritised structure for fulfilling the POT's objectives, where guidelines are provided for its management.[87] Among the interviewees, the most widely recognised natural structure providing benefits were wetlands, which were often brought up as an NbS of great importance bringing a wide array of benefits.

Interviewees however also the importance of having a clearer and gathered definition of what should be recognised as an NbS, stressing the point that it should have a clear contribution to societal challenges, as addressed in the IUCN standards. Thus, the opinions on whether all-natural structures, as those included in the MES, varied depending on the view of the contribution to

[87] POT. Article 6. Multiscale Model of Territorial Occupation -MOT-. 1. (P. 52)

addressing societal challenges must be a main objective of the management of the structures, or if it can be an implicit or secondary goal. The same argument was brought up for green infrastructure, such as green roofs and vertical gardens, where some interviewees noted that not all green infrastructures are designed with societal challenges in mind, and therefore do not include certain characteristics of green roofs which contribute to ES such as temperature regulation or supports biodiversity. Other naturescapes, are more convincing cases of naturescapes, such as the system of SUDS, which over the last few years have been implemented on a city level with a common methodology, and a clear overarching objective to reduce flood run-off and improve the water quality, and can provide a more clear case of how naturescapes evolve in an urban context.

In Bogotá, several interviews note, that the concept of NbS is gaining more attraction, and is included to a higher degree in the political agenda, especially in relation to climate adaptation and the city Climate Adaptation Strategy. Some interviewees also note that the focus of NbS shifts from understanding what general structures can contribute to wide societal challenges, to focusing more on what specific typologies can be used to achieve more context-based and localised conditions. The city has developed typologies for different designs of NbS within two of the naturescapes: SUDS and Urban forests, which are currently used for implementing the NbS on a city-wide scale. PU1 notes that *"I think in the last years, nature-based solutions are maybe related with the public space, maybe with parks or green corridors. But right now, the idea is to involve more nature-based solutions or more typologies of nature-based solutions. For example, urban forests or maybe green corridors, maybe urban farming. And the city is in the process to do the regulation of that type of nature-based solutions."*

While many of the naturescapes were brought up in the POT, the term "nature-based solutions" was only used a few times in relation to SUDS systems. The interviewees however recognise a broader usage of NbS. As the field of NbS evolves, and as NbS are increasingly being implemented systematically on a landscape level, the terminology is likely to develop along with new technologies as well as recognition of traditional practices as NbS. Overall, the values expressed by the interviewees were compatible with those expressed by the POT, where both the interviewees and the POT put a high focus on the connectedness within and between ecological structures. Interestingly, this was however discussed more for natural structures (type 1), than for more technical structures (type 3). While the ES for connecting natural structures (type 1) was widely recognised, there was less notion of connecting artificial ecosystems (type 3), such as green roofs and vertical gardens or SUDS.

5.1.4 Considerations for naturescapes

To understand how NbS can be implemented in the future it is vital to understand what shapes the dynamics which shape the urban landscape in which the naturescapes are implemented. The interviews uncovered several considerations which are to be made to allow an upscaling of systems of NbS in Bogota, considering both political, economic and ecological factors.

i. Naturescapes borders and System limitations: Natural and administrative borders

When planning for Nbs, whether as a single instalment or as a part of a larger governing or functional assemblage, it is important to define a system limit for which the Nbs should function. In a project where SUDS were implemented, engineers were focused on the water catchments as the most important borders for the NbS, whereas the landscape architects were more focused on urban planning units as borders. Some interviewees expressed the need to consider the natural landscape more in urban planning, by recognising that natural systems do not consider administrative borders, and therefore the governance of natural resources and ecological structures should be planned with natural landscapes in mind. For example, NG1 promotes more land use planning through watersheds: *"I always try to push that those landscapes are actually watersheds, […], because the water is the structure, it is the basis for the society that can grow, and if you organize everything around water, it is easier to understand what you should do and what you shouldn't do, if the landscape is not the watershed."* NG1 further points out that many in urban areas do not consider where their natural resources, such as water and food, comes from, and how it impacts the landscape around them. NG1: "*we need to start understanding that the urban area is actually located within an ecosystem, within a watershed. And that the decisions or the demands that the water, the urban area requires, model or transform the rural areas. So, therefore, we need to see it as a system. And that's the most difficult thing to do."* The borders of the Bogota region are largely designed around watersheds in the area, yet NG1 sees a need to protect the structures within it to contribute to benefits to all the region's inhabitants. NG1: *"There is a lot of effort that we need to do to protect the river itself, and to protect the forest, the riparian forest, and the vegetation that is around it. That will also help with not only preparing the city for floods or for droughts, but also will help with, for example, heat waves […] The connection with nature that will help to reduce the stress levels of the citizens. […] Wetlands and rivers within the city, and then of course the connection with the Paramos that provide the water."*

Another approach to borders is thinking about urban areas in zones. The World Resource Institute work with Bogota as one on many cities in an international project called Cities4Forests, where they promote the ecosystem services from NbS and natural structures. When working with the cities, they work in the perspective of three different zones: the inner zone, nearby zone and faraway zone. In Bogota, the inner zone includes green ecosystems such as the Botanical Garden (El Jardin Botanico), El Parque Simon Bolivar, and green corridors. The nearby zone includes

ecosystems in the watershed, with the mountain wetlands, Paramos (Chingaza, Sumapaz, Guerrero and Huachineque). While being located outside the city, the ecosystems provide many ecosystem services to the city RI1 notes: *"These are not necessarily located within Bogotá, but these ecosystems are the ones that allow Bogotá to have access to water, for example."*. The faraway zone considers ecosystems which are far away from the city but still contributes with ecosystem services benefitting the city, which in the case of Bogota includes the Amazon rainforest as a faraway forest. RI1: *"While it's located far away from the cities like Bogotá, it still provides valuable ecosystem services to cities. In the case of the Amazon, of course, we're talking about clean air, but also sustainable products that could be coming from the forests."*

ii. Access to naturescapes

While connectivity is discussed as an objective in the POT, the discussion of access to various ES is less prominent. POT was the discussion of accessibility to ES both considering the distribution of ES, but also from other factors considering the access such as safety measures. For example, RI2 notes that the distribution of greenery is lacking in areas which are typically more prone to flooding and are more low-income areas: "*I think the East side of the city, more near to the Bogotá river, there are neighborhoods that have a lot of hard areas or gray areas and a lack of public space and green areas also. And there were a lot of wetlands that now don't exist more because of this urban expansion. So I think in general, the West side of the city have a lot of green areas and the part more near to the Bogotá river is now more gray or more hard. And there are also, here in Bogotá, we have an important segregation about that. I think this is very clear that the neighborhoods in the north of the city and with the high income have the best green areas in the city and that one that have low income or grey have a lack of green areas."*

The natural ecosystems, such as systems of wetlands and the Principle Ecological Structures are primarily located in the outskirts of the metropolitan area. Conversely, naturescapes consisting of more constructed Nbs, such as green walls vertical gardens and SUDS are located more centrally within the metropolitan area. For example, the remaining wetlands of Bogotá area are mainly located in the outskirts of the city in the West, which is a low-stratus area. Green roofs and vertical gardens, however, are concentrated to the east, which is primarily a high-income area.

Figure 14 WRI divides zones into inner urban zones, such as the botanical garden (left) to faraway zones, such as the Paramos wetlands (left). Authors own pictures.

The lack of even distribution of the naturescapes impacts the access to various ecosystem services from these naturescapes by people living in different areas in Bogota. People living on the outskirts of the city, and generally in low-income areas, have less access to the public and private benefits that green roofs and vertical gardens provide. Reversely, the wetlands that one's made out of most of the land where the city is located are now difficult to get to for many of the city's inhabitants.

Additionally, where a naturescape is located not only impacts the access physical accessibility to the NbS and their ecosystem services but also what ecosystem services they can contribute with. For example, the wetlands of Bogota are by many considered unsafe areas to be in, as wetlands in low-income areas which are unprecedented may attract criminal activities. Planning and management of NbS in urban areas is often seen from a technical and engineering approach, however, the success in providing ecosystem services can equally depend on their governance. Maintaining ecosystems that have both benefits for biodiversity and recreation are often values that can be "added" to NbS which also addresses more technical issues, such as improving water quality, or dealing with stormwater. However, there is also a need to address larger societal issues to improve the function of NbS and naturescapes.

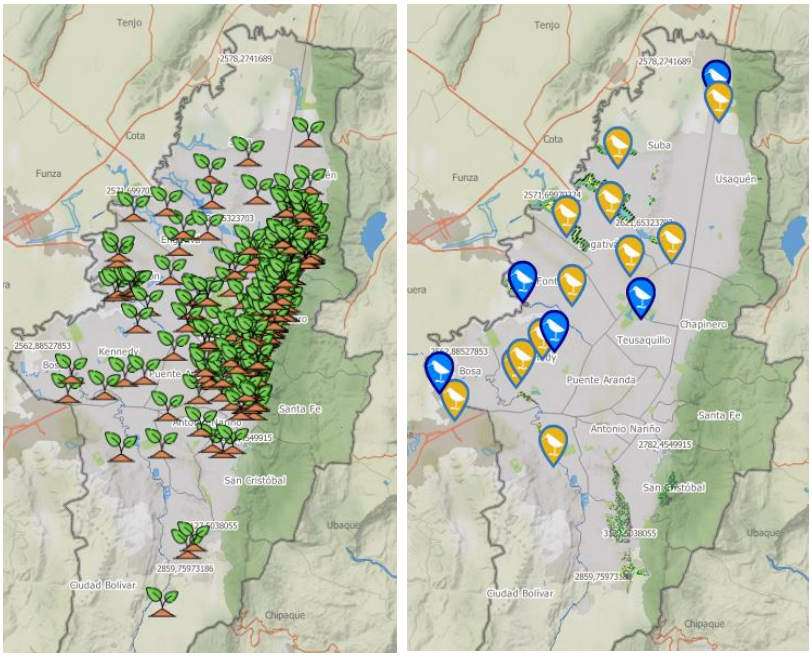

Figure 15. Distribution of naturescapes. Green roofs & vertical gardens, and wetlands.

Several interviewees commented on that, as similar to many other Latin American cities, the safety of natural areas in the urban landscape, is a great challenge. In Bogota, the wetlands are mainly located in the periphery of the city, in the west and south of the city, which is largely low-income areas. While much effort have been put in from both local governments, NGOs and communities, in preserving wetlands, the issue of safety has to be addressed on a societal level. And unsafe places will lack community engagement, according to NG1: *" A complementary action in the city for nature-based solutions to thrive is to make those places safe. That, I would say, is the biggest challenge with nature within a city. Usually in third-world cities, nature is a very dangerous place. They*

are dark, you get robbed or whatever, and they are not safe places. And you usually don't see those connections. But if you have a very nice, well-restored wetland and you don't have a governance plan around it, usually those places are seen by the citizens as not a place to go, and of course then they don't care about it."

The safety of the wetlands not only impacts their attractiveness for recreation, but also the safety for people working with maintaining the wetlands. PU4: *"Yes, and in the wetlands, there really exist many dangers about the persons who stole other persons' drugs consumption in many places, because they are like a natural space in the middle of an urban matrix. So, it's very difficult, some social issues. When I do this study, there really is a problem. we have to go with the police officer to some places, because there are people who stay in their places. Not only the community that want to see birds or to take contact with nature, but many other people, for example, people who sell drugs in this place, or persons who consume these drugs. And here we say homeless people that stay there and live there. Also, persons who rob you. For many places it's dangerous if you don't have this police accompaniment.".* The District Environment Secretariat can provide information of which wetlands are safe to go to, and which wetlands are not recommended without police accompaniment. But to make the areas a safer environment, PU4 thinks the best solution, apart from addressing general social issues of homelessness, is to promote activities in the wetlands to draw more people there with communal activities. PU4: *"If it's always alone the place and it's dark, I don't know, I think in some places near to the dangerous neighbourhoods, it's very difficult. It's a difficult question. For example, homeless, for example, come fish there, and take a shower there, in this water, and cultivate some plants. I don't know. I think if there is a community and there is an effort to the district to give a safe space in this place, for example, I think it can be better."*

Figure 16. The Cordoba wetland in western Bogota, like many others in Bogota, is fenced off and only open to the public during the day.

5.1.5 Naturescapes case study: Considerations for the implementation of Sustainable Urban Drainage Systems - SUDS

To better understand the considerations related to the implementation of naturescapes, SUDS are used as a case study to demonstrate how a newly adopted naturescape has been implemented using a methodology for systematic thinking for its planning. This section thus presents the learning experiences drawn from designing, planning and implementing the naturescape of SUDS systems in Bogotá. Drawing from interviews with people who have been a part of designing, planning for and implementing SUDS in Bogotá over the last couple of years has provided insights into how a naturescape can develop in an urban landscape. In this section, insights from professionals in academia, urban planning and urban governance are presented regarding the process of planning for urban nature-based solutions in a systematic approach.

i. SUDS Implementation in Bogotá

Sustainable Urban Drainage Systems stands out as a naturescape in Bogotá, as it is a technical nature-based solution (type 3) which has been systematically implemented in the city through its inclusion in guidelines and regulations for urban planning. After having been piloted in the city for the first time in 2017, the city today implements a variation of SUDS systems, and currently, more than 260 SUDS structures have been implemented in the city (Urban Development Institute 2021). Appendix D includes examples of SUDS structures which have been implemented in Bogotá. The implementation in the city has focused on mainly ten typologies of SUDS, where the most common implementation includes Infiltration Trenches and bio-retention systems (Plataforma Oficial de SUDS Bogotá D.C. 2024) as demonstrated in Table 13.

Table 13. Typologies of SUDS implemented in Bogota, (registered as of May 2024). Source: Plataforma Oficial de SUDS Bogota D.C. 2024.

Typology	*% of Registrated SUDS-structures in Bogotá*
Infiltration trenches (Zanjas de infiltracion)	50,7 %
Bio-retention systems (Zona de bio-retención)	20,0 %
Vegetated Swales (Cuenta verde)	7,7 %
Attenuation storage tanks (Tanque de almacenamiento)	6,2 %
Tree Pits (Alcorque Inundable)	4,6 %
Pervious Pavement (Pavimento permeable)	4,6 %
Extended dry basins (Cuenca seca de drenaje extendido)	1,5 %
Wetland (Pondaje humedo)	1,5 %
Green Roof (Cubierta verde)	1,5 %
(Acuacelda)	1,5 %
Wetlands	1,5%
Ponds	No data
Rainwater harvesting systems	No data

One of the success factors of SUDS, several interviews note, is the fact that the requirement of and guidelines for the usage of SUDS, over conventional grey drainage infrastructure, is integrated into plans and regulation, such as the POT, and therefore led to a systematic implementation of the NbS. PU3 notes that this differs from other cities, which have not integrated the NbS into their regulation: "I*n Spain, the development of SUDS is quite advanced, but they don't have a standard that forces the new contracts to generate SUDS. They all [depend on] marketing, to sell themselves environmentally as green and as environmentally friendly projects. The conception is not as in Bogotá, that this is already a mandatory criterion, and that it has to be done. We may have many errors, we may still have a lot to refine in our projects, but just doing things makes it so that we can learn in practice and improve much faster than other cities."*

ii. Methodology of selecting SUDS

Another criteria for the systematic implementation of SUDS is the methodology for making informed decisions about sites and typologies of SUDS, to implement SUDS bearing in mind both the physical limitations, and the socio-ecological benefits they contribute with. The implementation of SUDS in Bogotá follows a methodology developed for selecting sites and typologies of SUDS in Bogotá, which was developed in academia in collaboration with several local authorities in Bogotá (Jiménez Ariza et al. 2019).

The methodology was applied in three scales, city wide, local and microscale. Firstly, analysis were made on a city scale to determine priority objectives and priority areas (strategic sub-catchments) for the SUDS implementations on a city level. The prioritised objectives of the city were identified through workshops and participation activities with the main stakeholder in spatial planning of Bogotá. Three main objectives were identified for SUDS implementation in Bogotá, : (1) water quality improvements, (2) runoff management, and (3) amenity improvement, which guided the further development of typologies of SUDS recommended for the city. The priority areas for the city were determined by using publicly available data to determine areas for implementation of SUDS based on 1) feasibility of implementation and opportunities in future urban development plans, and 2) areas which needed interventions to improve socio-ecological (Jiménez Ariza et al. 2019).

Secondly, the local scale of the prospective areas was analysed based on what typologies of SUDS would be suitable to implement. Both public and private spaces were analysed, for which twelve typologies of SUDS were identified: (1) grassed swales, (2) infiltration trenches, (3) permeable pavements, (4) wet ponds, (5) bioretention zones, (6) tree boxes, (7) sand filters, (8) constructed wetlands, (9) soakaways, (10) infiltration basins, (11) extended dry detention basins, and (12) rain barrels and cisterns. For private constructions also green roofs are considered.

Thirdly, the microscale considers the recommendations for selecting SUDS at the local scale and specifies the selection of SUDS typologies for implementation at the specific site. This is a continuous process as SUDS are implemented in the city where technical standards and guidelines are provided to support the decision for what SUDS typology, or system of typologies, are most

Figure 17. An extended dry basin and vegetated swale were implemented as the first piloted SUDS in Bogotá in Parque San Cristobal in southern Bogotá. The author's own photo.

suitable for the selected site. The guidelines include different criteria which can be considered at the microscale implementation of SUDS (Jiménez Ariza et al. 2019).

iii. Considerations for selecting SUDS

Choosing the main objective at the city level – current and future objectives

Following the implementation of SUDS using the methodology described above, actors have shared their considerations and reflections on the implementation. In the first stage of determining objectives for the city, AC1, who has been involved in developing the methodology, noted that the objectives of the city (water run-off management, increasing the water quality through water treatment, and improving socioecological conditions) were based on stakeholder discussion, however, it does not necessarily represent the objectives of the whole institution. Including a more future-oriented perspective can contribute to a more holistic criteria selection basis for the naturescape at a city level. AC1: *"We interview people, not institutions. So, the people that we interviewed in*

the past, somehow, represent an institution, but they are not the institution itself. […] I think the way the city is looking at the future should define how to prioritize those criteria, not a person or an institution in particular."

Furthermore, AC1 notes that while the guidelines for the SUDS, and the designed SUDS structure are still the same as when the methodology was developed in 2019, the objectives of the city are changing over time. One consideration for the application of systematically selecting SUDS therefore relates to how often the objectives of choosing typologies for NbS on a city level should be updated, to reflect the most recent perspectives of what societal issues the NbS should address. AC1: "T*he top priorities [for Bogotá] were runoff control in terms of volume reduction and in terms of water treatment. But, for example, value diversity and any other criteria were not prioritized. So, it can be different depending on other cities. If we carry out those workshops now, perhaps those criteria can change."*

While the methodology applied to select SUDS was based on data for understanding the current socio-economic and environmental conditions of the city, AC notes that considering the future challenges could be a valuable contribution to the methodology. This can include future demographics and climate conditions, as well as future visions and ideal scenarios of the economic and environmental ambitions of the city. AC1: "*In these methods, we work closely with the different stakeholders, including communities, regarding their current needs and their current perspectives. But we are not necessarily assessing how they perceive the future of their perspective or how the perspective can change in the future."*

However, AC1 also notes that including future scenarios and visions into methodologies for selecting NbS includes dealing with large uncertainties, as well as varying visions. However, AC1 also notes that planning for such conditions includes large uncertainties, which are difficult to account for. AC1:" you can play with that around and try to select something that is more resilient to those changes or those uncertainties now, knowing that will be in place, let's say, in the future. I mean, those uncertainties will increase, but you are defining what should be in place and will last for many decades. You have to consider that."

Choosing location

On a local level the methodology considered both the presence of natural elements or future urban infrastructure works to determine where SUDS were most suitable to implement (Strategic Urban Drainage Sub-Catchments), and the need for improved socio-ecological conditions in line with the three objectives (Priority Urban Drainage Sub-Catchments), through considering data on water quality, water quantity and social environmental information, availability of green and blue-green corridors in the city, and new development and redevelopment projects. To result in recommendations for SUDS, these factors have to be weighed against one another in an index. For example, higher weight was given to areas located adjacent to existing blue and green corridors, as it would make the implementation of SUDS easier. Another factor considered in the index was the

development that would occur in the city in the coming 5-10 years, as areas that are already going to be developed are easier to implement new structures in. AC1, notes that the selection of this weight to a high extent impacts the results of where SUDS were considered more favourable to implement. For example, major barriers in the implementations were not considered, something which would have a potentially large impact on the selection of sites (Ortega, Rodríguez, and Bharati 2023).

The main objectives of the SUDS thus highly impact the selection of the Priority Urban Drainage Sub-Catchments, which determines which data should be considered when selecting sites. For example, a strong objective in the POT includes the ecological connectivity of ecosystems. Therefore, the understanding of where systems of NbS fall in relation to other naturescapes, such as Principle Ecological Structures, can be valuable to consider for future evaluations. The weight that is given to the different criteria which reflect the main objectivity highly impacts the selection of the resulting suggestions of where SUDS should be implemented. The methodology thus has to consider how the feasibility of implementation of SUDS should be weighed to the need for SUDS in the area. AC noted that different planning strategies put different weight between looking at where it is feasible to construct NbS, and where it is needed: *"We have like a disagreement with another team that created the guide for implementing nature-based solutions in Colombia. Because they were looking for places with opportunities to implement nature-based solutions, so they were looking at the city as it were. Like, this is the city as it is, where can we implement nature-based solutions? And that's their first step. And we didn't agree because as planners and designers you shouldn't conform with the city that you have. You have to look further and look for where are the ideal places where nature-based solutions should be, and obviously considering the current situation of the city, but also the future and the people, and everything […] But if no one thinks about it, we're going to remain with non-functional cities.[…] For sure you should implement nature-based solutions on that space. But there are areas in the city, as this one, which is fully developed, fully impermeable by urbanization, that you need to change. You need to transform that."*

The paper notes that private space has to be considered particularly in the northern and southern parts of the city, as public space is less available. This limitation, can however also argue for the need of larger typologies in these spaces, as it lack other types of public spaces.

Choosing Typology

After having selected the Sub-catchment where NbS should be implemented, typologies were recommended for the different spaces, considering site-specific restrictions, such as slope, distance to groundwater, infiltration rate and distance to foundations. The restriction also considers the size of the SUDS typologies and their proximity to conventional drainage systems, and for wetlands and ponds, the distance to channels and streams were considered. The SUDS typologies which

were found to be most suitable for public areas in Bogotá (Public space included parks, squares, road dividers, sidewalks and parking lots) included tree boxes, cisterns, bioretention zones, green swales, extended dry detention basins, and infiltration trenches. In private areas (e.g., residential, commercial, or industrial), the most suitable SUDS typologies included rain barrels, tree boxes, green roofs, and green swales (Jiménez Ariza et al. 2019). AC1 notes that in a city which has already been densified, water systems which can be implemented on buildings have a lot of potential of private land: *"What is most possible to implement is just to store and to use rainwater systems at the building scale[…] For example, rain barrels systems. To collect rainwater out of buildings, because you have many buildings. So what is most possible to implement is just to store and to use rainwater systems at the building scale. […] And green roofs, large potential because we have a lot of buildings."* According to the results, the constructed area is very important for runoff management.

An overall limitation of the implementation of SUDS, particularly when considering residential areas which is the dominant land use in the city, is the availability of space, as much space is fragmented and only available in small lots. This favours smaller typologies of SUDS, while larger typologies are less feasible to implement.

Other typologies of NbS, however, have limited possibilities to be included, such as wet ponds and constructed wetlands, as they require more area. These SUDS showed potential limited to the south of the city (Jiménez Ariza et al. 2023). AC1: *"Constructed wetlands demand large areas, and you don't have that in many places. So, there is a constant kind of fight between what's possible and what's ideal. […] We cannot implement everywhere a constructed wetland, even though they provide a lot of benefits. There are many restrictions, not only the area they demand, but also how was the depth to where the groundwater table, because you don't want to promote infiltration in areas in which the water table is so high, because you will then have a lot of flooding in the area, because you don't have capacity to infiltrate. So it's a balance, what is possible but what also is needed."*

Choosing a SUDS-system

The selection of SUDS to implement is a continuous process for the implementation of SUDS in various projects in the city. Based on how the site scores in the priority and strategic sub-catchment weighing (city-wide) and the restrictions for typologies of SUDS (local), the project can choose which typologies of SUDS, and systems/trains of SUDS, are most suitable to implement based on the criteria and priorities for the project. To compare the feasibility of different SUDS typologies, a matrix was developed with criteria for stormwater quality improvements, stormwater volume reduction, amenities, maintenance, and costs. The methodology applies a system thinking though not limiting an area to the use of one typology of SUDS, but rather promotes the implementation of systems of typologies based on the site-specific need. AC1: "*The concept behind is not to select just*

one typology, but a train or a system that consists of different SUDS, because it all depends on which processes you want to promote in that area. If you want to infiltrate water, carry the water, or if you want to store and reuse [the water]. Not all the sustainable urban drainage systems provide the same processes."

AC1 notes that it is important to have a variation in typologies which allows a flexibility in what criteria can be met when the typologies are applied by different actors, in different areas and context of the city: Ac1: "*I think having flexibility on the criteria is important because they provide flexibility for the type of project, because not all implementation of nature-based solutions come from the public institutions, [they also come from] the privates. And the privates should have their own criteria […] And the criteria change at the city scale, but also for a certain specific project, because the criteria for this area of the city is not the same for another one."*

Another challenges when moving from the theory of the methodology to how it is used in practice relates to ensuring that the user of the methodology applies it in the correct way, and that is used in the most effective way in the process. As NbS of type 3 often use new types of technologies, which differ from conventional technologies, such as pipes. AC1: *"There is a lot of decisions that has to be made in order to properly use this methodology. For example, how to assign weights to select certain types of suits or how to properly design from the hydrological and hydraulic perspective. That is something that is not certainly easy. […] you have to know about how to design properly the systems. And the design guidance provides information on that. But this is kind of a new topic. Not many engineers are used to do this […]. Even though it is simple, but new. When something is new, there are some problems in start using the designs and procedures.*

One example of the difficulties with new designs involves understanding all parameters to make informed selection of what criteria should be prioritised. Despite there being guidelines for selecting criteria and designing SUDS, this calls for various competences being involved in the process of selecting criteria. For example, engineers may be more trained working with hydrologic conditions, but less with NbS on improving water quality. For this there is a need of various competences, according to UniAnd2: "*there are some recommendations, but still no one has all the knowledge to do the entire process. So, I think, for example, it is very difficult for one civil engineer to entirely design a SUDS system because they have to make decisions on hydraulic and hydrological parameters. […] But they have also to define what type of substrates, what type of vegetation covers. So, that is certainly not part of the knowledge of a civil engineer. So, they have to work in combination with other disciplines. And that is difficult. I mean, they are not used to that, or they just recommend whatever is generic to use. […] We have guidelines. We have information. But putting all the knowledge in place and combining it well is not easy."*

Furthermore, the one who does the design of the SUDS, may not be in the position to make the calls on what priorities should be made. The practitioners using the methodology, are not always the ones who have the capacity to make an analysis of what criteria should be prioritised in the

area. Ac1: *"I think what is actually happening, [is] the ones using this methodology are the ones designing the SUDS for a certain project. But they are not the ones that have the better [possibility] to identify how to prioritize the criteria. I mean, how to choose if the cost is more important, let's say, [or] to promote and enhance ecosystems or biodiversity or maintenance or so on."*

To apply the method correctly, there would be a greater need of general information available to the designers on how to prioritise among the different criteria, keeping in mind the many different objectives for the construction Ac1 *"What's what is lacking from my point of view, [is that] there is not some guidelines or general information to the designers on how to assign those weights or assign those percentages to the criteria. So I'm not sure how the current designers are assigning weights to select what type of suits should be implemented. But it should be used by planners, not by designers, because the planners are the ones that know what we have to promote in this area, this and this. Not the designers at the end."*

While there are certain criteria that are prioritised for SUDS, the SUDS should ideally serve different functions depending on the circumstances. A flexible design of SUDS allows it to fill multiple functions over time. For example, the design should keep in mind both how the SUDS can deal with large quantities of water during flooding, but also how it can contribute with services when it is not flooded, e.g. as a recreational space: PU3 brings up an example from a park in Peru as a successful example of a flexible design of SUDS: "*Let's say that this is how a complete network of an urban area discharges its drainage in a flood park, without the need for any other conventional complementary system. So, when it doesn't rain, this allows cities to use their infrastructure at a social level, and when it rains it has the capacity to contain all the volume of this urban basin."*

iv. Considerations for implementing SUDS

Following the planning stage of implementing a SUDS system, interviewees noted that there were several opportunities and challenges in the implementation stage of the SUDS in Bogotá, spanning from using the guidelines to maintaining the SUDS.

Correct application of the methodology

The technical standard for SUDS guides the designers of SUDS on what considerations to make when implementing SUDS. This includes prioritising between criteria relevant for the site, and selecting the right typology given physical limitations and the criteria that needs to be addressed. While this is an opportunity to guide the process of implementing SUDS, which is a new engineering-based NbS for the city, much of the result comes down to its correct application. Several interviewees noted that how well the selection of SUDS are made can depend on to what capacity the person designing them has to weigh different criteria against one another. While this process ideally should be made early in the planning phase with input from various disciplines, interviews note that in reality it is often made by one person often in a late stage of the planning

process, who often is not in the position to make informed decisions on how to prioritise between factors such as biodiversity and economic costs.

Furthermore, there may not always be the data available for making decisions on election of SUDS, or in the construction phase. PU3 notes that many constructors faces challenges in obtaining the required data needed to make SUDS: *"In academia they tell you that you have to have a lot of information to be able to execute a SUDS, but in practice, there are many variables that are not known. The hydrology is not enough, there are parameters that are not available, you have to do field trials to be able to extract them.*

Furthermore, PU3 notes that the information on the design of SUDS not only has to be understood by the person designing the system but also by the people involved in the construction: . PU3: *"[An] important thing, is to not only to train the designer but also the person constructing. Construction is one of the most critical factors that makes a SUDS work or not. So, if that communication to the constructor is not done, many things remain unverified and quite a few errors can be made in the construction process.*

Economic costs and competitiveness

There are many known factors already for SUDS, such as how to make a feasibility analysis, and the conditions and criteria to consider for designing and constructing them. While the interest in NbS is growing in Latin America, the cost of implementing them is often higher than conventional solutions according to several interviewees. Much of these costs are associated with the logistics of implementing SUDS as they need other materials, and construction processes than conventional solutions, which do not have an established process for procurement, are expensive or not available in large quantities. However, they can still not compete economically with conventional solutions compared to conventional solutions. Therefore, there needs to be a way to consider the long-term gains of nature-based solutions such as SUDS "*putting [SUDS] to compete with conventional infrastructure, on the economic level, they are losing, until we can generate metrics or standards that allow us to consider the economic advantages of SUDS over time."*

To overcome these issues, several interviewees suggested that the calculation for SUDS and other NbS have to consider a wider socio-economic perspective when assessing the cost-benefits with the implementation of SUDS in over to compare them with conventional solutions. up a business case for SUDS is therefore both a challenge and an opportunity. It is an opportunity to consider the long-term benefits, such as residents' health and well-being, improved water quality and less human and property damage during floods, which can make up for its high investment costs. In addition, more investments of SUDS are likely to bring down the prices of material costs which can be produced on a larger scale with a more reliable supply chain. The implementation of SUDS can also increase the economic value, in ways that conventional solutions usually do not, as

it enhances its surrounding area of surrounding area, PU3 notes. For example, SUDS can generate green spaces and pleasant squares, which attract more consumers for the surrounding shops, and, additionally, the properties rise in value.

However, many challenges come with quantifying long-term benefits in a way which is comparable with calculations of short-term implementation. Furthermore, the uncertainties related to the new technologies for the market, make it difficult to appreciate the costs of implementing SUDS, which makes it a higher risk of investment compared to conventional infrastructure, where the costs are easier to assess. Therefore, much of the implementation of SUDS currently relies on the political will of investing in NbS: *"The economic return is not yet so it competes with the level of efficiency with conventional structures, as that level of development is not yet available. The SUDS are now based on political will, that is, if the city wants to do it, they can do it, but if one compares structures at an economic level, they do not look profitable, but not because they aren't, but because the benefits and saving it brings to the city and to the population have not yet been quantified effectively."*

Many of the feasibility challenges with SUDS are due to there being limited testing on SUDS on the market, making them a higher risk of an investment. Many benefits of SUDS, such as cleaning water, show once it's operating and cannot be easily quantified once the construction is completed PU3: *"When they are operating, it is where their benefits are shown, and monitoring of these structures can be generated to be able to continue doing them in the long term."* Having more pilot facilities can engage more learning, which is important to address the uncertainty in investing in new nature-based technologies: PU3: *Let's say that the major challenge at this time, is what is not yet sufficiently known. [It] is to quantify the economic benefits that the SUDS bring at an environmental level, that you can put on a scale."*

The success of some nature-based solutions and naturescapes, such as systems of SUDS, can improve the possibility of implementing others. PU3 says "T*he success of SUDS will support other nature-based solutions to come, and then it becomes a reference that if the SUDS could be made, now other types of things can be done, such as green infrastructure, urban forests, well, many more innovations are beginning to emerge in the context of a city."*

Maintenance

Another cost and resource issue for SUDS relates to its maintenance. For some SUDS, such as an extended dry basin in parks, the maintenance requires overground maintenance, such as grass cutting, which is already included in the parks maintenance procedures. But for other structures, and particularly for the structures underground, the maintenance is more difficult. For the current SUDS structure, much like for conventional structures, one of the main challenges in maintenance is handling litter which is carried in by water flows into the SUDS. However, PU3 notes that there are more actors interested in constructing SUDS, than maintaining them: "E*veryone wants to construct*

SUDS but no one wants to maintain them. The success of a SUDS depends on its maintenance, not the design nor the construction. So, this issue of quantifying environmental benefits and generating effective maintenance metrics that are met in time with activities and deadlines are the two things that will ensure that the implementation of suits in any urban centre to prospers."

The potentially increased maintenance has impacted the attitude of different public actors in engaging with SUDS, PU3 notes. For example, public authorities which deal with environmental risks, such as the District Environment Secretariat and the District Institute of Risk Management and Climate Change (IDIGER), respond to flooding events in the city and were positive to the implementation of SUDS in the city. However, other entities, such as the Bogotá Water and Sewer Company, which are in charge of the maintenance of the drainage systems of the city, were less positive to the implementation of SUDS, as they would generate more costs due to the need for monitoring and supervision of the projects. Therefore, PU3 notes, that there was a long process to get all the entities on board the implementation of SUDS. PU3 says that *"Since there were already projects that were forced by a standard to generate the SUDS, they had no choice but to accept and connect them to their network. And on the other hand, to generate a whole teaching of seeing the benefits that the SUDS bring, not only at the level of water management, runoff management but also of quality, water quality, biodiversity, landscape and amenity, social cohesion."*

Stakeholder engagement

To successfully implement a SUDS structure, PU3 notes that it is important to understand the public opinion of the SUDS, and to anchor the project in the community and gain social acceptance. PU3 brings up examples of communities worrying about SUDS contributing to more mosquitos which could generate diseases, which is not a problem associated with SUDS. PU3 "Y*ou have to first convince people that there is an infiltration, that the water is going to go, that there is not going to be a mosquito problem, because in Bogotá they are in a higher latitude, to be able to make that design that theoretically works viable."* The increased interest among communities to participate also reduces the risks of implementing NbS according to Pu3: *"when you already enter some neighbourhoods or some inhabitants with which the implementation of SUDS is going to value their home, they themselves were in charge of pressuring to make more SUDS in the project. And of course, when the requirement comes from society, from the same inhabitants of the place, it gives you a lot of security to continue pulling the subject."*

Knowledge sharing and learning

When putting theory into practice through constructing SUDS structures, there are many lessons learned for example how to apply regulatory frameworks to the SUDS in the context of the city, and how to get a hold of the right material and supplies. PU3: "*From the private sector, they only see the economic issue, so it is also a very important issue. You have to document yourself at the level of how it*

is made profitable, how is the issue of purchasing supplies, how is the issue of waste management, how much does a person charges to build, how long it takes, what is the planning of the work, at what time do you have to generate the planting of the tree, what are the environmental permits that the city requires. That is not explained by theory, there are many permits of public entities that you have to solve before to be able to make your infrastructure viable."

To share these lessons to other actors it is important to have platforms to communicate, both locally, nationally and internationally. PU3 notes that the international network "RedSUDS" is an important network which links private sector, public sector and academia: "*[This network] allows the academia to bring the theory, the most updated knowledge about SUDS. The public sector receive this knowledge and apply it in the public projects with standards and guidelines, and the private sector can feed of this knowledge and apply it in their different private projects. It's a community where the knowledge is free, there are no costs or payment for the integration of the communication for the different actors or stakeholders."*

PU3 notes that these communication platforms are critical for the development of successful infrastructure projects using new technologies, such as with SUDS, where instead of having a culture of corporate secrets, it becomes a benefit in sharing knowledge and developments: *"In an urban drainage project, […] it is one of the lessons learned: that not only an independent sector can work, but for this to be successful, open communication spaces must be generated, and all the actors involved must be linked so that everyone can advance hand in hand and not remain as an enemy actor of the implementation of these systems, because in some way it is still a vulnerable issue for the economic issue."*

AC1 also stresses the importance of individuals in accelerating the planning and implementation of SUDS: *"It was a matter of having champions. I mean people that really, not only understand the concept, that really think it is the good way to go. […] That was the game changer. It's people. […] As soon as you have more people in different institutions, public and private, in different roles, designers, builders, developers, the ones making the decisions. It's like a domino effect."*

Application to all NbS

Based on the experience from the SUDS selection system a methodology has been developed to choose between multiple NbS in Bogotá. Following a similar logic to the selection of SUDS systems, this methodology identifies indicators and how effective certain NbS are in addressing the needs in the area. In this methodology citizens' perspective is used in addition to evaluation criteria in selecting the NbS for a selected area (e.g. air quality, climate regulation, water regulation, micro-contamination). Using this methodology for not only selected typologies for NbS, but for systems of NbS can have multiple benefits. One of the most valuable benefits, according to A1, is that the planning for NbS becomes integrated earlier in the planning process, than for implementing specific types of NbS, such as SUDS, which is typically carried out by designers rather than planners. AC1 said: *"[If] from the planning processes, we have to replan or plan this entire area, [then] let's look*

together what is better for this area. So, the planning process is clearer in this approach than in the other one [for SUDS]. SUDS are not seen from the very beginning of the planning process. These ones [NbS] are being used from the very beginning of the planning process. So, I think this more, the successful rate of properly applying the methodology is higher with this nature-based solutions framework."

Attempts have been made to develop the methodology even further through including a landscape design approach to designing NbS, rather than a purely engineering perspective. In this approach, local climate zones are added to guide the design of the landscape. This can benefit the design, not only in the type of solutions that are selected but also in what system boundaries are used for the naturescapes. For example, Ac1 notes that engineers often think of boundaries in terms of catchment areas, while landscape designers take more consideration to planning and jurisdictional boundaries, both of which are relevant when planning for NbS. Combining the perspectives allowed the analysis to consider planning units from the beginning of their analysis: "*We started from the beginning from the planning units to unify the unit of analysis."*

Table 14. Opportunities and considerations detected in the implementation of SUDS in Bogotá.

Stage	Opportunities	Consideration
Regulation	- Systematic inclusion in regulatory framework	- Practical implications of regulatory frameworks
Criteria Selection	- Multiple criteria - Stakeholder engagements from early stage	- Ensuring a holistic/representative perspective of selected criteria - Flexibility to changing criteria over time - Including future scenarios (climate scenarios) - Including changing/future objectives
Location	- Location for maximum impact - Consider feasibility - Inclusion of future development	- Materiality and double materiality - Consider how NbS contributes to NbS within and between naturescapes - Inclusion of future climatic conditions
Planning	- Combining engineering and landscape planning perspective - Long-term cost-benefit analysis, including socio-economic benefits - Increasing political will for NbS - Increased stakeholder engagement - Frameworks for calculating the cost of implementation - Forward-looking "champions" at institutions	- Potential of involving selection of NbS in an early planning phase - Considering natural boundaries (e.g. catchments) and urban boundaries (planning units). - Incorrect application of methodology - Difficult to assess costs of implementation - Reliance on political will - Difficult to quantify long-term benefits - Needs social acceptance
Construction	- Learning and sharing - Collaboration between institutions	- Working with different competencies - Not a set supply chain of material/availability of material - Discrepancies in practice (construction) and theory (academia) - Flexible/repairable constructions
Monitoring and maintenance	- Knowledge sharing and learning - Pilots and long-term data collection	- Communication to the public - Designing for inclusive monitoring

5.2 Short-term imaginaries (Horizon 2)

While the last chapter focused on the imaginaries of present naturescapes in Bogota, and what lessons are presented with its current implementation, this section moves on to explore the second research question: *RQ2. How are naturescapes imagined to facilitate transformative change for well-being, biodiversity and climate adaptation envisioned, in future Bogota?*

To understand how naturescapes are imagined to contribute to a transformation in a short-term perspective (10-15 years), three documents are analysed to understand how official imaginaries perceive how NbS as naturescapes can be included in the future development of the city. These documents all look into the planning or visioning of Bogotá in 2030-2035. The imaginaries for the short-term future can be detected in the official policy documents, such as the land use plan of Bogotá, which discusses the future use of the NbS which can be linked in naturescapes. In this section, the documents analysed are presented as imaginaries, where the ambition of the document (for 2035) has been achieved.

5.2.1 Bogotá Land Use Plan Imaginary

i. Background of Bogotá's land use plan (POT):

The Bogotá land use plan (POT) is a roadmap to the urban development of Bogotá in 2035, where greening of the city is one of the four main pillars, of a holistic approach in incorporating green structures in the urban planning all over the city. POT aims to create a harmonious and sustainable relationship between the city and its rural environment through implementing programs which improve ecosystem connectivity, greening and climate adaptation, using main ecological structures and creating multifunctional green and blue corridors in the city and adjacent areas.[88] The POT was a result of a vast interactive process, where over 9000 activities were led with over and almost 38000 contributions through among other ways, on-site workshops, virtual meetings and courses, suggestions through virtual channels such as social media and e-mail, phone calls (Mayor's Office Bogotá n.d.). The plan includes strategies, guidelines and future development of the different structures involved.

iii. General contributions to the urban themes:

Well-being and access to ES: Through extensive efforts from both public institutions guided by green and urban policies, and through community engagement Bogotá has begun a transformation to a greener city providing ES widespread in the city, both in urban and rural areas. The main ecological structures of Bogotá have been successfully protected and contribute to a harmonious and sustainable relationship between the city and its rural surroundings. Important environmental

[88] POT. Article 565. Programs of the Land Management Plan.

areas in Bogotá are protected and well connected, to ensure *"quality of life of its current and future inhabitants and the quality of urban, rural, district, and regional ecosystems."*[89]

The overall environmental conditions in the city have been improved, with increased green cover, improved soil permeability, and solutions which allow better water regulation and improved hydrological cycles in the city. [90] In the city, the function of natural structures in public spaces has increased through improving connectivity of natural structures, increased vegetation cover, more green infrastructure, and the presence of urban agriculture. [91] Here the main ecological structures are more well-connected with each other and throughout the city, with urban forests, green roofs and walls, and SUDS balancing the benefits of people, with its benefits to the environment.[92] New natural elements are integrated into current ones, to improve their conditions and provide better ecosystem services.[93] Public space has become abundant in green structures and nature has become visible in the city through *"opening up space for water and the green fabric, promoting a more orderly relationship with the Main Ecological Structures and the city".* [94]

Guidelines in the POT promote accessibility of the MES to all inhabitants of the region, along with activities and experiences for recreation, inspiration and public enjoyment, for which community proposals are encouraged. [95] The MES should be well connected with infrastructure for biking and walking, adapted to the topography and natural and cultural landmarks. [96] Also, public services for social inclusion should be promoted in parts of the MES, such as housing solutions, mobility infrastructure and public space. [97] Such development should however not negatively impact the status of the MES, or impair its connectivity and ecological functionality. [98] For example, permeability and eco-efficiency should be promoted in infrastructure projects in the area.[99]

Preserving and restoring Biodiversity and ecosystem connectivity are key objectives for preserving the MES, to support the region with ecosystem services. [100] In the MES, more research activities are promoted to better understand natural, social and cultural values and functions of biodiversity, and activities in the MES, such as ecotourism and resource extraction, should not alter biodiversity in a way which can be foreseen.[101] The natural structures connect urban and rural,

[89] POT. Article 5. Land use planning objectives.
[90] POT. Article 122. Design criteria for the public pedestrian and meeting space system. 4.a-b (p 146)
[91] POT. Article 122. Design criteria for the public pedestrian and meeting space system. 4.a-b (p 146)
[92] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[93] POT. Article 122. Design criteria for the public pedestrian and meeting space system. 4.a-b (p 146)
[94] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[95] POT. Article 74. Conditions and guidelines for the uses of the Principal Ecological Structure. (124-127)
[96] POT. Article 74. Conditions and guidelines for the uses of the Principal Ecological Structure. (124-127)
[97] POT. Article 14. Actions that concretize the Model of Territorial Occupation -MOT. (p. 61)
[98] POT. Article 74. Conditions and guidelines for the uses of the Principal Ecological Structure. (124-127)
[99] POT. Article 74. Conditions and guidelines for the uses of the Principal Ecological Structure. (124-127)
[100] POT. Article 4. Guiding principles of territorial planning. 2-10
[101] POT. Article 42. Strategies of the Principal Ecological Structure. 1.3-1.4 (p. 86)

empowering the natural and social connections between the two spheres. [102] In rural areas, historic architecture and farmers' housing are protected, and the ancestral knowledge of rural and farmer communities is recognised, through which their understanding of natural dynamics helps protect the water flora and wildlife. [103] The informal development in the urban-rural areas of the district has been contained, and a process has begun to resettle families located in high-risk areas while improving the environmental conditions protecting the natural heritage and preserving the architectural and cultural heritage.[104] Instead, the edges of the city provide an "organised transition" between urban and rural space through implemented edge parks and eco-neighbourhoods. Here, urban-rural "transition areas" with urban architectural typologies are supported with green structures, such as green corridors. [105] The city is increasing its food security through measures both inside and outside the city. In the agricultural lands soils are protected through sustainable agricultural practices, on which organic and quality food can be harvested.[106] The city's equal access to ecosystem services is improved through the general gender focus in the land-use planning through *"decisions and actions that guarantee women and girls the rights to the city in all its dimensions",* and through an ongoing elimination of feminisation of poverty. Gender gaps are reduced, and women are empowered both in urban and rural spaces, allowing them to inhabit the territory in a fair equitable and supportive manner. [107]

Biodiversity and ecology: In Bogotá in 2035, the conditions and connectivity of important ecosystems and environmental areas improved through protection and restoration efforts both within and outside of the city. The city cares for and recognises "biodiversity and inclusion of all forms of life in Bogotá, through the inclusion of flora, fauna, and domestic animals." [108] This is primarily done through protecting, restoring and connecting ecosystems within and outside of the city. The Main Ecological Structures serve a key role in strengthening the ecological connectivity both between MES and with other areas of regional environmental importance within and outside of the city. The ecosystemic connections between urban and rural areas have been strengthened, benefitting humans but also wildlife through sufficient wildlife crossings and ecological corridors. [109] In Bogotá coherence in land use planning is promoted on a regional, district and local scale, restoring both natural and urban areas. [110] Since the early 2020s, these ecological structures have

[102] POT. Article 394. Medium and short-term objectives of rural planning. (312)
[103] POT. Article 394. Medium and short-term objectives of rural planning. (312)
[104] POT. Article 394. Medium and short-term objectives of rural planning. (312)
[105] POT. Article 103. Guiding principles of urban planning in the urban component. (p. 125)
[106] POT. Article 4. Guiding principles of territorial planning (p.4). 12. (p.50)
[107] POT. Article 4. Guiding principles of territorial planning (p.4). 6. (p.49)
[108] POT. Article 4. Guiding principles of territorial planning (p.4). 10. (p.50)
[109] POT. Article 394. Medium and short-term objectives of rural planning. (312)
[110] POT. Article 4. Guiding principles of territorial planning (p.4). 2. (p.48)

increased by 30% and 4000 hectares of environmentally important areas have been restored (Manuel Vásquez Ardila 2021). The city is harmonising its relationship with surrounding ecological structures, such as the rivers, through promoting activities and infrastructure which is compatible with the ecological values.[111]

Measures have been implemented for strengthening the eco-systemic functions in the rural-urban borders, where the control of urban sprawl, and need of urban space is considered. [112] Through frameworks and policies, such as the urban planning policy, biodiversity and the quality of ecosystems have been improved, supporting their capacity to increase the city's resilience in the face of climate emergencies, and improving social services[113]. Through the implementation of strategies which promote public spaces in MES, without compromising the objective of conserving and connecting them, they continue to serve as ecological systems which "*conservation of spaces and ecosystemic processes that concentrate biodiversity in order to guarantee the provision of ecosystemic services offered to the city and the region"*.[114] Water systems are restored, recovered and re-naturalised, which allows for several ecosystem services, such as conservation and regulation of water.[115]

Many ecosystems have been restored, along with their soils and natural ecosystems, providing natural habitats for wild species to recover in their natural environment. Also domesticated species can find a home here. Furthermore, several habitats have been enhanced, thanks to management aiming at recovering biodiversity attributes, such as ecosystem restoration through activities aimed at management, repopulation and reintroduction or transplantation of species. This includes both restoration measures (ecosystem restoration RSE,[116] Ecosystem recovery EPR,[117] and ecosystem rehabilitation RHE[118]).

Climate adaptation: Greening of urban and rural areas has developed as an essential way to adapt to climate change. [119] The implementation of NbS in public spaces, such as SUDS, has allowed reduced volumes of run-off water, leading to a more resilient city. [120] Climate adaptation measures have been taken to adjust both the present and expected future impacts of climate change. These measures reduce the impact on the environment and vulnerability of the city and increase the resilience and the adaptive capacity of ecosystems, infrastructure and communities, which are

111 POT. Article 42. Strategies of the Principal Ecological Structure. 4. (p 86)
112 POT. Article 42. Strategies of the Principal Ecological Structure. 6. (p 86)
113 POT. Article 102. Urban planning policy of the Capital District.
114 POT. Article 42. Strategies of the Principal Ecological Structure. 1. (p86)
115 POT. Article 42. Strategies of the Principal Ecological Structure. 2-3. (p 86)
116 **Ecosystem restoration (RSE):** Restore ecosystems with composition, structure and functions in line with pre-disturbance.
117 **Ecosystem recovery (EPR):** Aims at recovering degraded ecosystem services of social interest. Generally, the recovery does not allow system to be self-sustainable and does not resemble pre-disturbance system.
118 **Ecosystem rehabilitation (RHE):** Aims to rehabilitate degraded systems and preserve some species, and provide some ecosystem services that allows the system to be self-sustainable.
119 POT. Article 4. Guiding principles of territorial planning (p.4).
120 POT. Article 122. Design criteria for the public pedestrian and meeting space system. 4.a-b (p 146)

taking advantage of climate opportunities.[121] Eco-urbanism and sustainable construction are promoted in which risk management and planning is incorporated in its construction. [122]

Water resources are sustainably and rationally managed, where alternative management of rainwater on infrastructure is promoted, and the highland wetlands, Paramos, which is the city's main source of water, and its surrounding ecosystems, are well protected. [123] The risk of disasters is being reduced and the city's adaptive capacity is improved to contribute to *"the wellbeing of current and future populations."*[124] This is done through the prevention of further degradation and increased restoration of ecosystems, and protection of soils. [125] The conservation and protection of MES contribute to this climate adaptation and risk reduction[126] where adaptation measures such as Eco-reduction[127] (Eco-RRD) and Ecosystem-based adaptation[128] (EbA).[129] To achieve this, the POT promotes the implementation of programs and projects for climate adaptation through using NbS, which, interestingly, is one of the few times NbS is explicitly mentioned in the land use plan. For example, interviewees promoted using more native plant species and the diversity of species in the mountain regions can have positive effects in limiting the impact of forest fires.

iv. Case study: contributions by Main Ecological Structures

The main ecological structures are vital in the support of this landscape of Bogotá as it supports both urban and rural inhabitants with a multitude of services.

Providing services: Bogotá can thanks to the sustainable management of MES rely on its surroundings for the production of various goods, as the diverse ecosystems support the inhabitants with sustainable extractive activities of both primary and secondary renewable products. Here, activities such as agroforestry, agriculture, livestock farming, forestry, aquaculture and fishing contribute to the basic needs and income of inhabitants, while supporting food sovereignty and maintaining ecosystem services in the rural landscapes.

Agroecological practices are used in both urban and peri-urban agriculture, which allows neighbourhoods and communities to organise around the design and implementation of such agricultural systems. This not only strengthens the well-being of the communities but also enhances

121 POT. Article 17. Territorial Measures for Climate Change Mitigation and Adaptation. 2.4. (p. 66-67)
122 POT. Article 4. Guiding principles of territorial planning (p.4). 1. (p.48)
123 POT. Article 4. Guiding principles of territorial planning (p.4). 1. (p.48)
124 POT. Article 42. Strategies of the Principal Ecological Structure. 5. (p 86)
125 POT. Article 42. Strategies of the Principal Ecological Structure. 5. (p 86)
126 **Structural risk reduction measures** are implementation of physical measures to prevent reduce risks/or hinder their increase, in extension and intensity, and ultimately reduce human and material losses.
127 Ecoreduction (Eco-RRD): Sustainable management, conservation and restoration of ecosystems to reduce risk, with the objective of achieving sustainable and resilient development.
128. **Ecosystem-based adaptation (EbA):** Using specific traits of biodiversity and ecosystem services as a part of a strategy of adapting to effects of climate change.
129 **Maintenance,** adaptation, and recovery of ecosystem functions: Interventions to maintain ecosystem conditions (structure and function) which ensures its ecosystem services. This includes the need of maintenance and operation of existing structures.

food sovereignty and promotes awareness and learning through activities such as waste recycling. A diversity of practices are used, such as vertical agriculture, agriculture with floating root systems and raised bed production, all of which aim to reduce waste and minimise the pressure on the surrounding ecosystems. Rather than chemicals, organic fertilizer and bio-controllers are promoted to have a productive, yet organic food production system.

The forests in and around the city provide many products. Many areas where invasive and exotic tree species were planted have been reclaimed by native species as the productive forest systems focus on native species in the production, planting and harvesting of timber products, without further reducing the forestry cover. The forests also provide secondary products such as flowers, fruits, bark, leaves, seeds and resin, which are harvested without compromising the integrity of the forest. Here nurseries provides a supply of plant material required for ecological restoration with an emphasis on native species.

Recreational services: The MES also provides space for contemplation, inspiration and recreation through actions which have been taken to enhance environments for recreational use. Here there is room for both relaxation and outdoor activity, which facilitates civic encounters and both physical and mental health. The activities arranged range from civic gatherings and spontaneous games to high-performance sports. The space is open to all inhabitants and different populations, especially those with disabilities, children, women, and the elderly, as well as caregivers and their dependents. Here one can find pedestal trails, scenic viewpoints, bird observatories and outdoor furniture to rest on, which are all built and designed to minimise its disturbance to the ecosystems, through using NbS and avoiding hardening of surfaces.

The conserved and restored natural environments have also become popular eco-tourism destinations where visitors come to observe, learn about and experience the ecological and cultural diversity which Bogotá region has to offer while minimising their negative impact on the environment. The visits promote learning and awareness raising but also contribute to knowledge exchange between tourists and the local communities which manage the eco-tourism. Here community-based eco-tourism empowers the communities and contributes with incentives to protect the natural structures.

Knowledge and awareness: The inhabitants have increased their knowledge and awareness about the surrounding nature and its services thanks to many activities which include civil society in research, monitoring, and educational activities. Here there is space for building and exchanging knowledge and increasing the understanding of natural, social and cultural values and function of biodiversity. The physical installations which facilitate these knowledge activities have taken into

account the environmental conditions of the area, allow for soil permeability and minimise the disturbance of their surrounding ecosystems.

On these sites, there are public services which contribute to sustainable maintenance of the MES, with public water and wastewater services, waste management where organic waste is taken care of and contribute to composting and waste recycling.

Table 15. Main Ecological Structures contributions to urban themes (Horizon 2).

Well-being and ES	- Urban and peri-urban agroecological practices - Primary and secondary forest products - Rural agroecological systems (food sovereignty) - Public water and sewage services - Regional ecosystems - Nurseries for native species - Increased access to public space - Ecotourism - Space for non-conventional and non-organised outdoor sport - Space for organised and high-performance sports - Environmental education - Monitoring and research - Communal activities (e.g. urban agriculture) - Ecotourism contributing to education and awareness - Ecotourism benefitting local communities - Activities for civic gathering/engagement among different populations (disabled, children, women and elderly) - Protecting and making use of cultural and natural heritage - Overall increased ES in metropolitan and rural edge zones
Biodiversity & ecosystems	- Conservation - Restoration - Blue and green ecosystem connectors - Conservation practices (RSE, EPR, RHE) - Developing and preserving natural vegetation cover - Sites for organic waste management and compost production
Climate adaptation	- permeable surfaces - Developing and preserving natural vegetation cover - Community actions for landslide prevention - Overall risk mitigation/unspecified risk mitigation

5.2.2 Imaginary elements in case study ZIBO

In this section, the development plan of ZIBO has been analysed to understand the current state of ZIBO, and how nature-based solutions are involved to revitalise the area until 2035.

As a measure to implement the objectives of the POT, Strategic Action has been pointed out in 25 areas of Bogotá, in which comprehensive interventions will be made over the coming decade. The areas are identified based on their need for revitalization, as well as their potential for development. In the revitalisation of these areas, public and private institutions, as well as communities, will be involved in developing social, economic, and environmental services, such as

mixed neighbourhoods with housing, public spaces, and work opportunities.[130] The Expanded Centre of Bogotá hosts 1 million people and attracts 3 million people every day, making out the greatest part of Bogotá's economy, and hosts many public and private institutions along with cultural and historical areas. Seven per cent of this centre is made out of the Industrial Zone of Bogotá (ZIBO) is characterized by its industrial structures and low residency.

i. Current state of ZIBO

ZIBO was planned already in the Pilot Plan for Bogotá in 1951 and remains the largest compound of historical industrial buildings in Colombia. The area which covers more than 500 ha is characterised by industrial buildings, with few residential buildings (Renobo, n.d.). In 2018, less than 18500 people inhabited the area (Renobo, n.d.). Despite being centrally located in Bogotá, the zone and its historical context, have largely been overlooked both by the city planning and citizens. The area is characterised by industrial, logistics and services, and has a low density of residents. The ZIBO area puts forward two major characteristics: one which is residential and service-oriented, and another which is dominated by logistics and industrial facilities. The population in the areas has overall reduced, while hotel services have increased. The industrial side of the areas is characterized by a small low population density, yet with a diversified economy within niches of mechanical industry, automobile services, retail trade, and waste, among others. The area has a high number of people living in (monetary) poverty, and over the last two decades the population in the region has decreased, especially the younger population (0-30 years) (District Planning Secretariat 2023).

However, in recent years the area has been recognised as harbouring a unique opportunity for development where the city's industrial past is recognised and repurposed. The Strategic Action of ZIBO, aims to make the area an urban metropolitan node which reinforces and supports multiple benefits to its inhabitants while being in balance with ecological structures and care for the environment (Secretaría Distrital de Planeación, n.d.). ZIBO is together with two other strategic areas, a part of the development of Bogotá's new technological hub, called "The Innovation and Knowledge Centre", which should be transformed environmentally, socially, and economically to facilitate science, technology and innovation. As with other strategic action areas, the development of ZIBO should identify ecological structures be identified and their conservation and restoration incorporated in the area, and develop mechanisms for the management and financing of the environmental dimension of the area.[131] Additionally, measures should be defined to mitigate the effects of and adapt to climate change, reduce air and noise pollution and soil contamination, and

[130] Article 478. Strategic Actions.
[131] POT. Article 479d. General objectives and specific guidelines of the strategic actions.

address the lack of green areas.[132] This is currently done through the formulation of a plan for the area, which will be used to develop the area over the coming 10-15 years. However, one of the features that has made the industrial area so attractive is the fact that the area is built with wide road networks and loading areas, which makes the area easier to reclaim for public space and greenery. UD1 notes that the features left from the 1950s make it a suitable place for renewal: "T*hose sidewalks you could actually turn into greenery without having to buy land, without having to turn this into a big kind of public space project, just by reducing car width without limiting the operability of the neighbourhood. You generally don't find that in Bogotá. It's very hard to find spaces for sidewalks in the public. Generally, what happens is the city bites into private land to grow the sidewalks inwards, but it never grows towards the street. One of the big reasons why ZIBO now exists is because there is a desire to create rain absorption and greenery in the whole city, but this is a place where you can actually do it quickly without going into taking private land away."*

RenoBo is the public actor coordinating the project development in ZIBO, which is an area that has been prioritised due to its social, environmental, and economic issues, and opportunities to develop. The low residential density and central space make the area an attractive space for transformation, from industrial and logistics service and trade to an economic hub of knowledge and innovation, including relocation of companies, and involvement of both the private sector and academia. PU1: *"There are a lot of actors that has interest in the area because the owners of the land want to sell the land, and it's more easy like to develop a project in there […] Right now, we are working with different actors and ZIBO is like a very attractive area because of the location, because of the background, and because there are a lot of actors right now in the territory, for example, some local government entities […] Also, Zibo is going to have in their interior the first technological and innovation centre of Bogotá, so it's a very attractive area"*

Well-being and access to ecosystem services

ZIBO has a low availability of public space and greenery, with poor environmental conditions in regard to air quality, soil quality and water quality. Noise level is, especially along the main roads in rush hour, above the permitted level of noise, and the air quality is above WHO's recommendations (District Planning Secretariat 2023). The quality of the natural landscape and the functionality of public space in ZIBO is in most areas considered deficient and degraded, lacking connectivity of green infrastructure, natural scenic values and presence of trees and green areas. Also the functionality of public urban space was overall rated low, such as the availability of safe passages, presence of street furniture for public gatherings, harmonious and aesthetic urban landscapes, and safe pathways for pedestrians ranked medium. The residential area Centro Urbano Antonio Nariño

[132] POT. Article 479e. General objectives and specific guidelines of the strategic actions.

(Urban Centre of Antionio Nariño) was the only area which was classified to have high values on all natural landscape indicators and is also considered an ecosystem connector.

Over the last forty years, the greenery of ZIBO has decreased and today has low access to greenery such as trees and parks. The low availability of greenery is both a concern for the availability of recreational public space and for the permeability of the area. UD1 has followed the development of ZIBO historically, UD1: *"It's very little. I think if you walk around, you can see that it's very scarce in terms of the existing nature but it's also very sad in terms of how local landowners have dealt with nature historically and the places. The private area of ZIBO is a full coverage where there's no empty open areas in terms of the private landowners. In terms of the public space, it's very scarce. Most of it is just roads and sidewalks. There used to be trees but in the 80s, they cut them down to create areas for trucks to park on top of sidewalks."*

Recreating greenery in the area will not only benefit the people living in the area but could also contribute to promoting its historical and cultural value UD1 notes: "*I actually think regreening the area would be very beneficial, even for the sake of the historic element, because it would make the public space more welcoming. And I do have this belief that if local residents or just general citizens are not given the welcoming conditions to come and value the historic architecture that's left, it will never be truly valued. And so if we don't start by the public space, and the greening of it, and the improvement of the public space, people will never want to come here. It will always feel dry and gray and dusty."*

The greenery of ZIBO is mainly concentrated along main roads, such as the large road Avenue American. Due to the low number of residents in the area, there were only (in 2021) 0.4 trees per

Figure 18. The Comuneros canal in western ZIBO is an ecosystem connector which faces challenges with litter and poor water quality.

inhabitant, which is above the WHO minimum recommendation of (0,33 trees per inhabitant). However, the tree count per hectare (14) is well below the city average (25), and the trees are mainly concentrated around the main roads and residential areas in the west, while the industrial areas in the west have a much lower amount of greenery.

While the greenery of ZIBO is relatively high per inhabitant (14.53 m2), this is mostly due to the fact that the amount of residents is low. Most green areas of the almost 27 hectares consists of parks, which mostly are characterized by scattered vegetation such as grasses, shrubs and trees, and separators of the major road Avenida de las Américas (District Planning Secretariat 2023). The lack of greenery and hard surfaces contributes to urban heat islands, due to the lack of shade, and the capacity for concrete and asphalt to store heat, which can impact the living environment with poorer temperature regulation, and increase air pollution levels. This impacts the health of the inhabitants, particularly vulnerable populations (sick people, elderly, and children), as well as people who conduct outdoor activities. As for green infrastructure, the plan has identified a couple of buildings with green roofs, and four urban gardens.

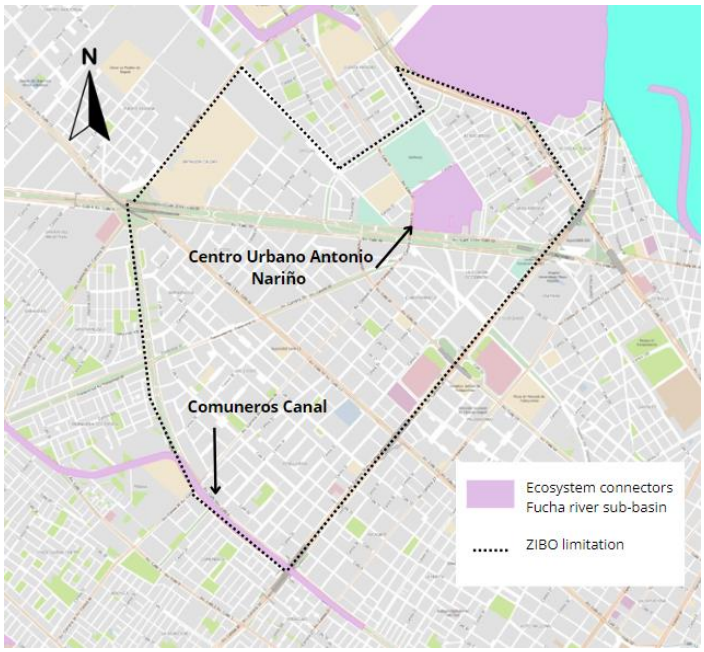

Figure 19. ZIBO has two eco-system connectors (in pink), which are sub-basins to the Fucha river. (Data from retrieved from IDU).

Biodiversity and ecosystems

The plan notes that there is low ecosystem connectivity in ZIBO, and a deficiency in green spaces, however it does not address the current state of biodiversity. While the diversity among urban trees

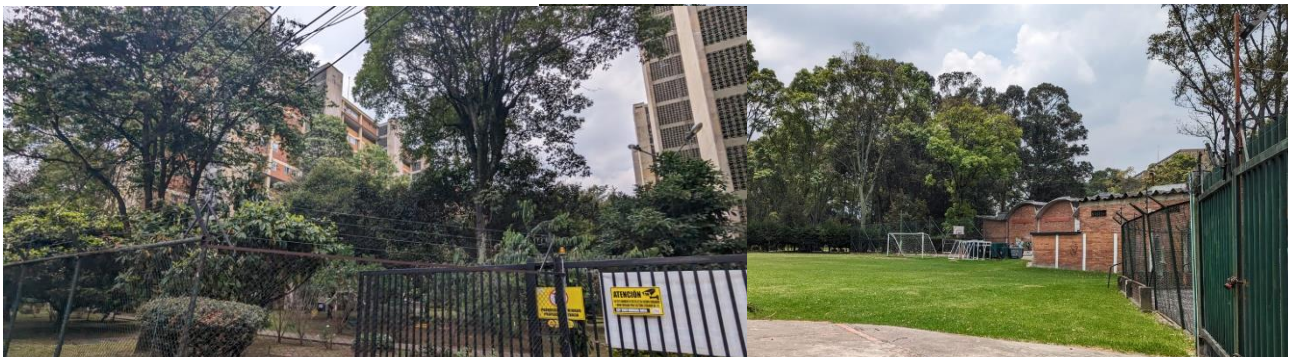
Figure 20. Residential area Centro Urbano Antonio Nariño is one out of two eco-connectors in ZIBO.

shows that the diversity overall is intermediate-high (District Environmental Secretariat n.d.), the ecological state of ZIBO is considered overall deficient (District Planning Secretariat 2023). ZIBO currently does not have any MES in the area but has two areas which are considered ecosystem connectors as they are a part of the sub-basin for the Fucha river. Firstly, the residential area Centro Urbano Antonio Nariño is considered an eco-connector as it makes out a small part (3%) of the Fucha river sub-basin. The area is the only area in ZIBO which is considered to have high values on all natural landscape indicators. While this area is located in the more inhabited part of ZIBO, the area is gated with no access for the general public. Secondly channel (Comuneros canal) contributes to the regulation of water. The channel currently faces multiple challenges, both with waste accumulation and discharge of wastewater, which impacts both the drainage of the channel and the water quality. The area is therefore pointed out as an important area for regreening through maintaining and recovering the ecosystemic functions of the channel.

Climate adaptation

Figure 21. Large parts of ZIBO is impermeable, and has insufficient draining capacity, which makes it prone to flooding in the western parts of the area. Authors own photo.

The lack of greenery and high cementation of ZIBO causes it to have very low permeability. UD1 notes that both private and public owners have contributed to this development: "*So it used to have more green, and it got torn down in the 80s. […] It has very few areas where the rain can actually reach the ground because either it's fully covered in the private area or it has been paved in the public area so it's very sad in terms of nature.*". While most of the ZIBO area has a low-risk level of flooding, there are areas in the western ZIBO which have medium to high risk of flooding due to restricted run-off availability, lack of and blockage of the local drainage systems. Additionally, the plan highlights the importance of improving the conventional sewage system, as large parts of the area have no or unfunctional drainage system. The increasing temperatures could generate threats for both the ecosystems and inhabitants in Bogotá, mainly through thermal stress of both high and low temperatures, increased respiratory diseases through air pollution (and forest fires) and modified behaviour of some plant and animal species.

ii. *Future state* - Naturescapes in ZIBO

As a priority strategic area, and as a part of the Innovation and Knowledge Centre, public entities of Bogotá are currently developing the formulation for ZIBO, which will present developing scenarios for the area. The formulation is based on both stakeholder engagements and the objectives of the overall land use plan for Bogotá, and is led by the Urban Operator for the area: The Urban Renewal and Development Company of Bogotá (RenoBo). Over 2023 and 2024 consultations sought to create scenarios involving both public and private institutions, as well as with the community in general including citizen dialogues and workshops, dialogues with specialised actors, and Co-creation workshops for the urban planning unit) (Secretaría Distrital de Planeación, n.d.). The development in the district focuses on innovation, knowledge, science and technology developing both public and urban spaces, and hosting both economic and academic hubs such as facilities for innovation and science, the Science Technology and Innovation Center (Renobo, n.d.). This hub will be integrated with mixed housing and public spaces. This will be achieved through developing almost 6000 new homes in social housing, and over 200 000 new jobs. The transformation of the area also takes into account the need to enhance ecological structures, for example through planting over 13,000 trees in the area (Renobo, n.d.), and the generation of 15,000 m2 of green areas prioritising native species. In this section, the plans for ZIBO are analysed for how NbS are integrated and how they can contribute to a transformative change in the area.

Well-being and access to ecosystem services

In the ZIBO imaginary, the district has improved the physical and functional connectivity of green infrastructure, protecting both green areas and individual natural structures such as trees. Greenery is incorporated into new public spaces which provide environmental and social ecosystem services to the city and the zone inhabitants. Here green areas are promoted, with ecological connectivity which generates provision of multiple ecosystem services. Green zones and green spaces for public use, such as gardens, shrubs and trees, are particularly important, as they contribute to multiple environmental values, such as regulation of micro-climates (temperature regulation), water regulation through run-off, and provision of recreational spaces for the well-being of social, cultural, and educational value. Different typologies of urban parks have been promoted in the area, creating a sense of variation for both inhabitants and biodiversity. Newly developed strategies allowed an increased planting of urban trees which are recognised to provide multiple ecosystem services such as recreation, regulation of microclimates (temperature and relative humidity) and water cycles, carbon sinks, and reduction of noise and air pollution. The increase of urban tree planting has been done in strategic green areas around road infrastructure, particularly focusing on

improving the green areas around the Comuneros Canal (an ecosystem connector) and the main avenues (such as the Avenida de las Américas & Avenida Ferrocarril del Sur & 19th Street) and local roads (such as around San Andresito). Here the plantation of native trees has been favoured, of various sizes to increase effective areas of public space for enjoyment of the community.

More than preserving the current greenery, ZIBO has several examples of green areas which have been restored, which has increased the presence of gardens and other vegetation in public spaces, roads and sidewalks. The increased greenery not only facilitates well-being through recreation but also has reduced noise and air pollution in the area as natural barriers (such as urban trees) and/or environmental control strips with acoustic insulation have been used as measures to reduce the noise levels. Measures have also been taken to reduce the need for driving in the area and the city's vehicle fleet has been updated with new technologies which emit less pollution and make less noise.

Here urban agriculture is promoted through providing available equipment and consultation which has resulted in more activities for communities to engage with the environment through agricultural practices while increasing food security and improving the hydrological cycle.

Natural resources are managed resourcefully, and "smart" NbS, such as SUDS are promoted to generate multiple benefits to the inhabitants. The SUDS are implemented to improve climate adaptation, particularly in areas in the south which are prone to flooding. However, the SUDS also provide secondary benefits, such as green space for recreation and relaxation, increasing physical and mental health, improving the aesthetics of the landscape, and thus increasing the value of surrounding properties and reducing air and noise pollution.

Here public health and well-being of the inhabitants is promoted through increased walkability in a walk-friendly city image, where green axes allow pedestrians to move safely and comfortably. The pedestrian networks are well-connected with continuous road networks with strong greening components which reduces pollution and increases contact with nature. And increased access to scenic routes with high landscape value in terms of natural historical value and strong greening components. Also infrastructure for cycling and micromobility has been developed along with the greening of these networks. Along the roads, vegetated strips are implemented to increase the urban resilience, and improve the environmental quality, while contributing to ecosystem connectivity. Here the streets are not only for walking but also for resting, sitting, playing and waiting, for everyone, including those with reduced mobility. The buildings are designed with "human-scale" in mind which provides a pleasant walking experience, where gardens and walls of private properties are covered in greenery.

Biodiversity

In ZIBO the increased availability of greenery and public space has not only improved the conditions for humans but also for biodiversity. The conditions for biodiversity have improved with both the protection of current green areas and the expansion of new areas. The planting of trees and increase of permeable and vegetated areas of various sizes along the roads and sidewalks, has generated better ecological and functional connectivity within the city and to Main Ecological Structures. All central separators which are wider than 3 meters have been transformed into green areas (in at least 70% of their surface), and functional and inclusive design has been made with the involvement of citizens. The improved conditions along the Comuneros Canel benefit a variety of biodiversity and have also improved the water conditions in the canal and in the Fucha River where the water is discharged. Due to a lack of sufficient space, small typologies of SUDS are favoured over large typologies such as wetlands, to handle storm and run-off water which also provides benefits to biodiversity. Continuous improvements are made to protect biodiversity and its ecosystems and reduce the vulnerability of the population of urban infrastructure, through strategies which guarantee sustainable construction.

Climate adaptation actions

From having been a hard-made surface with low drainage capacity, ZIBO now has adequate provision and intelligent management of water, sewage and electricity services for the current and future population of the EA. In public spaces, small typologies of SUDS have been implemented, which have been selected based on the spatial requirements, and the need for ecosystem services in the area. The SUDS are used to "imitate" the natural conditions of water cycles, to reduce the impact of flooding. The natural elements of the SUDS are also used to provide temperature regulation. Here there are a variety of SUDS, such as bioretention zones, green stripes, infiltration ditches and tree pits, which provide multiple benefits. Through increased vegetation covers they manage runoff water from roads, which usually have high concentrations of pollutants associated with vehicular traffic. They also support biodiversity and act as carbon sinks. The selection of SUDS has kept in mind (i) the need for the provision of ecosystem services (e.g., flood regulation, water quality improvement and generation of socio-cultural services), (ii) the budget available for their implementation, (iii) Consideration of guidelines of technical regulations (EAAB 2018). Due to lack of space, small-scale SUDS are favoured over other potential structures for managing runoff water, such as restoration of wetlands, artificial wetlands and drainage basins, because these solutions would require more space than is publicly available.

These water and sewage networks are designed to provide social and environmental ecosystem services while preventing flooding. The increased green space has been designed with nature-based

climate adaptation measures in mind, through the implementation of SUDS. Furthermore, the residential areas have an adequate provision of water supported by SUDS which improves the rainwater harvesting infrastructure. The NbS in the area successfully reduces volumes of run-off water which are discharged to the storm sewer systems, especially in areas with medium or high threat of waterlogging, and in areas which lack ecosystem services.

Several typologies of NbS, such as infiltration trenches more permeable pavement and other types of SUDS, have been implemented to reduce existing pressure on the conventional sewage system while contributing to climate adaptation. For example, SUDS has been implemented along the Comuneros Canal to deal with run-off water and improve the water quality of the canal and the recipient of the water. These reduce the concentration of pollution, as well as contribute to the recovery of natural hydrological cycles, improving the water quality of the waterbodies receiving the runoff and reducing the risk of flooding. The Centre of ZIBO is a diverse, green and intelligent space with mixed opportunities and experiences for all ages, where efforts have been taken to make it flexible and adapted to climate change. Nature-based solutions such as tree-planting and green roofs are used to mitigate the consequences of urban heat island effects and altered quantity and intensity of rain.

Through these interventions, ZIBO has improved the quality of life for residents and workers in the area through planning processes which has encouraged citizen participation in the development of the area. This transition has been financed with strategies which account for the distribution of burdens and benefits. [133]

Table 16. Figure 19. Naturescapes contribution to urban themes in ZIBO by 2035.

Well-being and ES	• Public health and well-being • Walkability • Contact with nature • Increased physical safety
Biodiversity & ecosystems	• Conservation of current green spaces • Functional and ecological connectivity • Protection of biodiversity generating ES
Climate adaptation	• General risk management • Run-off water management • Reduction of pressure on conventional systems • Reduced clogging of waterways

5.2.3 Short-term imaginary conclusion

To understand how naturescapes are imagined to contribute to well-being, biodiversity and climate adaptation in the short-term future, two planning documents have been analysed more closely above, the city-wide land use plan (POT), and a technical standard document for a prioritised area

[133] Distribution of burdens and benefits

for urban renewal (ZIBO). Both documents span from the present to 2035, and as such the imaginaries for natural structures, as included in the defined naturescapes, can be detected in the documents. The plans cover different geographical ranges, and therefore naturally contain different levels of detail, yet common themes can be found in the documents. For example, both documents promote increasing connectivity of green infrastructure to strengthen both ecological and functional connectivity. Furthermore, both plans prioritise small SUDS typologies, as they are more feasible to implement both in terms of space and economically.

The varying geographical scale can also give insights into the varying priorities in the city. For example, the POT puts high emphasis on increasing activities for nature restoration and conservation in the urban-rural border, increasing both ecological and social functions. For example, many ES that the MES can contribute with are listed such as primary and secondary products from forestry, and ecosystem-based climate adaptation approaches. While the need to develop more public areas applies generally in the city, the imaginaries for naturescapes connected to more central urban environments are less explicit. Here, the understanding of the ambitions for the renewal project of the centrally located industrial area ZIBO contributes to a better understanding of how the imaginaries from the wide-spanning POT are applied in practice. While the ZIBO projects mention several activities to increase greening and access to public space in the area, the gathered ES are far less than those mentioned in the land use plan. Even though this is not the final document of the plan, this indicates that the overarching urban plans have more ambitious images for NbS than practical projects, where the development of naturescapes has to be weighed against other measures such as physical and economic feasibility.

5.3 Long-term imaginaries of Naturescapes (Horizon 3)

In this section, imaginaries for naturescapes are explored in Bogota for the long-term future (Horizon 3), related to the second research question: *RQ2. How are naturescapes imagined to facilitate transformative change for well-being, biodiversity and climate adaptation envisioned, in future Bogota?* This has been explored through a novel- survey approach where an AI-moderated online-survey tool was used to provide the participants (10) with an interactive survey experience, which took most participants about an hour to complete. The survey uses a backcasting approach where the participants were presented with a scenario of Bogotá, specifically the industrial zone (ZIBO) which had been transformed into a place which generated high values of ecosystem services related to the three urban themes. This was done through a multiple choice question where the participants could select three ecosystem services within each theme that they considered particularly important, followed by open-ended questions about how they imagined that NbS could contribute to these themes, and how these NbS could be managed. The participants were presented with three case-

study pictures of areas in ZIBO, for which they could anchor their thoughts on transformation for the three urban themes.

5.3.1 Bogotá 2100: Well-being and access to ecosystem services.

In 2100, Bogotá is a safe, engaged and self-sufficient space where both public authorities and communities play a central role in designing, monitoring and maintaining a wide array of multifunctional NbS. The naturescapes in Bogotá build have been managed to improve their capacity in supporting provisioning services, such as food supply and water supply, while contributing to an inspiring and aesthetic environment which is managed and used by communities, and continuously contributes to individual and collective learning experiences.

Figure 22. Ecosystem services selected in the survey (Urban theme 1: Well-being)

Community engagement

Here naturescapes are common elements in public spaces, generating a multitude of services and providing educational learning and experiences for which communities are an essential part in the planning for and monitoring and management of NbS. This guarantees their inclusive management and their long-term use and functioning and empowers the relationship towards nature. AC4 shares a vision: *"Nature-based solutions can be used as promoters of citizen well-being. The change and transformation of public spaces, which promote permanent interaction with nature, transform the idea of well-being and increase the intangible values of these spaces and the sense of belonging."*. The involvement of citizens creates a long-term and cascading effect of sustainably managed public spaces, where people not only care for the spaces and their maintenance but feel as one with it. In this way, the citizens take ownership of and advocate for greening with NbS and all its intangible services, helping it expand to other areas and engage more citizens. The generation of awareness of environmental activities helps increasing the education of the region in general and contributes to an increased development of the whole country. Both scientific and governmental support and tools help communities to engage in ecosystem management which is crucial for long-term sustainability.

Water supply:

In Bogota 2100 the naturescapes are well connected and holistically managed to ensure the water supply of the whole region, not only relying on one single source for water supply but using different structures of NbS to manage water resources effectively and sustainably. While the highland wetlands, Paramos, continue to be an important ecological system which contributes to the city's water infrastructure, the urban area found innovative ways to be more self-sufficient on both potable and non-potable water, through harvesting rainwater and managing and making use of run-off water. This both increases the city's resilience in times of drought and lack of rainfall, while allowing the natural hydrological system to take time to regenerate. This has been possible thanks to successful incentives for all residential, commercial, and public infrastructure to collect, store and recycle rainwater, and prioritise potable water for drinking, while using non-potable water for other purposes, such as for flushing toilets and irrigation. Harvesting and using rainwater also decreases the amount of water that goes as run-off, which both decreases the risk of flooding, and decreases the volume of water which has to be treated.

At the same time, the watershed has had time to regenerate, and its ecological and functional services has improved with the help of restoration and reforestation, reversing land-use change in the Andean highlands. Wetlands, rivers and streams have been sufficiently restored which now regulate both quantity and quality of water, reducing the risks of flooding while providing spaces for both humans and other species to thrive. Also productive areas of the region have been rehabilitated with native species, in which sustainable production models are used to supply the region with products and services.

Food supply

In Bogotá 2100, the wide spread of urban agricultural activities supported by community efforts has generated more self-sufficient and local food production in the city, while benefiting biodiversity and health and well-being, and strengthening social bonds. Here urban gardens have been established in neighbourhoods all over Bogotá and are a norm among schools. These activities not only contribute to food but also education and awareness building in the society and more active citizen participation. The urban gardens, urban farms and vertical gardens, farms provide an open space, big and small, for people in all demographics can come to learn about food and agroecology and get involved in community led activities. Here multiple activities and processes ranging from reducing household waste and increasing composting and nutrient recycling to

vegetation recovery and carbon storage generate awareness and general environmental education which is carried beyond the urban gardens.

Here, people not only listen and learn but get to experience agroecological practices through digging their hands into the soil and reconnecting with nature and natural processes. But the gardens are not only a place for people to learn, but also to expand their knowledge, as they engage in citizen science projects, which are supported with physical and pedagogical tools, supported by, but not overtaken by, public and academic institutions. The citizen science contribute to both monitoring activities, and to a greater understanding of ecological systems through a variation of approaches, among others digital apps such as iNaturalist and other flora and fauna identification apps.

The agricultural activities are adapted to the capabilities of the local context where it is implemented and connect the urban centre with the rural agricultural areas. The rural agriculture continues to support the food production using sustainable measures, and improves the income for peasant families while providing quality food to the region and the city. While the agricultural activity is expanded in the urban region, is not done in such a way that it compromises ecological structures and functions, such as wetlands.

Urban agricultural activities contribute to the connectivity of ecosystems in the city, generating multiple benefits in the city. PU4 visions that "*Education and community participation are key to connect with these urban gardens and citizen science around, for example, establishing pollinator gardens or habitats and refuge for certain fauna that in the city, the trees and gardens also provide ecosystem functions associated with pollinators, birds. That can be done with a lot of connectivity in the city so that these green spaces are distributed equitably throughout the city, whether in schools, universities, or public places.*"

Connectivity

The greenery of the city is abundant and well-connected in the city, through parks, along streets and on infrastructure. The city has easy access to a variety of public areas, which are multifunctional and flexible spaces with functions which vary over the day and depending on the weather conditions. They provide recreation space for the general public and facilitate schools with outdoor activities, but they also provide other services such as water management. These green and blue structures are connected with other important ecosystems both within and outside of the city, which have been sufficiently restored and conserved to generate multiple ecosystem services.

Recreation

Despite remaining a highly populated metropolis, the inhabitants of the region have easy access to green spaces. Here NbS are implemented to enhance the landscape experience and for recreational and physical activities, such as space for games and trails for hikes, has increased people's general

well-being and health. The varying vegetation contributes to relaxation and enjoyment, and NbS has helped preserve cultural heritage and promotes cultural and spiritual values.

i. Case study: Pennsylvania Park

The participants illustrate their vision by anchoring their ideas to the Pennsylvania park located in the east of ZIBO. The picture is accompanied by a prompt describing how the park has transformed into a place which supports well-being and access to ES. Below their joint suggestions have been summarised to describe the park in 2100. The use of the garden is well captured in AC3s imaginary for the park's transformation:

AC2: "This is a park in Bogotá that was previously used by my ancestors solely for passing through and was perceived as a dangerous place, where we had to cross from one point to another without being seen. However, it has been completely transformed with the improvement of public parks. Lines of trees of different species were planted, educational spots were developed, so it has become a centre where students can come to analyse different types of species and their growth. Additionally, it is a place with a lot of shade, so the elderly come to sunbathe, but also to hide from it and only receive the warmth provided by the environment. It is a space that workers in the area tend to use to go to lunch, to interact, to create community. Additionally, in the background, there are composting bales, there are community organizations from the neighbourhood that have come together to create social movements in favour of nature protection, in defence of their park, which they now feel as their own. Spaces for collective gatherings or environmental meetings have also been created that promote almost constant interaction, almost every weekend, of the citizens with their surroundings, places for planting, urban gardens, and the improvisation or creation of workshops for the citizens."

Figure 23. Pennsylvania Park in ZIBO, Bogotá. 2024. Author's own picture.

In 2100 the Pennsylvania park located in the historical industrial zone has transformed to become an inclusive green public space which promotes a wide variety of ecosystem services supported by various installations of NbS, such as better integration of natural elements, multifunctional spaces, and activities for community learning.

Natural integration and Biodiversity:

What once used to be a park where nature and people were separated through hardened surfaces, interrupting infrastructure, and lack of natural structures, has now transformed into a place where natural structures are well integrated into the park. The lawn has been replaced with a great diversity of vegetation, supporting various structures and species, and promoting permeable surfaces where water can infiltrate the ground, and paths and other constructed ground use gravel and sand filters to help channel and filter the water safely and sustainably. The unesthetic infrastructure which used to interrupt the landscape, such as hardened surfaces and power poles, has been effectively minimised, where electrical cables are dug underground.

The park provides different elements of natural structures, varying from urban forests to more open areas for sports and play. The urban forests support a variety of diversity through its ecological and functional diversity, with native trees of various ages, sizes and species making space for prioritising species which are endemic to the Bogotán savannah and to Colombia. Here one can sit under the willow tree, tree ferns and endemic trees such as the *siete cueros* tree and enjoy its beautiful purple and pink flowers. These forests benefit biodiversity, where endemic birds, insects and other types of wildlife can find refuge and sources of food, and people as they can relax in the shade. NG1 shares her vision for the urban forests "*In the park, corridors of trees with native species were developed, allowing endemic birds of the region to nest and live in these forests.*"

All activities in the park are supported with permeable surfaces, which allow water to infiltrate the ground and support the local hydrological cycle. NbS, such as SUDS, provide spaces which can retain rainwater and shaded places which can keep the temperature down and retain moisture and rainwater. The park is rich in elements of water, from artificial wetlands, water mirrors and rivers which connect the water structures with other wetlands of the city. The wetland supports an abundance of species, particularly birds which are associated with the wetlands. The water structures are well integrated in the park, providing both recreational values and regulating ES, through supplying and regulating water. These water structures provide both recreational and spiritual values, where the region's natural heritage of water structures is reflected creating a secure place with a sense of belonging.

Inclusive multifunctional spaces for recreation and physical activity.

This park provides much room for recreation and physical activities which take place with nature, not next to nature. The park is available for all people, despite age and social status can enjoy the ecosystem services generated in the park, in a safe and comfortable environment despite the weather. As unnecessary infrastructure has been removed, this has generated more spaces for recreational activities, where the topography has been reworked to provide multifunctional spaces to benefit both play, aesthetics and water management in an efficient way. NG1 envisions what recreational services the park provides in 2100: "*Corridors or trails were established for people to engage in birdwatching, and lookout points were set up for birdwatching as well as meditation or sessions to connect with nature. Specific areas for pets and the dogs of people living near these parks were also created".*

Here equipment and spaces are provided to promote physical activity for people of all ages and constellations. AC3 imagines how the sports fields are made of permeable surfaces and serves several purposes: A3 *"To the left of the image, there would be a small depression for the soccer field [which] would also be a bit sunken to again be able to generate flood spaces or surrounded and surrounded by a sand filter that would help infiltrate the water into the subsoil."* Surrounding the sports field is greenery which creates a natural and protective barrier to the field, which also allows people to sit and watch the activities going on.

The design of the park generates a safe and secure atmosphere in both daytime and nighttime, where NbS provides clean and renewable energy to the park light sources to small and smart light installations provide simple and elegant lighting of the park, promoting a safety even at night, while minimising the disturbance of wildlife. AC1 shares the need to design with safety in mind to make it a more inclusive area *"I imagine that the lighting of that environment, which is used particularly for nighttime hours and is lit so that it is not unsafe, well, I would hope that by that time our society advances to the point where, as in other countries today, one can perfectly carry out physical and recreational activity in highly natural environments in cities, without the risk of physical security. I hope that will be the case, that nature-based solutions truly promote that sense of security and well-being."*

Also the buildings around the park, varying from four to ten floors, provide both residential housing and public space where the ground floor primarily provide space and services for the public.

Community engagement and learning

Once the park was an empty place situated in an area where few people lived. But even the workers in the area would not make much use of the park. In 2100 the park has transformed into a hub to community activities and a meeting point for civil society. These communities feel an ownership

over the park and are engaged to manage and care for it while strengthening social interactions in the park between different groups of society. Apart from the open green spaces, the parks have publicly accessible facilities clothed in green roofs and vertical gardens, providing a space for the city's inhabitants no matter the weather in a city with four seasons in a day. This space facilitates constant interactions between citizens through workshops, meetings and activities promoting learning activities for all ages. These learning activities are supported by the communal building, as well as learning spots spread out in the park. AC4 imagines the various ways the park can be made more inclusive: *"The park will have a trail, and along this trail, people will find different identified plants. And with these different identified plants, people will be able to learn about the ecosystem services these plants offer. Moreover, this park will have this information written in Braille to be inclusive for those who cannot see. And also, this park will provide citizens who cannot hear the opportunity to have someone interpret the messages in sign language. And the trails will be adapted so that people in wheelchairs and with disabilities can move through them without any problem. This is what I see in the park of the future."*

One of the key communities led learning activities is urban agriculture which has its own designated area in the park, providing ecological and cultural services. Here community member can engage in learning activities but also have agency over the park and rent their own plots to cultivate whatever they want, such as tomatoes, spearmint, oregano, green onions, bell peppers and cilantro. The garden is not only a place to generate food, but a test bed for different ecological practices and structures, with both agricultural lots and vertical gardens, for which they get tools and equipment provided for their needs. NG1 shares thoughts on the urban garden: "*Spaces for urban agriculture were created where species commonly used in Bogotá's cuisine, such as onions, aromatic plants, medicinal plants, and other vegetables that can grow without necessarily being in greenhouses, can be cultivated."*

5.3.2 Bogotá 2100: Biodiversity and healthy ecosystems

In 2100, Bogotá supports biodiversity and ecological values through well-preserved and well-connected ecosystems. Degraded ecosystems have been restored with native species to benefit the endemic biodiversity, and to make the region more resilient to climate change.

Figure 24. Figure 19. Ecosystem services selected in survey (Urban theme 2: Biodiversity)

Support of biodiversity

In 2100 Bogotá has embraced its unique and biodiverse landscape making nature visible in the city and more well-connected between urban and rural areas. The main ecological corridors, which used to be fragmented, have with the help of nature-based approaches for restoration and construction of new well-connected green areas and green corridors. For example, green corridors connect the different highland wetlands, Paramos, outside of the city, which improves the species' ability to migrate. The ecosystems are also connected through the city, for example connecting the hills in the east with blue corridors to the river in the west. The status of Bogotá river, which used to be both considered unsafe and in an alarming state of degradation has with the help of NbS restored its ecological functions. The ecological networks also provide refuge and food sources to wildlife using a diverse vegetation coverage using native and endangered species of both flora and fauna, which are typical to the area.

Water structures are available in various form, both as groundwater in the soil, and as surface water. PU3 reflects on NbS capacity to integrate greenery in the peri-urban areas: "*Nature-Based Solutions are an invaluable opportunity to contribute not only to water resource management but also to restore green areas that have been sealed off by urban development. By creating new green areas that encourage the permanence and conservation of wildlife species, the conditions for ecological and functional connectivity are improved.*

The well-connected blue and green structures uses a diversity of vegetation, and water structures and provide both refuge and food sources for wildlife and biodiversity. But they equally benefit humans with well-being and good living conditions and help the inhabitants of the city to re-connect with nature. Here the urban landscape allows people to co-exist with nature: *"I believe that*

in cities, maybe at this moment, we have become accustomed to living far from nature, far from animals of different kinds, but by 2100, it will truly be tremendously natural to coexist with nature, with animals, with insects, etc. And let's say that nature autonomously will generate these mechanisms of species control and control of some of the species that may become invasive or that disturb that collective well-being."

Action for managing climate change

Thanks to the well-managed ecological structures in and around the city, the region can better withstand the implications of a changed climate with longer periods of drought and extreme weather events. Using a diversity of native and endangered species when restoring natural and constructed ecosystems, the region can better manage dramatic climatic phenomena such as El Niño and La Niña. *AC2* notes the importance of preserving biodiversity to deal with climatic events in the future: *"Biodiversity is a pillar of nature-based solutions and it is a pillar because it ensures their resilience over time. In the face of Climate Change scenarios, this pillar becomes a mechanism of resilience for the future that ensures that the citizenry becomes an agent of change for the future."*

Learning from past experiences of forest fires in the hills close to Bogotá, the city has used native and endangered species, but to understand their role in the ecosystem in the face of changing climatic conditions. Native species do not only support biodiversity but also to make to better bind the soil and to find trees which are more adapted and resilient to extreme weather events, such as heats and storms. Many of the exotic pine tree forests have been restored with trees with greater foliage which in times of drought provide shade that mitigates the temperatures and preserves the moist. PU4 reflects over the importance of taking quick action to facilitate this change in the future *"Currently, in Bogotá, we have also suffered from forest fires, so it's important to start getting to know, researching, and implementing species that are adapted to these changes. For example, those associated with more pronounced droughts, which allows us to understand which species are susceptible or not to certain climatic conditions and secondly, to prioritize in the field, in natural ecosystems, in the face of these forest fires or climatic phenomena, which species would be at risk and therefore would be another indicator to be able to conserve them over time."*

Through restoring water systems, the soil is better kept and restored in the region, while supporting both aquatic and terrestrial biodiversity and generates recreational spaces for the surrounding communities.

i. Case study: Comuneros Canal

The participants were presented with a picture of the Comuneros Canal, located on the southern outskirts of ZIBO which is classified as an ecosystem connector in the city. The picture was accompanied by a prompt describing how the linear park has transformed into a place rich in biodiversity. Following are imaginaries for the transformed area of Comuneros Canal in 2100

Figure 25. Comuneros Canal in ZIBO. 2024. Authors own picture.

Re-naturalisation and biodiversity

In 2100 what once was a straightened canal on the outskirts of ZIBO with a cemented base and eroded sides, has transformed into a re-naturalised space where biodiversity has reclaimed its space for the benefit of people and nature. *NG2* imagines the re-naturalisation of the river*: "The change that has occurred between 2024 and 2100 would ideally be to denaturalise the river, to be able to give back the spaces to the water that has historically had over the Bogotá savanna. This basically means removing the river's channelling, generating water, creating normal flood areas of the river through ecosystems such as wetlands and riparian forests, generating connectivity between the mountains and the eastern rings with the wetlands that lead to the Bogotá river.*

Here, water has been given the right of way and wide buffer zones host a diverse set of ecosystems reclaiming its space resembling the place it was before the area was urbanised. The water flowing through the river is cleaned through NbS, such as SUDS, and the channel has been designed to adapt to the varying flowing capacities that can be expected both in 2100 and in the future. PU4 describes the new environment: *"In the future, I believe that the channel has been more naturalized, techniques have been found that allow for the re-naturalisation, so to speak, of these spaces. Along the*

edges, different types of flowers can be found, a different landscaping where we will find native species, but also wetland species that are in these edge zones and somewhat more natural areas, which allow for a more favourable water flow and thus integrate and form a more natural space in the city."

The channel and the area surrounding it has been transformed to a green and blue corridor which connects it from its source in the mountain, to its discharge in the Fucha River. The natural marriage of land and water makes room for biodiversity of all sorts. AC2 reflects on the re-wilding of the space: "*It is a place that attracts biodiversity, you can hear birds of different types, of different species, you can see how it has flourished the landscape has been rewilded and an environment has been created that promotes the well-being of the citizens.[…] You can see fish, ducks, different animals enjoying, let's say, the river."* Biodiversity is not only supported on land, but also in the water which provides a unique habitat for aquatic species PU4 notes: "*And in itself, this channel would then be formed as a green corridor because rivers also have a bit of a connection function, and we would use endangered native species as well as species associated with these floodable forests that you see here in Bogotá, not only trees but also herbs and others."* The riverbed not only supports biodiversity but also provides regulating services AC2 notes: *"By 2100, this river, this overflowing vegetation, the riverbed has different types of vegetation, aquatic vegetation, rooted, which helps with flood control.*

Recreation and services

The river that ones used to be a place unsafe and dangerous is now a meeting space for recreation and enjoyment. AC2: "*The river went from being a place violent or associated with insecurity to becoming a meeting space for the citizens around the river. So, you see places where the citizens have held different types of fairs to promote water conservation strategies, environmental awareness events with students from nearby schools. Community spaces have been created to interact with the water, with the river, and for everyone, it turns out to be very, very, very important to keep it this way."*

While infrastructure is still available in proximity to the river, the green corridor along the river is a space for space for citizens to come and enjoy nature and all its benefits. There are no cars allowed in close proximity to the river, but the river has in it self been recognised as an important and sustainable way of transporting in the city. "*The answer is that the river regains its course. Bridges are built so that people can cross the river. And I also imagine a sustainable river transport system. Because this is a very busy avenue, and it would be fabulous to have a transport system using this body of water."* Without the noise and air pollution generated along the heavily trafficked road, people can walk along the green corridor enjoying the fresh air and the sound of birds and insects thriving in the environment where the city meets the water. *AC2: "There are paths around the river so that people can jog and exercise, interact with nature. There are trees of different sizes on the banks, the water quality is perceived as spectacular, almost*

clear." The high status of the water quality of the water allows people to use it for their recreation through fishing and swimming when the weather conditions allow it. UD1 notes that: *"The water is clean and people can sit on the edge, even jump into the water if they like it on a warm day."* The river body provides a flexible and multifunctional space, for both recreation and management of extreme climatic events. AC1 notes: "*Although Bogotá is not a city where people tend to go swimming in a river, there are eventually times of the year when this is possible, even currently, and soon with climate change conditions, we may even see the benefit that in a city like Bogotá we will have moments when we can enjoy a body of water directly for fishing, swimming, enjoying with the family, also enjoying the presence of animals and natural coverings.*

Climate adaptation and water management

The river ecosystem is a multifunctional space, supporting recreation for people and biodiversity, but it also helps mitigate the impacts of extreme weather events. When there is heavy rain the river helps regulate and buffers the peak flows of water, generating a controlled flooding with NbS which prevents it from overflowing. This way the river protects urban infrastructure in the urbanised areas surrounding it. But the river is equally important in times of scarcity of rain the river retains water in the city which is used for maintaining green infrastructure. NG2: "*This model re-naturalises the river, as it allows for various ecosystem services such as the natural regulation of the river's flow rates that allow it to naturally adapt to changes in temperature and precipitation patterns caused by climate change, regulating the risks of downstream flooding, generating connectivity where biodiversity of flora and fauna species is strengthened, and soil is recovered, allows for carbon capture and additionally improves water quality due to those retention times that could be had in the wetland zones or the mountains, and also allows for water recovery, due to those retention times that could be had in the wetland zones or in the riparian forest areas next to the river."*

Social and economic transformation:

The transformation of the river was possible thanks to inter-institutional efforts with policy for environmental and recovery programs, but also has required a transformation of the city's development model changing the economic and social dynamics NG2 notes: "*However, this vision has a challenge, and that is that in a city as dense as Bogotá, recovering those spaces means changing the urban dynamics around it and recovering quite a few areas or large flood areas of the river, and this has significant effects on the economic and social dynamics with which the city has been built, and therefore not only a physical change is made with nature-based solutions to re-naturalise the river but also the economic and social models of the relationship in which families and communities and neighbouring neighbourhoods can somehow economically benefit from this re-naturalisation of the river. So the vision is really that of a change in the city's development model and where economic alternatives and alternatives in social dynamics around nature in the city are generated."*

5.3.3 Bogotá 2100: Climate adaptation

In 2100, Bogotá has with the help of ecosystem services provided by individual NbS and naturescapes built a resilient city which can withstand extreme weather events in the face of climate change. A network of SUDS helps regulate floods, tree covers and urban forests and green infrastructure helps regulate temperature and humidity, and permeable soils support the natural cycling of water. PU4 summarises how the changes made the city: "*Walking through my neighborhood, I start to notice that there are sustainable drainage systems that allow rainwater to be collected and stored for use during, for example, droughts. There are purifying filters that make the water drinkable and usable, meaning that there will never be a water shortage in the city. In the event of forest fires, there is also a source of water that can quickly drain the most affected areas. I also see green roofs that minimize the temperature on sidewalks or paths, reducing the heat and providing resting places for anyone traveling by bike or using these modes of transportation. Even on the bike lanes, I notice areas with trees that create cool zones for people. I see a lot of greenery, much more green, I see planters, I see green roofs on the Transmilenio (bus-system) stations and the future metro, which also help to lower temperatures.*"

Figure 26. Ecosystem services selected in the survey (Urban theme 3: Ecosystem services)

In 2100 the city still the climate threats predicted in the early 2000nds have become reality, and the city on a regular basis faces challenges such as heatwaves, wildfires, torrential rain events, floods, droughts and erosion. With the help of NbS, the city has adjusted to a new reality, not only managing the climatic events but also making use of it.

Flood mitigation

With heavy rains falling in the rainy seasons, the city has generated a wide and multifunctional system of NbS, which contributes to regulating and mitigating floods in urban and peri-urban areas. Floods are also regulated and managed through reforestation, and conservation of existing vegetation contributes to increased permeability of soils, providing better infiltration of water, and thereby reducing run-off water creating floods. The reintegration and connection of water bodies, such as the improvement of urban rivers, streams and wetlands has helped to create a more flood-resilient landscape which reduces the peak flow and runoff in urban areas in extreme weather

events. More than buffering the water the ecosystems improve the water quality, both through natural infiltration, and through NbS such as biofilters of various kinds.

Also more technical solutions are used extensively and systematically to deal with the heavy loads of water and to improve the water's quality. Thanks to SUDS, flooding due to heavy rainfall is no longer only an issue that has to be managed through buffering water and reducing the flow, but is looked upon as an opportunity for the city to recharge their magazines, to use in times of drought: AC1 reflects over how the city's water management should change by 2100: "C*urrently, we see how Bogotá is a city that has problems when it rains a lot; it floods very easily in multiple places in the city, and when we don't have water for our supply, we can't take advantage of water flows like rainwater, nor do we make the most of other water flows we have within the city. I truly hope that this current condition makes the citizens reflect, making decisions so that by 2100 our city can truly be independent of the climatic context, whether there is a lot of rain or little rain, and that it can be a very variable and dynamic context, the city can still manage and handle those excesses of water, runoff, and not flood. Likewise, that we can take advantage of those water flows, stop them, and store them for when we don't have water, so we don't have to rely exclusively and depend exclusively on drinking water.*

It is also important to implement solutions based on the context and location NG2 notes: "There is *a trend in the Bogotá region for precipitation to increase in some areas and decrease in others, it would be very important to identify within the city the areas where nature-based solutions are focused on regulating flows, mainly in times when precipitation increases and in this way retain precipitation water within the city, either to reduce the risks of flooding, which bring economic losses and loss of human lives, and on the other hand, let's say, reduce or have the capacity to store that water for times when it decreases when there are drought events and to ensure the city's supply. Likewise, in areas where it has been identified that precipitation is reduced in the city and there is a risk of droughts, then promote nature-based solutions that allow retaining moisture and precipitation to reduce those drought risks and obviously consequently in fires. Therefore, a resilient city adapted to climate change is one that regulates the temperature within the city and allows the city to guarantee its supply and reduce its risk of flooding.*

Through this approach, Bogotá will be used as a successful model for sustainable water management PU3 notes: "*NBS will be the key elements to combat climate change and adapt to its effects in the long term. Their main use will be the management of runoff, the reduction of the heat island effect, and drought prevention. […] Bogotá will be considered an example in the region for its full integration of SUDS as the main strategy of the NBS approach."*

Temperature regulation and fire control

NbS have despite the regularly occurring heatwaves managed to retain the population's health with help from green infrastructure which regulates the temperature in the city by reducing the urban

heat island effect through increased and more equally distributed green infrastructure, generating shade which reduces the surface temperature and retains moisture in the ground. The green infrastructure also improves the air quality NG1 notes, through air filtration: "*by absorbing atmospheric pollutants and producing oxygen, [air filtration] improves air quality and reduces the effects of urban pollution.* Public spaces are widespread and designed to provide thermal comfort even in critical weather conditions. NG1 notes that using biodiversity as an NbS can help regulate temperatures and reduce the risk of forest fires: "*2100, I believe that nature-based solutions could mainly contribute in […]* r*egulating the city's temperature, identifying those specific places where temperature can concentrate and increase the risks of heatwaves, but also fires. Nature-based solutions, through design and the selection of species and intervention areas, can reduce those places where the highest temperatures can concentrate. Similarly, strategies can be designed to reduce the risk of fires in the eastern hills.*

Erosion prevention

Areas which were previously in high risk of erosion and landslides are now sustainably manged through reforestation and through using more sustainable agricultural methods, such as terracing, windbreaks and no-till farming. The region has also taken action to improve the living conditions for vulnerable populations by reducing the risk of hazardous landslides. NG1 notes that *"In the Bogotá of 2100, the hills in the south-eastern area are protected and restored, just as is currently happening with the hills in the north-eastern area. I imagine that the homes on the hills in the south are relocated to safer areas and that all the hills are restored. […] By relocating informal housing that is on the hills and around the wetlands, it is possible to ensure that people live in safer houses and that these areas are freed up and restored to improve water infiltration and prevent landslides of poorly planned houses.*

Case study: ZIBO Neighbourhood

The participants were presented with a picture of a street in the industrial area of ZIBO. The picture was accompanied by a prompt describing how the areas have been adapted to climate change through interventions of NbS. Following are imaginaries of the transformed area of ZIBOs streets in 2100. AC2 provides a summary of how the area in the picture has changed*: Well, before this area was dangerous and above all, it was an area that felt vulnerable in every aspect because it showed a neglected side of the city. There were hardly any permeable spaces that allowed the normal flow of water, there was no presence of vegetation, and the vegetation that was there was in poor condition. Now, however, green corridors have been created, spaces have been created for pedestrian circulation that use or are made of permeable materials. When it rained, this street used to flood and was basically a problem for the neighbours who tried to get things out of their house because it could be flooded up to their feet. Now, the sustainable urban drainage systems that have been implemented, which*

are part of the nature-based solutions, have made this space green, resilient, but also a space that is prepared to handle changes in temperature and climate. Additionally, there are areas where you can observe nature, which are suitable for bird watching, and also spaces where most of the elderly take a rest under the shade of the trees to stay cool."

Figure 27. Street in ZIBO. 2024. Authors own picture.

Green transformation

In the 2020s ZIBO was an area lacking public services and public spaces. It was an example of the singular design of many areas, which were purposed for one use only. Bogotá has transformed all its urban areas, where instead of single-use spaces, there are multifunctional spaces spread out all over the city, mixing residencies with commercial activities, rather than having them concentrated. While some areas have transformed completely, with new buildings and facades with green roofs and vertical gardens, other areas have remained the same reusing the infrastructure and preserving the cultural heritage of the area. NG1: "*Spaces have been created on the verges on either side of the street with native trees that help to lower the temperature on the streets and also generate connectivity with other forests and forest patches within the city and the mountains, thereby increasing the biodiversity of these areas. It can also be seen that there are stations where the temperature and precipitation can be measured in each of the city's neighbourhoods, generating almost hourly information or even with a lower temporal resolution to be able to generate early warning systems."*

A notable change is the greenery that now makes out an important structure in the area. The streets are covered by the canopy which provides multiple purposes as PU2 notes: "*there is a lot of vegetation, tall trees, with a canopy that completely covers the corridor, so that in rainy times this irrigation is used for the hydration of green coverings in times of drought and with plenty of sun, these shadows generated by the trees*

adequately and satisfactorily reduce the heat island effect, providing the population with a comfortable climate both inside the homes and outside." Both on the new buildings and the repurposed industrial buildings green roofs have been installed providing both recreational space and retaining water, which ultimately has reduced the risk of flooding. Infrastructure for harvesting rainwater has been installed on all the houses, which captures and collects rainwater and stores it for drought periods.

Now that the industrial activities have been moved out of the city, the wide streets have been transformed to a green space which facilitates infrastructure reducing the impact of extreme weather events. UD1: "*From the cafe I'm sitting at, I can see how a wide street that used to be for cars has now become a thin street and the extra space freed up is now vegetable covering a floor, be it grass or surfaces that allow for rainwater to go through. I also see sustainable urban drainage systems on the sidewalks, cleaning water and absorbing water. I see a lot of trees along this path, many different types, and I see birds and insects visiting these trees."*

Flood prevention

In this part of town where flooding had become a growing issue, the implementation of more urban greenery and NbS on a landscape level reduced the flooding events. The concrete has been removed to provide space for trees, and for permeable surfaces, which allow water to filter through PU4 notes how the water is used more efficiently, through a system which is better connected*: The city has changed. I see through the window that it's no longer concrete, for example, on the sidewalks, but now we have cobblestones and sustainable drainage systems that allow not only the reuse of this water but also in the rain gardens, which take advantage of all that rainwater for watering the species found there. The sewer system and others have improved, and there's no trash on the ground either. People have learned a lot about recycling. So, there's no clogging of sewers or anything like that. Therefore, the excess water can flow to these places that connect, for example, with canals or wetlands, but the water is much cleaner and allows the water to flow easily.*

The greenery in the area is well connected to other ecological systems, as noted by NG2: "*The city has evolved into a city where additional rainfall can be retained through sustainable urban drainage systems, areas where urban vegetation coverage has been increased, and spaces have been created underground, either by purely nature-based solution designs or also through schemes, for example, of a sponge city where integrated green-grey solutions are also allowed to retain that precipitation, remove it from the streets, and carry it through underground conduits to large reserve tanks where this water can be used for supply during the dry season. […] Awareness has been raised around garbage, where there is no longer garbage on the streets but it is collected and does not clog the aqueducts' paths, reducing the risks of flooding. There are green roofs and green walls that make the city look much more friendly and healthy to create those spaces of nature and improve the mental health of the inhabitants. There*

are also spaces where water is retained in the city both to reduce the risk of flooding but also to generate that green and blue connectivity within the city with aquatic species as well.

Table 17. Summary of ES in long-term imaginary (2100).

Well-being and ES	- Food security & sovereignty - Agroecological practices - Vertical gardens - Nutritious food - Reliable water supply through - Rainwater harvesting - Clean energy - Multifunctional spaces - Inclusive recreation spaces - Inspiration - Awareness raising - Learning - Education - Knowledge sharing and collaboration - Community engagement - Citizen science - Spiritual connection - Belonging - Increased relation - Physical safety
Biodiversity & ecosystems	- Ecosystem connectivity through increased public space - Connection of blue infrastructure - Increased artificial wetlands - Habitats for native species - Food sources - Nesting opportunities - Native species - Reduced pavement - Increased space for roots - Air purification - Noise reduction - Support for soil structures
Climate adaptation	- Urban heat islands - Moist preservation - Blue carbon storage through re-naturalisation - Reduced exposure to landslides - reforestation - Technically designed permeability - Reduced pressure on paramo systems - Native species in reforestation

6. Concluding discussion:

This thesis has researched how the concept of naturescapes can be applied to an urban landscape in a Latin American context using Bogota as a case study. This has been explored by identifying seven naturescapes in Bogota, and exploring how academics, public institutions, private actors and NGOs, imagine their contribution to three urban themes: (1) well-being and access to ecosystem services, (2) biodiversity and healthy ecosystems and (3) resilience and climate adaptation. The contributions of the naturescapes have been explored in three time horizons, the present, short-term future (2035) and long-term future (2100), using interviews, document analysis and an interactive envisioning survey exercise. This section aims to bring together the discussion that has accompanied the results to highlight the main contributions of the findings in relation to the research questions.

6.1 Applying naturescapes in Bogota

This section highlights findings related to the first research question (RQ1): How are naturescapes imagined to facilitate well-being, biodiversity, and climate adaptation, in present Bogota? The first part of this research question (RQ1.1) explores how the concept of naturescapes be applied in Bogota, and what opportunities and challenges are related to their implementation. Based on interviews on document analysis, seven functionally linked naturescapes were identified, within all three types of NbS. The type 1 naturescapes included for example, Main Ecological Structures (MES) widely defined naturescapes both geographically and functionally, as it include major ecological structures in the Bogota region such as wetlands, mountain ranges and edge parks in the urban-rural border. The land use plan emphasizes the importance of the MES social, cultural and ecological function as it binds together the urban with the rural, and provides many ES to the metropolitan area.

While the functionally linked naturescapes were identified as separate naturescapes, they do not exist in isolation from each other. The systems interact both in terms of physical borders and in terms of governance, and some naturescapes overlap with others. For example, wetlands whose importance was emphasised by many interviewees is a subsystem to both MES (natural wetlands) and SUDS (artificial wetlands). The interviewee's perspective of what should be considered an NbS varied somewhat, which ultimately impacted the understanding of naturescapes in Bogota. However, in both plans and interviewees the most prominent NbS structure, as a system and as an NbS according to IUCNs criteria is the naturescape of SUDS, which has been designed as a systematically implemented NbS in Bogota.

While the naturescapes all contribute to ecosystem services (ES) within all three urban themes[134], their multifunctionality largely depends on how firstly their structure (natural or technical) and how they are governed (with what objective they are designed and managed). While not a significantly tested trend, the characteristics of the naturescapes indicate that type 1 naturescapes tend to be 1) more equally distributed within the three themes and 2) more rural, while type 3) naturescapes tended to be 1) more central and 2) designed with certain objectives in mind. For example, even though green roofs had a wide variety of values included, their support of investments is linked to the owners of the building, and therefore ultimately tied to their objectives. Similarly SUDS, for example through the typology of artificial wetlands, have the main city-wide objective to manage run-off water and improve the water quality, while natural wetlands are more widely recognised for their multiple benefits, such as providing recreation, supporting endemic species, and buffering water.

On the other hand, access to the ES can not only be measured through their geographical distribution but also has to not social structures which make them more or less accessible. For example, safety was noted by several interviewees as an important criterion for access to ES in a Latin American context, as more natural systems in the outskirts of the city also tend to be more unsafe. This serves as an example of the need to consider the context of where the naturescapes are planned and include a variety of stakeholders in both the planning and management of naturescapes to provide inclusive and accessible spaces. This also stressed the need to understand the historical context, as well as the political and socio-economic conditions in the context, bearing in mind inclusivity to avoid replication of colonial structures as previously discussed by Escobar in the context of development export (Escobar 2012). While the identification of the natural systems which these naturescapes are made up of are anchored among both actors and planning documents, naturescapes is a developing terminology, and its applicability in Bogota is likely to change over time, as both the urban landscape, and the academic understanding of the concept, evolves.

The understanding of how these naturescapes have developed in Bogota reveals many considerations which have to be made to successfully upscale NbS at a landscape level, which is recognised as a necessity for socio-ecological transformation by both practitioners and academia (IUCN 2020; Palomo et al. 2021; Tye, Pool, and Gallardo Lomeli 2022). These considerations are to be made in the planning, implementation and management of naturescapes, both regarding what objectives the naturescapes are planned for, the criteria for where they should be located, and the time perspective which is considered when planning for naturescapes in an urban setting.

[134] See the gathered themes in Appendix E.

6.2 Imaginaries of how naturescapes contribute to transformative change, at present and in the future

This section brings together the imaginaries of how naturescapes in Bogota contribute to three urban themes at present (RQ1.2) and in the future (RQ2).

6.2.1 Imaginaries contribution to well-being, biodiversity and climate adaptation

The imaginaries were explored through a limited set of interviews, document analysis and surveys, and thus do not represent the imaginaries held by all actors in Bogota, nor does it uncover the potential discrepancies between imaginaries of different actors in the city. The approach of using multiple sources to assess imaginaries of different time horizons also limits the comparability between imaginaries over different time horizons, as they consist of different constellations of data. Nevertheless, the approach gives insight into how various datasets can be explored for their imaginaries, such as through the novel approach of using an interactive visioning exercise using an AI-moderated survey, which opportunities and limitations are discussed in Appendix B. Furthermore, the imaginaries can indicate how naturescapes are valued on a more general level on different time horizons, as summarised in table 24 in Appendix E.

The main recognised values of current naturescapes are related to the multifunctional contribution of natural structures, such as the wetlands, mountains and Paramos (highland wetlands). The need to protect and restore these ecosystems was stressed in both plans and by actors. While other naturescapes were also recognised for having multiple ES, such as food contribution of urban agriculture and flood management by SUDS, they are present to a lesser extent, and thus not currently as impactful and central as the natural (type 1) naturescapes. Other reoccurring themes included for future imaginaries included increased community engagement, increased presence of native species, and better use of water resources through harvesting rainwater and re-using run-off water. Comparing the present imaginary with the future-looking imaginaries, the major differences between the imaginaries are not mainly to what types of NbS or naturescapes are present, or what ES they contributed with, but to what extent they are present. For example, both short-term and long-term imaginaries envisioned green public spaces and parks to be more widespread and accessible, ecological structures to be more well-connected and urban farming to be a more common practice. The case study of the industrial area ZIBO demonstrated a great distinction between the imaginary for the channel in the zone, which had been vividly transformed into a natural, safe and biodiverse green corridor in the long-term (personal) imaginary, while the short-term (official) imaginary, rather focused on increased maintenance of the drainage system, with limited increased greenery.

Also comparing the views within the imaginaries of different documents for the same time horizon can be valuable to understand how naturescapes are envisioned and valued in different contexts. For example, the short-term imaginary compared the city-wide urban plan with a district-wide local plan, both working as guidelines for urban development until 2035. The city-wide imaginary naturally has a wider array of ES within the three urban systems, as it covers more geographical areas, and thus more naturescapes. While some elements of the land use plan were recognised in the district plan, such as the increased need for public space, and increased implementation of SUDS to deal with water run-off, the two imaginaries bring different understandings of what change is manageable until 2035, as the more local plan which materialises the plan, has to consider many trade-offs with the access to budgets and feasibility of planning for greenery given the availability of space.

Healthy ecosystems, often understood as biodiverse ecosystems, were widely recognised as a core strategy to contribute to the two other urban themes: public health and well-being through climate adaptation, and were more considered in terms of providing these services, than in the act of preserving biodiversity for the sake of its own right to exist. As such, the urban plans, more than the personal imaginaries in the scope of this thesis, considered nature's contribution to human well-being as a more prominent objective, than the sole need to preserve biodiversity.

Many features include not only an expansion of NbS, but a fundamentally changed structure, such as the long-term imaginaries for rainwater harvesting and localised water management, which fundamentally need to change the way water is collected and used. Also, the increased extent of urban farms has multiple objectives, both increasing community engagement and increasing food security while increasing soil permeability and thus making the city less flood-prone. To have a transformative impact this has to be applied at a wide scale and change the urban relation to nature, but also to other aspects of society. For example, the more localised production of food would require more urban space located for urban farms, in an already highly competitive environment for space. Just as stakeholder engagement has been recognised to be of central importance in previous literature both in Colombian and general contexts (Marino et al. 2024; Kabisch, Frantzeskaki, and Hansen 2022), the imaginaries put communities in a central role in managing and monitoring NbS and naturescapes both short-term and long-term. This however, has to consider how society has to transform to allow such a commitment, relying on individuals having time and engagement for such structures in their free time, which in reality has to be balanced with other time commitments, such as the need to work. The understanding of what has to be considered to when designing naturescapes to facilitate transformative change several considerations have to be made, as discussed in the final section 6.2.2.

6.2.2 Imaginaries contribution to well-being, biodiversity and climate adaptation

Finally, this section aims to connect the two research questions to discuss the practical applicability of the findings in this thesis, for moving from the imaginaries in the present state, (horizon 1), to imaginaries of a future state, (horizon 3) where the socio-ecological systems have been fundamentally altered to contribute to a transformative change within the three urban themes.

To understand how naturescapes can facilitate transformative, this section connects the findings of the imaginaries to the transformative criteria introduced by Fedele et al. (2019); restructuring, path-shifting, multi-scale, innovative, system-wide, and persistent.

i. Restructuring and Path-shifting: Imaginaries, now and in the future

Fedele et al., (2019b) notes that a transformative change requires elements of "*altering fundamental features and/or interactions in ecosystems and societies"* (re-structuring), as well as *"shifting the trajectory of a social-ecological system towards a different direction"* (path-shifting) (Fedele 2019b, 8).

Naturescapes is a dynamic concept, and its understanding and function will naturally change over time as the urban landscape changes. Nevertheless, naturescapes, just like many other urban infrastructures, are an integral part of the urban landscape and therefore have to consider what landscape they will interact with in the future. Much like any infrastructure project, the planning of naturescapes should therefore consider future planning in its application, to consider objectives and criteria not only for the present urban landscape but also for the future landscape.

In the context of Bogota, the development of SUDS is based on a methodology which considers a variety of objectives and interests. However, all objectives and conditions considered are considering the current state of the urban landscape. While the plan accounts for development plans as an indicator of where SUDS can be more feasibly implemented, it does not consider future conditions in which SUDS will be implemented (e.g. increased temperatures, increased amount of rainwater, changing population dynamics), nor does it consider what objectives are envisioned for a desirable future (e.i. increased access to public space, water self-reliance and decreased dependence on and presence of grey infrastructure such as roads). While working with current conditions, and addressing contemporary urban challenges is a crucial consideration, it is not likely to facilitate transformative change. If future scenarios and objectives are considered, however, the naturescapes are likely to include path-shifting designs and processes aiming to restructure the socio-ecological environment of the landscape. Including such future perspectives in urban planning, both those of the city's objectives as framed in the POT, and of other stakeholders' perspectives, the naturescape has the potential to contribute to city development in a more transformative and forward-looking way.

Despite urban constructions being built to stand for decades, if not centuries, they seldom consider the long-term future perspective and environments they will interact with, and how they contribute, and potentially lock in, such environments. It is therefore important to explore how imaginaries can be used to better understand preferred futures, and learn how those can be better integrated into governance and planning processes. This thesis contributes to the field by exploring multiple sources and methodologies from which imaginaries for both present and future urban environments can be explored. As such this thesis contributes with insights about not only public objectives but also personal imaginaries for the long-term future development of naturescapes in Bogota. To better include these perspectives we must however understand how to deal with uncertainties that come with trying to predict future conditions, which understanding could be a large contribution the field.

ii. Systemwide: Systems-thinking and boundaries for naturescapes

Fedele et al. (2019) recognise a system-wide implementation of NbS is considered a critical pillar for achieving transformative change in socio-ecological ecosystems, where NbS should be planned for natural (Fedele 2019; Fedele et al. 2019). Other authors, such as Cohen-Shacham et al. (2019) have contributed to this discussion by stressing the need to apply NbS on a landscape scale considering watersheds or large forests, where several ecosystems may be combined and be transboundary, and can contribute to upscaling. The findings of this thesis contribute to the conversation of systems thinking through the notion that NbS can not only be linked by their geographical scale but also by their function, here referred to as naturescapes. However, it is important to consider the many system boundaries that can be applied to naturescapes.

As noted in the developing methodology for planning for NbS in Bogota, different practices consider different boundaries for their systems. For example, landscape architects often focus on urban planning units, while engineers consider physical features such as water catchments, both of which are important from a planning perspective. However, when planning for a single NbS it is also important to consider how they are located and designed in relation to other NbS with similar functions in their naturescapes, and not only the geographical boundaries. While considering the local conditions are essential when selecting typologies of NbS, it is also important to understand how the NbS impacts the naturescape functionality. With the example of the SUDS methodology, both the needs of ES and the physical limitations were considered when selecting a location for SUDS, and the objectives were often set by the person or company planning the area. As cost and availability of physical space are constant challenges in urban development, it is likely that some typologies of SUDS are continuously favoured, typically smaller SUDS. However, as this is continuously done through the naturescape of SUDS, the functionality and diversity within the

SUDS naturescape decrease, and the naturescape potentially becomes more vulnerable, for example, to supply chain disturbances or reliance on certain types of infrastructure – such as road networks, which SUDS are often linked to (Frantzeskaki, McPhearson, and Kabisch 2021). On the contrary, large and/or more costly SUDS, may be continuously disadvantaged despite their potential long-term benefits and more diverse contributions to ES. For example, as in the case of Bogota, artificial wetlands are generally disfavoured both due to the lack of space and to physical conditions. However, even where they are possible to implement they may be disadvantaged due to the costs of implementation. Through considering the diversity of the functionality, and of the ES generated in the naturescape, the selection criteria such as biodiversity, which are often a second priority, but which are of long-term importance and can facilitate more transformative changes, may be better favoured in relation to other criteria, such as cost of implementation and need for maintenance. In this way, a more holistic criterion can be applied to the selection of NbS, accounting for all values identified in the imaginaries for transformation, and not only a selective few which are replicated.

Diversifying NbS typologies within a naturescape can also bring economic and administrative benefits. While it may be more expensive to invest in piloting different typologies, it can create a better resilience for criteria and events that we might not foresee currently. For example, only relying on technical systems, or systems connected to conventional infrastructure, maybe a disadvantage if there are maintenance issues (for example disturbances in the supply chain of material), or a need to make large-scale changes to the current infrastructure. Drawing this argument further, the upscaling of NbS could also consider systems of other naturescapes in its design.

Moving from planning from NbS to naturescapes can however allow system thinking to be applied as a tool to systematically empower different demographics on a landscape level. For example, POT promotes regional development which empowers vulnerable demographics, such as children, women and the elderly. This could be done by promoting naturescapes, such as urban agriculture, within a system for public service units such as schools, hospitals and elderly homes. By considering public services as systems, naturescapes can develop over a varied landscape by systematically reducing the vulnerability of vulnerable populations. As such, the planning for naturescapes should not only be functionally linked through the functions to which NbS contribute (e.g. flood mitigation) but also consider the functional linkage of their location (e.g. schools). This increases the likelihood that NbS reaches certain demographics, and reduces the risk that they are concentrated in a single geographical zone, such as where the city already prioritises urban renewal projects. Furthermore, it is important to consider naturescapes in the context of non-geographical

systems, such as governance systems and economic systems, as previously recognised by Kabisch et al., (2022) who recognise systemic thinking as a core principle for the implementation of NbS structures in urban spaces, recognising that NbS does not exist in isolation, but are a part of both a socio-ecological system as well as a social and political system (Kabisch, Frantzeskaki, and Hansen 2022).

iii. Persistent and innovative: Flexible naturescapes

The criteria for "persistent" emphasise the need to implement NbS which leads to long-term impact. As an example of this criteria, Fedele et al., (2019b) mentions the need to institutionalise land-use policies or management committees. It is also considered as one of the more difficult criteria to meet as the future is uncertain to plan for (Palomo et al. 2021). Additionally, the element of "innovative" describes the need of *"introducing new functions or states"* for the location, such as expanding the usage of early warning systems(Fedele 2019). For naturescapes to contribute to transformation through persistent and innovative structures, this thesis argues that it also has to consider a third term: flexibility. An innovative approach will need to include features in NbS which have not been considered before, as well as implementing NbS in spaces where they are not typically considered. The imaginaries paint up some innovative approaches to the design of NbS, such as features which facilitate citizen science projects and allow easy monitoring by communities. Also the upscaling of locations for NbS requires more innovative features, for example, to better allow effective use of water resources through rainwater harvesting in combination with other infrastructures. These imaginaries require the naturescapes to include NbS with flexible designs, both in terms of how they are built, and where they can be located.

Additionally, flexibility can tend to make NbS more persistent as a network, though being designed with the notion that conditions in the future will change and that the NbS and naturescape too have to adapt to those conditions. This relates to changes in the physical conditions, such as restructuring of roads and related grey infrastructure but also governance-related conditions, such as changing priorities in what ES are prioritised. Furthermore, all infrastructure needs to consider changing climatic conditions to a higher degree in the future. If NbS are not flexible to both foreseen and unpredictable conditions but instead rely on other conventional solutions, they too will be short-lived, and of little contribution to a transformed landscape. This becomes particularly important given the uncertainties that come with planning for the future. For example, in the context of planning of SUDS in Bogota, the lack of future considerations makes the SUDS typologies potentially undermentioned to the changing rain patterns in the future. However, with a flexible design, for example, a design that connects to natural structure, or allows the SUDS to

be easily rebuilt or repurposed, it can compensate for these uncertainties in the future, without being locked into inflexible designs, such as the conventional sewage system.

Finally, a flexible design also applies to the flexibility of changing objectives for a naturescape. This is required to be in line with changing values and avoid locking the landscape into path dependencies. For example, in the case of the implementation of SUDS systems, stakeholders were consulted to determine the main objectives of SUDS on a city-wide level. However, these priorities are likely to change over time, with changing landscapes, conditions and political will.

In this regard, it becomes important to understand how flexible different typologies are in naturescapes. This thesis contributes to the understanding of flexibility through the assessment of how current and future imaginaries perceive the multifunctionality of various naturescape's contribution to the three urban themes. While this is not an assessment of their actual multifunctionality, it can indicate that natural structures (type 1) such as wetlands and forests, are more multifunctional, and therefore more flexible, than type 3 naturescapes, such as SUDS. However, even within naturescapes, this can be considered. For example, typologies which are less reliant on conventional structures, such as artificial wetlands, may be more flexible than structures connected to drainage systems, such as extended dry basins.

iv. Multiscale: Management, monitoring and Stakeholder engagement for naturescapes

Finally, the design of NbS should be "multiscale" and span over multiple scales, both through sectors, levels of governance and geographical scales (Fedele 2019). The understanding of the importance of involving multiple stakeholders in the planning of NbS which has been recognised by previous literature (Ferreira et al. 2020; Kabisch, Frantzeskaki, and Hansen 2022), is also prominent in the imaginaries for present and future naturescapes in this thesis. Drawing from the long-term imaginaries emphasis on stakeholder engagement, this thesis contributes to the discussion by noting that stakeholder engagement should not only be considered in the planning phase of naturescapes but that multiscale monitoring and management is equally important to consider when planning and designing NbS.

This is important both to create an inclusive design considering multiple objectives, but also to make the projects more long-lived. Many interviewees noted that the realisation of NbS currently relies on the dependence of political will to scale up the work for NbS, as much of the NbS structures in public plans rely on public funding. In the context of Bogota, the land use plan provides many positive examples of naturescapes as featured in the imaginaries along with other policies and strategies for how the urban landscape can live in balance with natural landscapes. However, several interviewees point out that the plan is far from a reality. For example, NG1 notes

that even though many ecological and water systems are protected in regulations and plans, the imaginaries from institutions may not correspond with how it look in practice *" Those spaces, even though we have it in the paper, they are really hard to materialize it because you have different interests, and it's really hard to make all the people have the same view. Here in Bogota, I would say that it's more about environmental education and having the right incentive from the local government to do it."*

Therefore many actors have to be involved in the planning, implementation and monitoring of NbS, to make it resilient and scalable, and to have a transformative impact. For example, interviewees mentioned several actors who have to participate in the effort of scaling up NbS. Public institutions play a large role in formulating policies and guidelines for the implementation of NbS to allow it to be implemented at scale, such as regulations exciting for the implementation of SUDS. Secondly, local authorities must incentivise the implementation of NbS in urban planning, and collaborate with private institutions to increase the means of financing.

It is also important to involve civic society in the planning, implementation and management of naturescapes to ensure the long-term longevity of the naturescapes projects. Bogota brings a positive example through the multistakeholder involvement in wetlands, which are not only protected through institutional regulations but have attracted an increasing civic engagement to protect the natural structures. PU4 notes the importance of involving communities to ensure that the maintenance of the areas becomes more long-lived: *"I think it's very important to the community to be involved because there are these guarantees that the process can be longer in time. Because some projects are very few years, for example, but if the people have engaged with this type of program, I think the program is more successful."*

7. Conclusion and recommendations

This thesis explores how systems of nature-based solutions, referred to as naturescapes, can be applied to an urban landscape, using the Andean metropolitan area of Bogotá as a case study. Furthermore, the thesis explores imaginaries for how naturescapes contribute to three urban themes: well-being and equal access to ecosystem services, biodiversity and healthy ecosystems and resilience and climate adaptation. This was done over three time horizons: present, short-term (2035) and long-term (2100), using interviews, document analysis and a novel interactive visioning exercise powered by an AI-moderated survey. The research questions which have been explored are:

RQ1 Present Bogota: How are naturescapes imagined to facilitate well-being, biodiversity, and climate adaptation, in present Bogota?

- How can the concept of naturescapes be applied in Bogota, and what factors are considered in their application?
- How are naturescapes in Bogota perceived to contribute to well-being, biodiversity and climate adaptation imaginaries?

RQ2. Future Bogota: How are naturescapes imagined to facilitate transformative change for well-being, biodiversity and climate adaptation envisioned, in future Bogota?

The findings of this thesis, as critically discussed in section 6, contributes to both the academic understanding of naturescapes and imaginaries, as well as practical recommendations for urban planning and urban governance.

Firstly, this thesis proposes seven naturescapes in the Bogota region which are functionally linked, on different geographical scales and with various functions. These include naturescapes consisting of natural ecosystems, such as (1) main ecological structures in the periphery and rural Bogota and (2) wetlands. It also detected semi-natural naturescapes, such as (3) managed urban forests and urban trees, (4) ecosystem connectors which connect greenery in the city, and (5) urban farming. Finally, the identified naturescapes include technical and intrusively managed naturescapes such as (6) Sustainable Urban drainage systems (SUDS) and (7) green roofs and vertical gardens. These systems all contribute to a varying degree to human well-being, biodiversity and climate adaptation in Bogota through for example recreation, support of native species, and flood regulation through permeable surfaces.

As this thesis applies the newly developing concept of naturescapes in Bogota for the first time, this chapter closes the thesis by opening up for further research on the concept of naturescapes, as it can be understood and applied in many ways. Further research could also contribute to the

understanding of the nexus between different naturescapes, and further explore how these named naturescapes are linked by governance. As such, it is important to consider what system boundaries are adequate for the application of naturescapes. While these naturescapes are identified on a city and region-wide level, naturescapes can also be applied through other system boundaries, such as urban units or natural boundaries, such as catchments. Therefore it is relevant for both academics and public institutions to consider how system boundaries for naturescapes can be altered to provide a more inclusive design.

Secondly, several lessons can also be learned from looking closer at the implementation of SUDS which has taken room in Bogota since 2018. Three prominent success factors of the systematic implementation which has allowed an upscaling of SUDS in the last few years, includes; (1) early stakeholder engagement, (2) incorporation of standards into regulation and (3) collaboration between institutions. However, it is also important to consider what can be done differently when implementing methods for planning for naturescapes which will be a part of the urban landscape for a long time to come. Three considerations from the implementation of SUDS in Bogota include (1) the need for considering futures-thinking into current planning of naturescapes and how to deal with uncertainties, (2) understanding how different boundaries can be explored within and between naturescapes, and (3) how to make an economic cost-benefit analysis which advocates for the long-term benefits of implementing NbS more accessible. These lessons can guide public institutions, and other actors involved in the development of NbS, to understand how they function in systems, and how they more successfully can be upscaled. This includes making room for including systems of NbS into regulatory guidelines.

Thirdly, Over the three time horizons explored in this thesis, urban agriculture and SUDS stood out as naturescapes which were imagined to expand the most in the long-term personal imaginaries. The short-term official imaginaries had a varying focus on the city-level imaginary and the district imaginary. The city-level imaginary focused on the conservation and restoration of main ecological structures and increasing the urban-rural relations and connectivity, while the case study focused on access to public green space, primarily through tree planting, and implementation of SUDS in flood-prone areas.

The results contribute both the understanding of possible methods for exploring imaginaries in the context of naturescapes in urban landscapes and what ES the public imaginaries prioritise. The understanding of different personal and official imaginaries can be of great use to understand how urban planning of naturescapes more inclusively can consider future objectives. As the future perspective was something that was lacking in the current application of naturescapes, public institutions are recommended to better include perspectives of the future in the practical urban

planning, and not only in visions and objectives of the land use plan. This can be greatly supported by future research on testing how future imaginaries can be used the context of urban planning, for example using any of the methods adopted in this thesis to pilot in a case study for naturescapes in collaboration with public institutions and other relevant actors. Furthermore, future research can play a pivot role in better understanding how uncertainties for including future imaginaries can be dealt with, and how far into the future urban planning should consider in different urban contexts.

Finally, this thesis directly contributes to conversation of futures-consideration in urban planning by exploring a novel methodological approach to research imaginaries through an interactive visioning exercise. The results from the survey show a potential for the tool to be used more widely in academia, as the response rate was high (71%) and the user experience high (average 9/10). However, the tool was only tested on a small group of people (10) who had already participated in an interview for the study. Thus, future research could contribute to the understanding of how the online AI-moderated survey tools can best be applied within academic research, and contribute to the discussion of the ethical implications of using AI and AI-generated results in research.

While these imaginaries indicate values and visions commonly held by key actors involved with the design and development of naturescapes, there would be a need for a wider data analysis to conclude how public imaginaries view the landscapes for NbS in Bogota. As such future research can contribute to the field through using a robust set of data to explore how imaginaries for present and future naturescapes, to understand how imaginaries of different actors varies. As such this research contributes to an ongoing conversation of how the upscaling of NbS can be considered in different context. The thesis finishes with the notion that socio-ecological transformation can with the help of naturescapes be within reach, but we must understand what we are reaching for.

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9. Appendix

Appendix A. Interview Guide and Consent Form

i. Interview Guide

The semi-structured interviews followed an interview guide aiming to address RQ1. RQ1 How are naturescapes imagined to facilitate well-being, biodiversity, and climate adaptation, in present Bogota? (1.1.) How can the concept of naturescapes be applied in Bogota, and what opportunities and challenges are related to their implementation? (1.2) How are naturescapes in Bogota perceived to contribute to well-being, biodiversity and climate adaptation in personal and official imaginaries? All interviews covered similar topics as addressed in the guide, however not all questions were covered in every interview due to time limitations, and not all questions were framed the same way. Much of the interviews evolved through the participants experience and understanding of NbS.

Table 18. Interview Guide.

Questions	Themes to analyze
Background: What is your current role in the organization? How do you/your organization work with NbS in Colombia and Bogota?	Actor category relation to NbS
Context of Nbs in Bogota - What natural elements/NbS are you aware of in Bogota? (Examples of successful/less successful) **Current systems:** How can natural elements and Nbs complement each other in a landscape perspective (e.g. water sheds and biodiversity corridors)? - How are you/your organization involved in the development/management of these NbS? - Under what criteria do you/do you not consider natural elements as NbS? - How are they linked functionally? - How are they linked in governing? - What multifunctionality do they have (primary and secondary function)? - Do you have examples of synergies and trade-offs made between these Nbs/natural elements? **Developing systems:** Are there any areas where systems of Nbs (e.g. water sheds of biodiversity corridors) are under development?	Identification of NbS Identification of systems of NbS (naturescapes) Understanding of functional and governmental linkage
NbS Development: Considering previous NbS (systems) **Drivers:** What are the drivers for the development of such Nbs (in systems)? - What issues should they address? **Barriers:** What barriers have been seen in the development of natural elements and Nbs (in systems)? **Finance:** How have these projects been financed? o What have been the benefits of such finance? o What are the barriers to such type of funding? **Space:** Where are NbS more prominent in Bogota? - Where are NbS less used? - Where is there a use of more NbS (as systems)? **Actors:** What actors have typically been involved in developing and governing natural elements and Nbs in urban spaces? Are there any actors that have been left out (which should be involved)? **Access to nature:** Who has access to these natural elements? Who/what areas need more/better access? - How does NbS impact gentrification?	Governance and development of NbS as systems in Bogota. Drivers and challenges with NbS Actors involved and excluded in the development of Nbs. Opportunity for upscaling

- Who would have access to such areas? - How will/could these natural elements be linked (functionally and through governing)? Can you give examples	
Urban themes **Contribution:** How is your organization currently working with Nbs to address: - Climate adaptation - Biodiversity - Access to nature and ES? **Competitiveness:** What would you consider to be the major benefits of Nbs compared to other solutions (e.g. technical)? What are the major challenges of Nbs compared to other solutions (e.g. technical) **Additional questions:** Do you have anything you want to add, or any questions to me?	Linkage to urban themes

i. Consent form

The structure of the consent form was as follows:
This interview will contribute to a thesis study about the development of nature-based solutions and naturescapes in urban spaces, and their potential to contribute to a transformative change from a socio-ecological perspective. The study period runs from January 2024 to June 2024, hosted by the Central European University (Vienna), and co-hosted by the University de los Andes (Bogota). The interview is conducted to better understand the role of different actors' perspectives on the use of natural elements in urban spaces, how they have developed, and what role they could play in the future. These themes will contribute to the topic on understanding:

- **Nature-based solutions** role in a landscape perspective (**Naturescapes**)
- Various actors' perspectives on the role of Nature-based solutions in achieving a **transformative change** from a socio-ecological perspective.
- What **imaginaries** of future naturescpaes in urban spaces exists.
- The transformative potential of naturescapes in urban **imaginaries**

The aim of the study is to get a better understanding of how imaginaries can be used to understand the role of nature in transformed urban spaces. If you have any questions, please don't hesitate to contact Hedda Thomson Ek through e-mail: Hedda.thomson@mespom.eu

This form is to ensure that you have been given information about the project on "Naturescapes role in Facilitating a Transformative Change" conducted by Hedda Thomson Ek as part of her thesis project. This form gives you the opportunity to confirm that you are willing to take part in this research. Your participation is voluntary. As an interviewee, you do not have to answer all the questions that are asked; you reserve the right to refuse or cease participation in the interview process at any time without stating your reason and may request to keep certain materials confidential. If such requests are received, the researcher guarantees full and unconditional compliance with them. For all activities below, please indicate which applies to you:

☐	I have been **familiarised** with the thesis project on "Naturescapes role in Facilitating a Transformative Change". I have had the possibility to ask questions and I have received satisfactory answers to my questions.
☐	As a research participant, I am aware of my **right to withdraw participation** at any time.
☐	I give my consent that the interview can be **audio- and video-**recorded, transcribed, and analysed.
☐	I understand that the results of the research will be presented so that **no information can be traced to me personally.**
☐	I give my consent that a record of my interview can be **safely stored** for future reference.
☐	I give my consent that certain information and quotes can be used anonymously beyond the thesis for **communication purposes**, with the condition that I receive [prior] notice of any such use.

Appendix B. A novel methodological approach using interactive visioning exercises through AI-moderated survey

i. Background of AI-tool

The Interactive Visioning Exercise uses an AI-moderated survey tool, powered by Wondering ©. The survey tool is moderated by AI, which allows the survey to be built with prompts and follow-up questions adjusted to the participant's answers. The survey can be built using prompts (Message), multiple selection criteria (Choose), open-ended question sections (Explore), discuss pictures (Show) and ratings at scales (Rate). For all question-framed elements (all elements put "Message") follow-up questions can be added, for which the AI generates a question based on the respondent's previous answer. The follow-up question can be left open for the AI to for more in-depth reasoning of the previous topic, or with a selected focus. Most of the elements can be answered through typing (writing) or recording (speaking). The survey can be selected to be presented in a given language, or to adjust to the participant's language, based on their location. Once the study has been completed the AI presents the individual results, and makes an analysis of the user's responses and presents key quotes and themes brought up by the user. The tool is primarily designed for user experience research aimed at companies, however, it has many valuable features for research as it allows to research meanings and understandings of individuals or groups of people consistently, yet allows for more flexibility through the AI-moderated follow-up questions. Furthermore, the tool can develop to be an effective way to systematically analyse results with reduces limitations from human use: such as selective in the selection or interpretation of data or limitations related to time constraints of analysing data. Next, the study design for this study will be presented, followed by a brief discussion on the lessons learned from applying the survey tool for academic research.

ii. Study design

The survey was sent out to 14 persons, who had prior to the survey participated in this study through interviews both in person and online, out of which 10 respondents answered within the given time frame. Prior to the send out, the survey had been tested on a pilot group of three people with knowledge in the area. The survey used in this thesis was designed using 22 steps (17 study-oriented and 5 informative) based on all the five elements previously mentioned (Message, Choose, Explore, Show and Rate). Firstly the participant was made familiar with the design and conditions of the study to ensure that the survey was completed without disturbances. The participant was for example encouraged to sit in a room where they could speak or write undisturbed and were encouraged to have somewhere to take notes on the side of their device for answering the survey. Secondly, the participants gave their consent to the conditions of participation in the study, through information based on the consent form used for the interviews. The research-oriented body of the Survey consisted of 16 study elements divided into six sections. The first three sections, one for each urban theme, which was the main body of the survey, explored how the participants perceived that NbS could contribute to ES in the long-term future, on both a city-wide scale and on a local level. Each section for the urban theme was divided into three subsections with the same structure. First, the participants were presented with the ES indicators related to the urban theme, of which the participants were prompted to select the three most important ES that NbS can contribute to in the future (Choose). The prompt was framed as follows (with slight variation over the different themes):

Theme 1. Well-being and equal access to ecosystem services:

🌳 Nature offers numerous ecosystem services! Below are examples of cultural and provisioning ecosystem services that various nature-based solutions offer. In the city of 2100, many of these services are available, and their benefits are equitably distributed.

✔️ Please choose three ecosystem services that you believe are crucial to ensure inclusivity for all residents in the city of 2100.

🖍️ Once you have selected your three services, please note them down, for example, on a piece of paper.

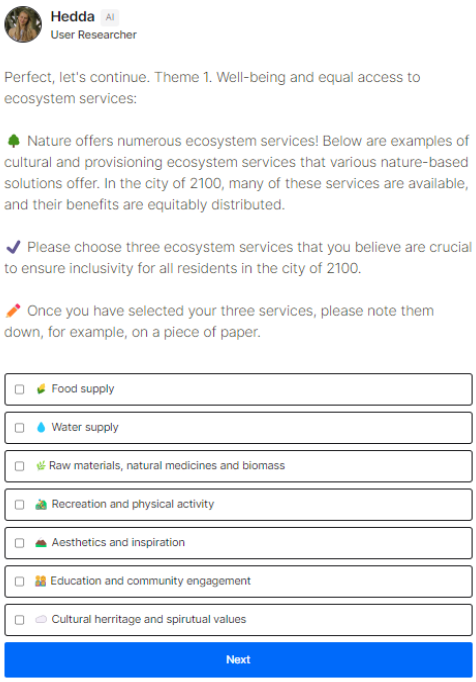

Figure 29. Survey photo 1.

Secondly, the participant was presented with a prompt about in 2100, and was encouraged to describe how NbS helped support this future scenario. The question was followed up by one AI-generated follow up question focusing on the monitoring perspective of the suggested NbS. The prompt was framed as follows (with slight variation over the different themes):

Thank you for selecting these three services. Now, let's explore how nature-based solutions can provide these services in the city of 2100.

🌆 In the past, the city lacked access to nature and its services, with unequal distribution of green spaces. Wealthier areas had more access to parks and other ecosystem services, while natural areas in low-income areas often were perceived as unsafe.

🍀 However, in 2100, the city has transformed to ensure that everyone can benefit from nature. As you walk through the urban landscape, you notice numerous examples of natural elements and nature-based solutions are integrated into the city, making them accessible to all.

🌳 Please share your thoughts on how nature and nature-based solutions can be used in urban environments to provide well-being and other ecosystem services to inhabitants of Bogota in 2100. Feel free to use the three ecosystem services you noted down previously as examples.

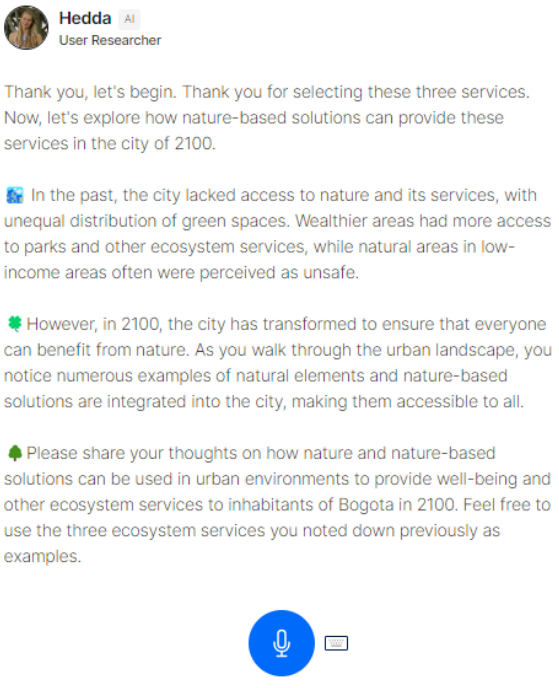

Figure 28. Survey photo 2.

Thirdly, the participant was presented with a short scenario for the future and a picture of a place located in ZIBO. The pictures were selected bearing in mind the geographies and structures which were pointed out in the technical assessment as particularly important and/or vulnerable areas. For example, the first case (well-being) features Pennsylvania Park, in the eastern ZIBO, which is the largest publicly available green area in the industrial zone. This was selected to tie in how an area created for recreation can transform from the present to the long-term future. The second theme, focusing on biodiversity, featured the Comunero river, which is one of the two ecosystem connectors located in the area. This was selected for the participants to focus on how NbS can generate ES which benefits biodiversity. Finally, the third case featured cemented streets in the middle of the industrial zone, which was used as a case for NbS which contribute to climate adaptation. Below the scenarios for the three urban themes are presented along with the pictures which were presented to the participants.

Urban theme 1: Well-being and equal access to eco-system service

📹When you start recording your answer you will see a picture of a park in Bogota in 2024. Your task is to describe how the picture has changed from 2024 to 2100.

🏢 As you stroll through the city, you pause in a park where groups of people are enjoying the benefits of nature. You pick up a photograph taken by your grandfather in 2024 when he worked in this area in Bogota. At that time, this area was an industrial zone, and the park was one of the few green spaces. Despite its central location, few people visited, and it was considered unsafe by many.

🍀 Standing in the same spot as your grandfather once did, you now take a photo with your phone. In this new picture, you see a secure green space with nature-based solutions that provide both cultural services and many benefits to the people who visit.

🌳 Please use your imagination to describe what this park looks like, which provides well-being to the city inhabitants. Feel free to use the three ecosystem services you selected earlier and explain how nature-based solutions contribute to providing these services in the park.

Figure 30.. Survey Photo 3.

Urban theme 2: Biodiversity and healthy ecosystems

📷 When you start recording your answer you will see a picture of a channel in Bogota in 2024. Your task is to describe how the picture has changed from 2024 to 2100.

🪧 As you follow a river of water through the city, you come across a sign showing a picture of how the area looked in the 2020s. At that time, the river was straightened and canalised. The water was polluted, with only a few trees and grass separating it from a busy road.

🚣Now, in 2100, the stream has transformed into a healthy ecological system supporting biodiversity and providing ecosystem services.

🌳 Please use your imagination to describe how this area looks in 2100. Feel free to use the three ecosystem services you selected earlier and explain how nature-based solutions contribute to these services.

For this question, you can only record your answer, and not type it.

Figure 31. Survey photo 4.

Urban theme 3: Biodiversity and healthy ecosystems

📷 When you start recording your answer you will see a picture of a road in Bogota in 2024. Your task is to describe how the picture has changed from 2024 to 2100.

🌆 As you walk home again, the rain starts falling heavily, and the wind is strong. You sit down at a café and receive a news alert about the stormy weather. The news story shows a picture of a street in your neighbourhood from the 2020s, highlighting its susceptibility to flooding. At that time, the ground was impermeable, with few measures to adapt to the changing climate.

⛈️ Looking out the window of the café, you can see numerous examples of how nature has been utilized to adapt to a climate with more heavy rains, stormy weather, and warmer, drier periods.

🌳 Please use your imagination to describe how nature-based solutions have been used to improve this area. Feel free to use the three ecosystem services you selected before.

For this question, you can only record your answer, and not type it.

Figure 32. Survey photo 5.

The final three sections of the study further explored the connectivity and monitoring, actors involved, financing opportunities for upscaling NbS and what challenges had to be overcome to allow for the transformation. These results have been left out of the thesis, due to limitations of time and space.

i. Lessons from applying the survey study

The outcomes of this interactive visioning exercise show much potential for the usage of AI-moderated survey tools in research. Out of 10 participants, 9 completed the full survey to the end, after which they evaluated the survey experience. More than half (5) rated the experience with the highest rating on the scale (10/10).

Figure 33. Participant survey experience.

Some examples of the high rating included the ability to visually link imaginaries to a spot in the city, and that the survey gave room for reflection of the topic. Other positive comments regarded the opportunities to capture personal values for sustainable and innovative city development. Several participants were positive about the dialogue characteristics of the survey, where the AI moderation reacts and adapts to the participant's response. For example, one participant said: *"It's the first time that a survey makes me feel like it's adapting to my answers, adapting to the information I can*

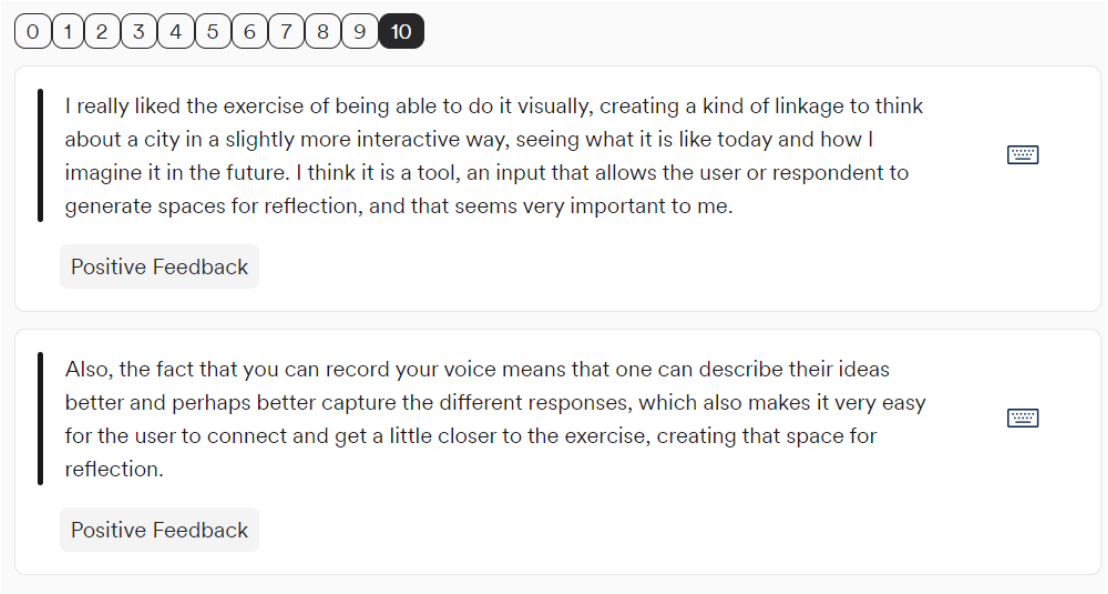

Figure 34. Participant survey experience 2.

provide, guiding me in a very dynamic and enjoyable way to give information and opinions. Truly a very beautiful and very interesting experience."

The lowest generated feedback (7) that the new method is very interesting and valuable, with an interesting take on future visualisation of urban settings, but commented on the user-friendliness of the tool, requesting an increased speed of how the text appeared, possibility to see how much is left of the survey. Furthermore, the participant commented on the format of some questions "There are questions that are too open-ended and can leave the user without direction."

From a research perspective, this novel survey approaches several insights into how the tool can be used in research. Firstly, the survey received a high response rate (71%), over the two weeks it was accessible to the participants. This, although the response time was limited (two weeks), and the survey was communicated as a time-committing study (30-60 minutes). For most people, the survey took just under an hour to complete. Though one might expect that a long online survey would generate more negative experiences, the survey received a surprising amount of positive feedback. Therefore, it is important to note that the success rate of this survey is closely linked with the conditions they were made under. Firstly, the survey was sent out to a selected group of people who were working in the field of NbS, and therefore had known interests and stakes in the topic. Secondly, while no compensation was given for the completion of the survey, the participant's stake in completing the survey was probably raised by the previous interaction between the participants and the researcher. The survey would probably not have had as high of a response rate if it had been sent out to people with less stakes to participate. Thirdly, the willingness to participate may also depend on the local context and culture. While all participants had already offered their time for an interview, most offered additional time for the survey. As this survey was sent out to people of similar professions for a case study in Sweden, no responses were received. As such the culture may impact the willingness to participate.

Finally, the further usage of this survey tool in academic research must consider the ethical and research implications of the selection. While the tool has a lot of potential, it still has to be further developed to fit more in-depth studies in line with academic norms and necessities. This relates to the user-friendliness of developing the study as well as completing the study (as indicated by one participant), and the consideration of how the results can be used. One of the main benefits this survey contributed to was the ability to have an interactive visualisation exercise with people in various languages. The survey was constructed in English, but for all but one the survey was completed in Spanish. As the AI-tool translated the results it allowed the researcher (who does not speak Spanish) to easily analyse the results generated from the interaction exercise. While most of the participants spoke English, this allowed them to express themselves in a language they were more comfortable speaking in. This shows potential for generating more inclusive research where language becomes less of a barrier. However, it is also important to note that transcriptions for various languages are not equally developed. While Spanish, which is one of the world's most widely spoken languages, is well developed in AI-transcription software, less spoken languages are not likely to be as well developed.

Both the possibility to interact with the survey moderator and the possibility to speak in one's mother tongue are conditions which generate a better environment for online and/or remote visioning exercises. One of the main opportunities with this survey tool is the automated results generation, where the recordings of and written answers of people are automatically translated and summarised by the AI-tool. This feature was however not considered scientifically sound, as it requires more insight into the selection basis of the algorithm, and thus was not applied to this research. However improving these features can provide large contributions to academia, and to future-oriented imaginary exercises.

Appendix C. Main ecological structures.

1) Protected areas in National Protection system (SINAP).[135] This involves both publicly protected areas, such as publicly managed national parks (e.g. Sumapaz National Park), and privately protected areas (such as El Tauro Civil Society Nature Reserve).[136]

2) Conservation Zones; areas that are strategic and contribute to the protection, planning and management of renewable resources. This includes both in-situ conservation areas, which focus on protection, planning and management of renewable resources, namely forest reserves,[137] and District System of Protected Areas, which focuses on management measures for are areas which due to their cultural and biophysical conditions can contribute to biodiversity and ecosystem services at a regional or local level, with focus on Sustainable landscapes, Mountain Ecological Parks, and Wetland Reserves.[138] (E.g. District Mountain Ecological Parks.)

3) Areas of Special Ecosystem Importance: Includes areas of special ecosystemic importance which contribute to protecting hydrological cycles through conservation of natural deposits and flows of surface and groundwater. This includes paramo (highland wetlands) such as the Cruz Verde paramo, and natural and artificial water bodies and wetlands.[139] These water systems include:[140]

a. Water sources and their water courses.
b. Rivers and streams and their water courses.
c. Lakes and lagoons.
d. Wetlands and their water courses.
e. Aquifer recharge areas.
f. Channelled natural water bodies and their water courses.
g. Artificial channels.
h. Reservoirs.
i. Linear drainage structures

4) Complementary Conservation Areas: Include spaces which due to their bio-physical conditions offer vegetated areas, or remains of natural ecosystems, which contribute to structural and/or functional environmental connectivity. These areas should also offer cultural, physical and ecological value in the region through providing improved urban aesthetics and environmental values. These structures includes parks, structuring networks, edge parks and areas prioritised for climate resilience and risk protection areas.[141] This includes urban parks, urban vegetation structures and Climate Resilience and Risk Protection Areas. [142] Edge parks include parks in urban edges, which functions as a transition between urban and rural environments, such as the Bogota River Park Network, which contributes with both ecosystemic and landscape value, including recreation, cultural, educational and research values, ecotourism and climate adaptation services.[143]

[135] Management according to National System of Protected Areas - SINAP, according to National Decree 1076 of 2015
[136] Article 46. Private Protected Areas of the National System of Protected Areas -SINAP. (p. 93)
[137] Article 48. In situ conservation areas. (p. 93)
[138] Article 51. District system of protected areas. (p. 94)
[139] Article 58. Component of Areas of Special Ecosystemic Importance. (105)
[140] Article 60. Water system. (p106)
[141] Article 66. Complementary Conservation Areas. (113)
[142] Article 66. Complementary Conservation Areas. (113)
[143] Article 68. Edge Parks. (115-117)

Complementary areas for climate adaptation includes, such as Bogota River Linear Park, has characteristics which are important for risk management and climate adaptation, such as ecological and landscape rehabilitation, ecosystem connectivity, as well as provides recreation. [144] These can be both private and public.[145] The areas included in the MES are different types of ecological structures which are included in various protection and conservation efforts. While it is the diverse ecological structures and ecosystem services which are the functional value of this naturescape, the structures included in the areas are largely determined by the governance of the land. This includes 1) nationally protected areas, owned by public and private actors, 2) Conservation zones, with a focus on forest reserves, sustainable landscapes, ecological Mountain parks and wetland reserves, 3) Areas of special Ecosystemic Importance, including Paramos as well as natural and artificial water bodies, and 4) Complementary conservation areas, including parks, areas along the POMCA river, and certain climate resilience and risk protection areas.

Table 19. Areas within the Bogota region which are included in the Main Ecological Structures

Type of area	Characteristics
Protected areas in National Protection System (SINAP	• Public and privately protected areas

Conservation Zones	• Insitu Conservation Areas: Areas for management of renewable resources
	• District System of Protection areas
	  ○ Sustainable landscapes
	  ○ Ecological Mountain Parks
	  ○ Wetland reserves

Areas of Special Ecosystemic Importance	• Paramos (Highland wetlands) • Natural and artificial waterbodies
Complementary Conservation Areas	• Parks and edge parks • Sub-zones of environmental importance (in the POMCA river) • Climate Resilience and risk protection areas

Appendix D. Examples of Ongoing SUDS project:

This Appendix provides examples of Sustainable Urban Drainage Systems which have been implemented in Bogota. The SUDS have been implemented with different installations and combinations of SUDS typologies, including infiltration trenches, tree pits, vegetated swales, extended dry basins and bioretention zones. The information is compiled using internal planning documents and interviews with involved actors in the planning department of Bogota.

[144] Article 68. Edge Parks. (115-117)
[145] Article 71. Areas of Climate Resilience and risk protection. (122.)

Example 1: Infiltration trenches

The first pilot of SUDS in Bogota was in 2017 when a 1.6 kilometres long infiltration trench was constructed in seven sections between two roads. The infiltration trench was built using 27 drains and 2700 infiltration boxes with high porosity, creating a 450 m3 storage possibility of water. The stored water is useful for grass and trees growing on the infiltration trench. PU3 takes the first implemented infiltration trench of Bogota as an example of a conventional-looking solution, and says *"People, if they pass by this area of the city, they would not see this is a SUDS, but it is an example that it is not an infrastructure that will interfere with conventional urban development of a city, but can be integrated and adapted to the conditions that you have in your city."*

Table 20. SUDS Example 1.

Place	Status	Functionality
Av. Bosa	**First SUDS pilot in Bogota**	1 Infiltration trench system

Figure 35. SUDS Example 1. Picture source: IDU (with consent).

Example 2: Tree Pits

PU1 notes that this solution was multifunctional, as it not only contributes to flood mitigation (6m3 per rainfall event), but also contributes to ecological and recreational values through improving the green connectivity of the city and while improving the aesthetics of the city. Furthermore, PU1 says that the trees in the tree pits grew in a faster rate than other trees that were not used in a SUDS-structure. Furthermore, the plant manages to capture and filter some of the pollutants in the filter some of the stored water.

AV Rincon: In 2019, 3 interconnected tree pits were piloted for the first time in Bogota in the northwest of Bogota, constructing an underground box with high infiltrating substrate for a tree *(Grevillea robusta)*, which were tested out in tanks before securing the SUDS infiltration rates and storage volume before being delivered to the city.

Tramo 1: In Extension Troncal Carcas – Tramo 1, 50 tree pits are tested in different configurations, where the tree pits will both handle flood water, but also contribute with additional water storage and water reservoirs for dry seasons.

AV Congreso Eucaristico (68): The largest implementation SUDS project (in numbers) in Colombia is planned on the major avenue Congreso Eucaristico (Av 68) in western Bogota, where 140 Tree pits are under construction along the road. This project will benefit more than 3 million people in 10 locations in Bogota.[146] The tree pits will be implemented in single, double, and triple configurations and will be evaluated to see which design is better.

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Table 21. SUDS Example 2.

Place	Status	Functionality
Av. Rincón	First pilot project for tree pits in Bogota (2017)	3 Tree Pits
Extension Troncal Caracas	FILL IN	50 Tree Pits
Av. Congreso Eucarístico (Av. 68)	Under Construction	140 tree pits

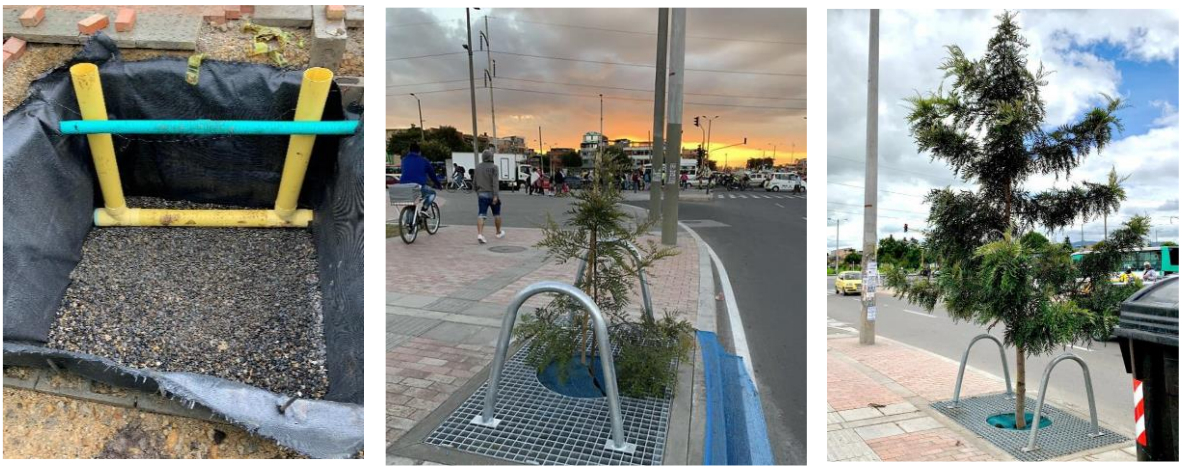

Figure 36. SUDS Example 2. Picture Source IDU (With consent)

Example 3: Vegetated Swales

A 200-meter-long vegetated swale is planned to generate wetland structures primarily to generate ecological values through providing habitat for amphibian and reptile species. PU3 shares that *"Some species of wetland ecosystems were included, precisely to favour this type of ecosystem*

Table 22. SUDS Example 3.

Project/Place	Status	Functionality
PROYECTO IN-HOUSE AV. GUAYACANES – TRAMO 5A	In planning	Vegetated Swales

Figure 37. SUDS Example 3. Picture source IDU (with consent) left. Authors own photo (right).

Example 4: Bioretention zone

On Calle 116, eight bioretention system finished in 2024, which was implemented on a round public square that used to be a parking lot. The SUDS were implemented to improve the landscape design of the area. The area has different designs of bioretention-zones and internal drainage, and with both native species, such as *Dietea indioides, Fuchsua panicualata* and *Helecho arborescente*, and exotic species, such as *Drypoteris filix-mas, Vinca major var.* and *Heterocentron elegans*.

Table 23. SUDS example 4.

Place/Project	Status	Functionality
Aceras y ciclorrutas. Calle 116	Implemented (2023)	Bioretention System

Figure 38. SUDS Example 5.1 Authors own photos.

Example 5. Av Rincon (127): Tree pits + Bio-retention zone

Some projects have also combined SUDS systems, such as Tree pits and bioretention zones at AV. RINCÓN CON CALLE 127, which is the first pilot project in Bogota in a public space to have combined tree pits and bioretention zones. The project aims to reduce flooding events and improve the water quality of run-off water. At the same time the SUDS-system will create green spaces for wildlife and improve the recreational and aesthetic values in the area. Here 18 types of SUDS are being constructed, evenly divided within tree pits and bioretention zones. IDU1 notes that this project is special as it is financed by the city, and does not rely on a private actor or academia to be generated, but has coordinated between entities in the city.

Place/Project	Status	Functionality
Rincón Avenue - 127th Street	**Under construction (2024)**	18 types of SUDS: 9 Tree pits 9 Bioretention zones

Bio-retention zone under construction. Picture Source Google Earth, September 2022

Tree-pits under construction. Picture Source, Google earth, August 2023

Figure 39. SUDS example 5.2. Picture source Google Earth Street View 2024.

Example 6: Extended dry basin + Vegetated swales

In the parque San Cristobal, located in the southeast of Bogota, the University of the Andes piloted a SUDS-system consisting of a 70 meter long vegetated swale and an extended dry basin, connected to a drainage system. The SUDS cover 1,6 ha of drainage area and can store up to 164 m3 water for each rainfall event. Additionally 10 trees are planted for recreational and ecological benefits.

Project/Place	**Status**	**Functionality**
Parque Metropolitano San Cristóbal Sur. Bogotá D.C.	Implemented (2017)	Vegetated Swales Extended dry basins

Pilot project for Bogota's first SUDS system of Extended Dry Basin and vegetated swale in Parque San Cristobal.

Figure 40. SUDS Example 8. Authors own photo.

Appendix E. Summary Urban Themes

Table 24. Summary naturescapes contribution to ES in Urban themes over three horizons.

Ecosystem services	Present Interviews & POT	Short term (2035) POT | *ZIBO* | **Both**	Long-term 2100 Survey
Well-being and equal access to ecosystem services			
Food supply	Rural agriculture Urban agriculture	Urban and peri-urban agroecological practices Secondary forest products Rural agroecological systems (food sovereignty)	Food security & sovereignty Agroecological practices Vertical gardens Nutritious food
Water supply	Water supply	Public water and sewage services Regional ecosystems	Reliable water supply through Rainwater harvesting
Raw materials, natural medicines and biomass	Forestry	Nurseries for native species Primary forest products Secondary forest products	Clean energy
Recreation and physical activity	Well-being & quality of life Recreation Sports & Recreation	**Increased access to public space** Ecotourism Space for non-conventional and non-organised outdoor sport Space for organised and high-performance sports	Multifunctional spaces Inclusive recreation spaces
Aesthetics and inspiration	Inspiration Quality of landscape	Ecotourism **Actions for physical and mental health** Scenic enjoyment	Inspiration
Education and community engagement	Education Learning Traditional knowledge Ecotourism Community engagement	Environmental education Monitoring and research Communal activities (e.g. urban agriculture) Ecotourism contributing to education and awareness Ecotourism benefitting local communities Activities for civic gathering/engagement among different populations (disabled, children, women and elderly)	Awareness raising Learning Education Knowledge sharing and collaboration Community engagement Citizen science
Cultural heritage and spiritual values	Human-nature relationship Cultural identity	- Protecting and making use of cultural and natural heritage	Spiritual connection Belonging Increased relation
Other			Physical safety
Biodiversity and healthy ecosystems			
Well-connected green corridors and connectivity for biodiversity	Ecological connectivity Habitats	**Conservation** **Restoration** **Ecosystem connectors for terrestrial structures**	Ecosystem connectivity through increased public space

Well-connected blue systems and connectivity for biodiversity		**Conservation** - Ecosystem connectors for water structures	Connection of blue infrastructure Increased artificial wetlands
Ecosystems supporting native and endangered species	Habitat for native/endemic species Nesting Resting spots	Conservation practices (RSE, EPR, RHE)	Habitats for native species Food sources Nesting opportunities
Ecosystems adapted and resilient to a changing climate	Biodiversity for resilience		Native species Reduced pavement Increased space for roots
Disease & natural pest control and pollination	Pest regulation		
Air purification & photosynthesis	Air purification Noise reduction		Air purification Noise reduction
Water cycling purification and bioremediation	Water retention Water quality improvement		
Soil formation, purification and nutrient cycling	Nutrient recycling Soil permeability	Developing and preserving natural vegetation cover Sites for organic waste management and compost production	- Support for soil structures
Resilience and Climate Adaptation			
Temperature & humidity regulation	Temperature regulation Reduction of Urban heat islands		Urban heat islands Moist preservation
Green & blue carbon capture	Green carbon mitigation		Blue carbon storage through re-naturalisation
Erosion & landslide prevention	Reduced risk of landslide Erosion control	- Developing and preserving natural vegetation cover - Community actions for landslide prevention	reduced exposure to landslides Reforestation
Wind break & wave break			
Flood regulation and mitigation	Soil permeability Run-off water management	permeable surfaces *Run-off water management (small SUDS)* *Reduced clogging of water ways* *Reduced pressure on conventional systems*	Technically designed permeability
Water cycling and drought prevention	Water cycling Regulation Support hydrological cycles		Reduced reassurance on paramo systems
Other	Reduce risk of forest fire		Native species in reforestation