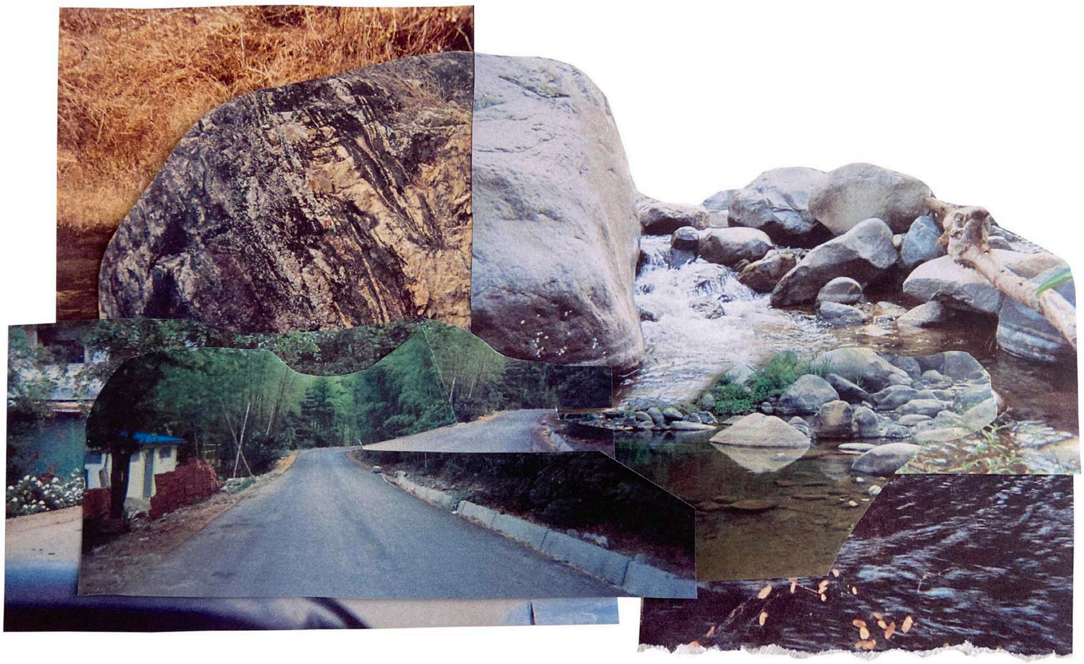

dancing with El Niño

Finding the learning space to build Piura's evolutionary resilience towards floods and droughts

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Content

THIRD PART

FOURTH PART

Abstract

Piura is a land of drastic, and even deadly, contrasts. It's inherent desertic conditions makes water a scares resource; on the contrary, during El Niño phenomenon, heavy rainfalls are 60 times it's average annual precipitation, resulting in oscillations between floods and droughts. Consequently, as the second biggest city of the country, over 2 million people are affected directly. This thesis finds that the underlying issues arise from the disassociation between the natural environment and its habitation, resulting in a cycle of recurrent disasters. Therefore, the research explores the intersection of urban morphology and geomorphology in order to find spaces that can mediate between them. Employing the longue duree theory and principals of evolutionary resilience, the project aims to understand and address the enduring geographical and urban structures in Piura. Above all, it recognized the fragility of the ecosystems for critical design and embraces an interdisciplinary approach across various scales, from the territorial to the material in order to integrate the changing water events within everyday life.

Personal motivation statement

As a Peruvian, I was always taught about climate cycles in the vast and diverse topography that is Peru. This is no exception for the El Niño phenomenon. Despite being a well-known phenomenon, with each event, the desertic northern regions of Peru would oscillate between too much water and too little. I became deeply intrigued by this water paradox.

My journey into researching this complex issue began with my architectural bachelor's thesis, where I focused on the housing problem, informal settlements and their exposure to floods. This research continued during my internship in Blue Deal Peru at the North Waterschap in the fourth quarter of the Master's program, where I explored the existing projects and policies proposals aimed at reducing the effects of El Niño in urban areas.

Along this journey, I came to realize the gap between plans and projects and their implementation. One of the many factors that contribute to this gap is not considering the realities of the place. My internship extended throughout the year of my thesis, providing me with the opportunity to work closely with the team at Blue Deal Peru, in collaboration with the National Authority of Water in Piura and Proyecto Especial Chira-Piura. This practical experience allowed me to incorporate the tangible realities of the field into my academic pursuits.

The current project emphasizes the importance of considering the on-site realities of Piura, as evidenced by my direct involvement in site visits. My motivation lies in finding a balance between academic and professional work, minimizing the inherent abstraction often associated with academia, and bringing forth the practical realities of the place. Simultaneously, I aim to explore a different perspective offered by academia and apply it to the unique context of Piura.

Acknowledgments

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FIRST PART

Image 1: El Niño 2017
Source: El Comercio

1. Introduction

Piura is a land of drastic, and even deadly, contrasts. The northern region of Peru is characterized by a water paradox, oscillating between drought and floods. During periods of drought, the average annual precipitation is less than 100 mm per square meter (Senhami, 2019),, affecting crop fields and people, with serious health consequences for the population due to heatwaves (El Comercio, 2016, & La Republica, 2023). On the contrary, during El Niño events, the average precipitation can reach around 3000mm per square meter (Senhami, 2019), affecting the population with floods, destroying vital infrastructure and agricultural fields (Plan Regional Piura, 2022). The disparity in average precipitation between drought periods and the El Niño events is approximately 60 times, and Piura lacks the necessary infrastructure and resources to cope with these oscillations (Convoca, 2022).

In modern history, the region of Piura has experienced three of the most intense El Niño and El Niño Costero events on record: 1982-83, 1997-98 and 2017. Despite a decrease in mortality from the 1982 event to 2017, there is an increasing trend in the number of affected people, as well as damages to transportation, homes –both damaged and collapsed– and urban services and infrastructure (Venkateswaran, MacClune & Enriquez, 2017). Historical analysis shows that these sectors continue to be vulnerable without a significant reduction over time (French & Mechler, 2017).

These recurrent disasters can be traced to the interaction between the geophysical characteristics of El Niño events and the exposure and vulnerabilities that Peru's population and infrastructure has –specially Piura—. It's root problem relies in its socio-political and institutional characteristics of centralization, sectorial division and corruption, which results in such high level of disaster risk. (French et al., 2020).

2. Problem statement

Climate change and the exacerbation of El Niño phenomenon in Piura / Social realities / Disassociation between natural process and urban systems

The city of Piura faces a double vulnerability resulting from the combination of natural events, intensified by climate change, and socio-cultural conditions marked by decades of government neglection and informality. Even worse, what exacerbates the situation is the disassociation between these vulnerabilities: the first originating from geomorphologies and natural systems, and the second from idiosyncrasies and resultant urban forms. This dissociation signifies a lack of coordination between the planned urban structure and the natural systems, resulting in a recurrent cycle of disasters.

Image 2: El Niño in Piura 1968
Source: Piura's archive

Image 3: El Niño in Piura 1968
Source: Piura's archive

2.1 Climate change and the exacerbation of El Niño phenomenon in Piura

Data evidences that climate change influences the frequency and intensity of El Niño phenomenon. In a recent study, it was discovered that extremely high sea temperature during El Niño events have become approximately 10% stronger in comparison with pre-1960 levels. (Cai, W., et al. 2023). This supports earlier research that suggested that El Niño events will be happening twice as often in the next 100 years because the Pacific Ocean is getting warmer due to the overall rise in global temperatures. (Cai,W.,et al. 2014). For instance, historical records of El Niño events indicate a recurrence every 4 to 7 years; however, in the past decade, these events have been occurring more frequently (French & Mechler, 2017).

The El Niño-Southern Oscillation (ENSO) is a natural phenomenon that occurs in the tropical region of the Pacific Ocean and is related to the interaction between the ocean and the atmosphere. ENSO has a warm phase known as El Niño, which occurs periodically and lasts for several months. During this phase, warming is observed in the surface and subsurface layers of the ocean, which has impacts on global weather patterns (Senhami, 2014). This results in heavy rainfall and flooding in arid regions, and even heavier rainfall in the highlands and the coast of Peru (French et al., 2020). This is particularity the case of the northern regions of Peru. Additionally, river flows and overflows, avalanches, landslides and mudslides occur in the upper parts of the basins (CAF, 1998). On the other hand, Coastal El Niño is a local phenomenon that occurs when coastal winds from south to north decrease, generating high temperatures on the sea surface of the northern coast of Peru (Venkateswaran, MacClune & Enriquez, 2017). In contrast, the cold phase known as La Niña is characterized by the cooling of the sea surface temperature, and as a consequence, drought conditions also occur in the highlands of the south (Senhami, 2014).

The El Niño is characterized by its uncertainty and variability (French & Mechler, 2017). Despite advances in monitoring and forecasting the El Niño phenomenon by the National Study of El Niño (ENFEN), it is difficult to pinpoint the duration and intensity of the event (Glantz, 2015), which can lead to situations of underestimation or overestimation (Venkateswaran, MacClune & Enriquez, 2017). For example, the El Niño event in 2017 took many by surprise, causing devastating disasters in Piura, as the predictions for the 2015-2016 events turned out to be milder than expected, and preparation measures were delayed (Defensoria del Pueblo, 2018). This is partly due to the lack of monitoring stations and measurement points, which limits data collection, as well as the lack of maintenance of existing stations (CAF, 1998). Additionally, the prediction of Coastal El Niño depends on capturing wind patterns that are observed a few weeks in advance (Venkateswaran, MacClune & Enriquez, 2017). Within this uncertainty, the forecasting of El Niño events will be even more challenging considering the effects of climate change (Beobide-Arsuaga et all., 2021).

Concerning the ecological impacts of El Niño, it significantly affects the dry forest, biodiversity, and aquifer recharge in the region (Senhami, 2014). The northern coast of Peru, especially the dry forest, is an extremely dry and marginal landscapes, with delicate ecosystems that can be altered even with the smallest change in plant life, moisture levels or human activities, disrupting the delicate balance within the ecosystem (Sullivan, 1996). The plant composition in these arid areas adapts to extreme conditions, with vegetation growing despite the little water available, leading to a high number of unique species found (N. Padilla., J. Espejo., J. Pardo., 2018) such

Fig 2: Anomalies during El Niño in Peru
Data source: Senhami

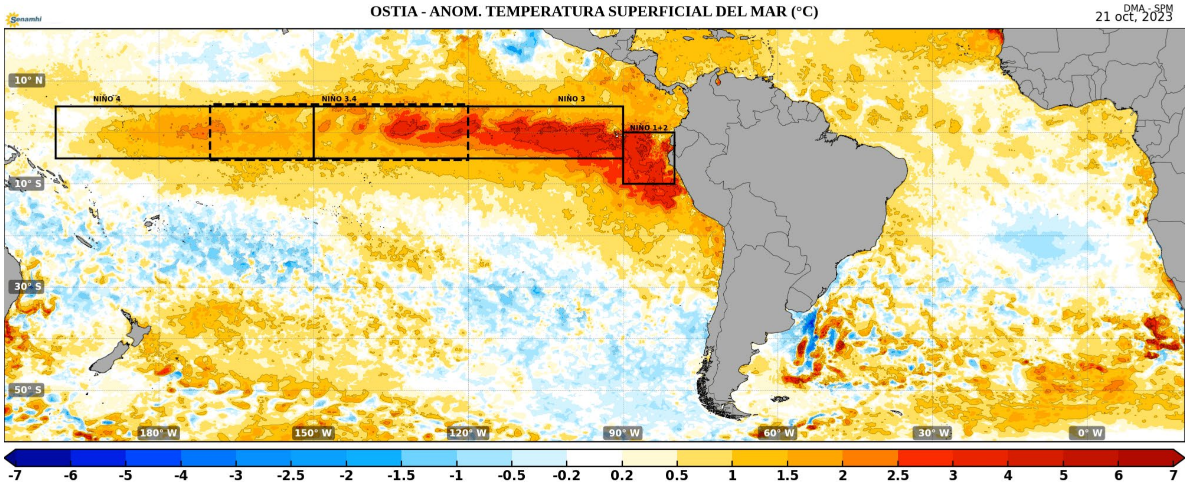


Figure 1: Anomalies temperatures in the sea during Niño impacting South America
Source: Senhami (2017)

as el Algarrobo tree (Canziani, 2013). Additionally, the increase in rainfall during El Niño events has a positive impact in the recharge of underground water. It is suggested that in the past, ancient springs might have been refilled after El Niño-related floods, which played a crucial role in maintaining the groundwater levels. (Magilligan et al., 2007)

Regarding the social impacts of El Niño, its effects are extensive and multi-faceted. The loss of agricultural land is a significant challenge, disrupting the livelihoods of communities that rely on farming. The destruction of productive infrastructure, including communication pathways like roads and bridges, as well as housing infrastructure, is another critical consequence. The increase temperature during El Niño events can contribute to forest fires, posing a threat to both human settlements and natural ecosystems. It also affects basic sanitation facilities, leading to a breakdown in essential services and further compromising community well-being. These are the cases of waterborne diseases such as cholera, malaria, and dengue, which adds a public health dimension to the social impacts of El Niño, putting additional strain on local healthcare systems and affected communities.

In summary, the social-ecological impacts of El Niño encompass a range of challenges, from economic disruptions and infrastructure damage to health risks and environmental threats.

Image 4: Streets of Piura 1970
Source: Piura's archive

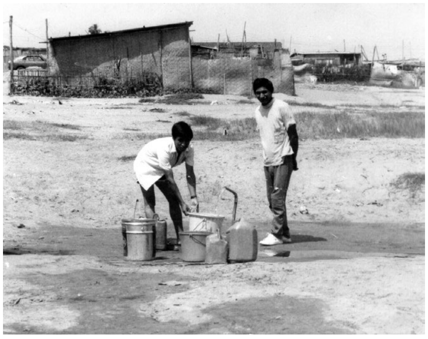


Image 5: Streets of Piura 1970
Source: Piura's archive

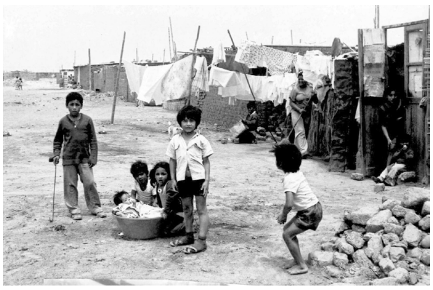


Image 4: Streets of Piura 1970
Source: Piura's archive

2.2 Social realities

Piura is Peru's third most populated region, with almost 2 million residents (INEI, 2018). It's capital city, also named Piura, is the fifth most populated in the country with almost 900,000 inhabitants and it has one of Peru's highest urban growth rates, (Zucchetti & Freundt, 2018). In 2016, the Regional Government of Piura reported that manufacturing was the leading economic sector, contributing 15.7% to the region's economy, followed by commerce and resource extraction. However, agriculture remains the primary employer, playing a vital role in regional employment (Government of Piura, 2016) and shaping the territorial development of the region (Canziani).

The geographical features of the region of Piura has led to a variety of ecological and economic spaces that have shaped Piura's territorial development into a complex network of urban centers with hierarchies. The region has a rich diversity of ecosystems and natural resources, with an Andean topography with low elevation that does not exceed the 2500 meters above sea level which facilitates transversal access to the Amazon. Canziani (2014) categorizes these ecologic-economic spaces in four main areas: the coastal zone, the fertile coastal agricultural valleys, the dry forest, and the Andean highlands (Sierra Andina). (Canziani, 2014)

Since the second half of the 19th century, the integration between the fishing activities in the coastal zones and the agricultural valleys began to link with international economy, driving the region's agricultural development. At the beginning of the 20th century, this agricultural momentum was complemented by the rise of industry and the implementation of major infrastructure projects, giving the region a significant economic role at the regional and national level. In contrast, The Andean highlands underwent a process of marginalization, the economic role focused on self-consumption in small scale and labor supply (Aldana & Diez, 1994).

With internal migration to the cities, Piura's dry forest began experiencing changes, with the development of economic and social activities like beekeeping and tourism. However, this ecosystem faces significant threats due to agricultural and urban expansion. Particularly around Piura's outskirts, new land developments are impacting the forest's soils, crucial for protecting against wind erosion and moderating the climate during heatwaves, as well as acting as a natural barrier during El Niño rains by retaining water. A worrying consequence of this expansion is the overexploitation of the carob tree (Algarrobo), an emblematic species of the region. Its wood is highly demanded for both domestic use (combustion) and supply to chicken restaurants, leading to an increase in the illegal logging of this vital species. (La Republica, 2019)

The internal migration from the Andean highlands to the coast was driven during the 60's and 70's, a period in which not only the north, but all of Peru, experienced these internal migrations. This phenomenon was pushed by the search of better economic opportunities, the agrarian reform during Velasco Alvarado's government and the internal armed conflict. The rapid surge of internal migration to the coastal cities exceeded the capacity of the Peruvian State to manage, respond and plan accordingly, resulting in a rapid growth of informal settlements. This urbanization process was characterized by being spontaneous and self-managed, as these self-organizations are seen as forms of adaptation and survival in a context of housing shortage, marginalization and neglection by the State (Matos Mar, 1984).

The urban growth was also accompanied by political centralization, sectorial division and corruption. Social and institutional conditions have long supported informal settlements and development in hazard-prone areas despite the impacts of recurrent disasters (French et al., 2020), incrementing the exposure of the inhabitants of Piura towards El Niño-floods. For example, the expansion of infrastructure and housing in areas near marginal strips along rivers, floodplains, valleys and green areas –contributing to the deforestation and the risk of landslides– (Defensoria del Pueblo, 2018) have increased exposure to El Niño-related hazards (ANA, 2015). In many cases, municipal governments themselves support these occupations for political reasons, such as reelection. Once the informal invasion is acknowledged and formalized, they have the right to access to public services, basic infrastructures and urban equipment such as schools, hospitals, and institutions, consolidating their permanent establishment (Defensoria del Pueblo, 2018). Once established, relocation becomes extremely complicated (RPP, 2023).

This lack of institution and government neglect also increased the physical and social vulnerability within the city of Piura. With respect to the physical vulnerability, besides the settlement's exposure due to its location in hazard-prone areas, the construction is with low-cost materials such as thatch, wattle and daub, adobe, and brick, contributes to the vulnerability of infrastructure (French et al., 2020, & French & Mechler, 2017). This is even more severe given that approximately 80% of the houses are self-built, which implies a lack of technical supervision (Calderon et al., 2015). Another significant factor to consider are the vulnerabilities that lie within the water supply and sanitation systems. This is because they require regular maintenance to prevent blockages and overflow during heavy rains, which can lead to water contamination and affect health (French & Mechler, 2017). For instance, as an indirect consequence of El Niño, Piura is experiencing a severe dengue sanitary crisis due to the lack of clean drinking water (El Comercio, 2023). Finally, the transportation sector is also highly vulnerable to the impacts of El Niño. This is due to the significant portion of the transportation network that traverses steep, unstable terrains, or is located near rivers (French & Mechler, 2017). As a consequence, the damage to this network disconnects isolated communities, leaving them without access to assistance during emergencies (French et al., 2020).

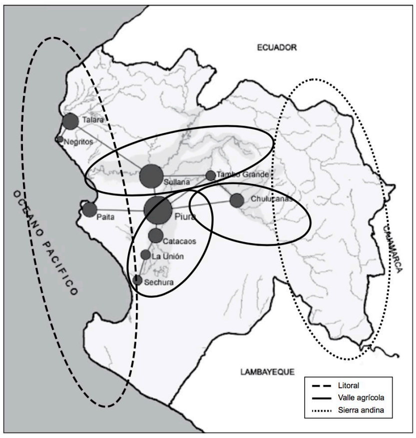


Figure 3: Territorial development from ecologic-economic spaces in Piura
Source: Canziani, 2014

With respect to the social vulnerability, between 2005 and 2012, there was economic growth that reduced poverty and improved well-being, but inequality persisted: access to basic services such as clean water, sanitation infrastructure, electricity, and public assistance programs still depends on economic status, racial, and cultural divisions (Venkateswaran, MacClune & Enriquez, 2017). In addition, knowing that agriculture in Piura has 40% of regional employment (Canziani, 2014), encompassed by big scale and small farmers, it is during the El Niño-flooding events that small farmers are particularly affected (Plan Regional Piura, 2022).

Image 6: Satelite image of new urban expansions
Source: google earth

Image 7: El Niño in Piura 1968
Source: Piura's archive

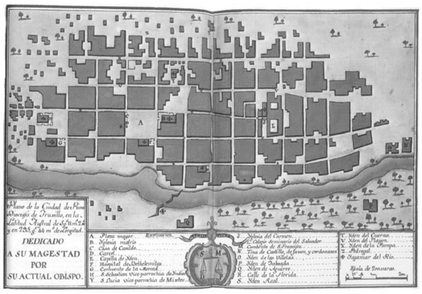


Figure 4: Colonial Map of San Miguel de Piura (1737-1797)
Source: PuroPiura

2.3 Disassociation between natural process and urban systems

There are records from the colonial period about the El Niño phenomenon in the north of Peru and their struggles with these events. (Senhami 2014). Previously, pre-Hispanic cultures such as the Vicus, Tallan, Mochica, Sican, Chimú and Incas inhabited the land and lived synchronized with its natural dynamics. For example, the valleys in Piura respond to a man-made transformed landscape through artificial irrigation systems, dated back to pre-Hispanic times, where they practiced agriculture in consideration of El Niño events. (Canziani, 2013).

Piura was the first colonial city of the country, and it went through the imposition of the colonial grid. Canziani (2014), mentions that as a result, a dichotomy between the city and the territory was established, creating a contraposition between the "city of Spanish" and the "indigenous territories". The colonial city of Piura faced significant challenges, as its structure were substantially different from the complex territorial management that characterized the pre-Hispanic cultures. Then, in the republican times, along with agricultural development, the introduction of new industries and machinery significantly altered the way the territory was inhabited. For example, the construction of new transportation lines, such as railways, would ignore the natural forms of the landscape.

In the last decades, the city of Piura was steered by a great wave of migration from rural areas. With a government that neglected the demand for housing, much of the city was based on autoconstrucction and autoplanning (Matos Mar, 1984). For example, the occupation of residential areas in dry ravines or flood-prone areas. Furthermore, not only in the housing sector, but real estate companies, agricultural enterprises and industries will be driven by economic forces rather than what the local characteristic could offer. For example, cultivating rice in a desert city like Piura demands substantial water, a resource that is already scarce. This reflects a lack of understanding from the region's intrinsic natural systems and local characteristics.

2.4 Summary

The city of Piura faces a dual vulnerability. On the one hand, it's geographical exposure to El Niño phenomenon –exacerbated by climate change—, which brings heavy rainfalls, flooding and ecological and social disruptions. On the other hand, it's socio-cultural vulnerabilities which are rooted in decades of governmental neglection and informality. A city which has experienced rapid population growth and and informal expansions in hazard-prone areas, marked by inequalities and limit access to essential services and infrastructure. This dual vulnerability is also followed by the fact that there is a disassociation between them. In other words, the urban systems, its structure and forms of inhabitation do not respond the natural events, the natural geomorphological conditions. This thesis highlights that the cycle of disaster is perpetuated by this disassociation between the urban morphologies and natural forms.

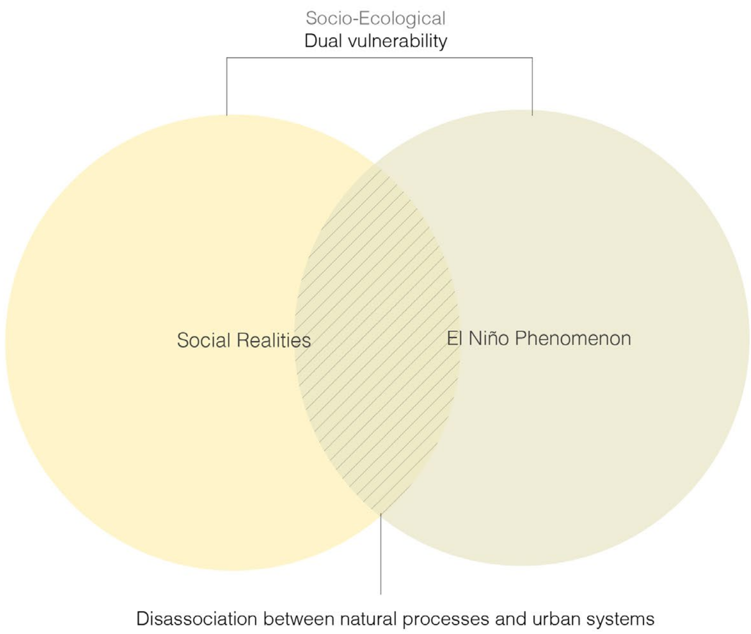


Figure 5: Summary of problem statement

3. Positioning

Within this intricate context, the research navigates through nuanced positions that are not straightforward. It delves into specific positions that were shaped by the on-site visits, interviews with local communities and empathetic understanding.

---> Coexisting with El Niño Phenomenon: Historically, the El Niño event occurred every 5 to 7 years, however, its frequency has increased, now appearing every 2 to 3 years. This shift indicates that El Niño is becoming a recurring aspect of societal life. Therefore, the design considers the population coexisting in harmony with El Niño.

--->Beyond formal and informal: Go beyond formal and informal developments because the research sees it as complex and nuanced realities, and therefore proposes a framework that emphasis in access to opportunities in relation with the spatial structure of the city.

---> Relocation of homes: Acknolwadge that one of the main problems is that people are inhabiting in places that they should not be, and many current alternative contemplate the relocation of these houses. However, I stand that this approach is only necessary in critical situations. It is important to understand the multifaceted motivations that have led to such settlements initially and to demonstrate empathy towards the inhabitants, for whom these dwellings represent more than mere structures, but homes with personal significance.
---> Precariousness: Given the precarious nature of the situation, it is important to work with what there is. This involves a deep understanding of the ecosystem's fragility for the advantage of the project. Thus, the essence of this project lies in strategic identification. This includes pinpointing the lowest areas in the topography, assessing current infrastructure, and recognizing existing tendencies of expansions. Such an approach ensures that the project is grounded in the reality of the environment and community needs.

---> Evolutionary resilience approach: The lens which the problem is addressed is through evolutionary resilience approach instead of the traditional concept of resilience. While traditional resilience often focuses on returning to a previous state, evolutionary resilience is about proactively adapting, embracing change, and building capacities for transformation in the face of uncertainties

4. Framework, methodology and expected outcomes

Research question and subquestions / Research hypothesis / Methodology / Conceptual framework / Theoretical framework / Expected outcomes / Summary

4.1 Research question and subquestions

The research question arises from a direct response to the problem statement and the position. It addresses the dual challenges faced by Piura: the natural impacts of El Niño, intensified by climate change, and the socio-cultural conditions marked by decades of government neglect and informality, along with the disassociation between these issues.

Therefore, the research question is:

How to build Piura's evolutionary resilience towards El Niño induced water extremes, taking into account the realities of the place, where informal and formal activities are present?

The research sub questions leads to a contextual sub question, meaning the what, as well as analytical sub questions, meaning the why, propositional sub questions, meaning the how.

a. What are the dimensions of resilience that contextualize the El Niño phenomenon?

b. What is understood as informality in the context of Piura?

As well as propositional sub questions, meaning the how:

c. How to harmonize both urban morphologies and geomorphologies to reduce Piura's social and ecological vulnerabilities? To what extent can the urban form adapt and how can design re-manage and redistribute spaces to enhance the urban system flexibility?

d. How can Piura design just and equitable spaces that are evolutionary resilient to extreme water events?

e. How do policy, governance structures and socio-cultural factors in Piura influence community responses and adaptability to El Niño induced water extremes?

And to analytical sub questions, meaning the why:

f. Why are social, environmental, and economic vulnerabilities from El Niño water extremes prevalent in the city of Piura? What variables contribute to the cycle of disaster-flooding?

g. What historical urban development patterns influence Piura's vulnerabilities to El Niño induced water extremes?

· Research hypothesis

By integrating an evolutionary resilience approach, Piura can build towards coexisting with water extreme events and therefore minimize the flood and drought impacts in the city. This adaptation can be achieved through finding a balance between the social and ecological bodies, its urban systems and geomorphological transformations by understanding the extent of flexibility of the urban form and activities. In addition, the identification and relation between urban patterns, ecological characteristics and socio-cultural dynamics will help understand better how to head towards a just and equitable city. This includes understanding the complexities behind the formation of informal settlements for which relocation is the last option. Lastly, this approach uses is about proactively embracing change, and therefore, allowing Piura to evolve and transform in response to environmental uncertainties and socio-economic challenges.

4.2 Methodology steps

Regarding the contextual sub questions, the research starts with a literature review to understand the dimensions of resilience in the context of El Niño phenomenon and the concepts of informality in Piura. This involves academic papers, policy documents and case studies that provide insights into these areas and helps establish a theoretical and contextual framework for the research. Secondly, to gain a deeper understanding of local perspectives, during the on-site visit, interviews were conducted with residents and local authorities in the city of Piura. These interviews aimed at capturing the perceptions of people affected by El Niño, complementing the information in the academic papers. Third, historical reviews will be used to trace the evolution, plans, and responses to urban expansions and informal settlements in Piura. This review will help understand how historical patterns have shaped current vulnerabilities and informality and accessibility in the region.

Addressing the analytical sub questions, the research will involve identifying and mapping areas at risk, as well as understanding daily systems and local economic at various scales. This method will help visualize the spatial dynamics of Piura, including areas vulnerable to environmental risk and socio-economic patterns. Secondly, mapping and quantifying flooding events in parallel to a multidimensional risk assessment is crucial to inform strategies for designing urban spaces that are resilient to water extremes. This also includes referencing case studies to understand the extent of flooding and its impacts.

Regarding the propositional sub questions, an exploratory design approach will be used to proposed and evaluate potential solutions to the challenges identified. This will include creating scenarios and models that address policy, governance, socio-cultural factors and their influence on community responses to El Niño. Finally, scenarios will be developed as a tool for evaluating the effectiveness of the design proposal and interventions. These scenarios will help assess how different strategies might perform under the water-cycles —between floods and droughts—and development patterns.

4.3 Conceptual framework

The conceptual framework for this research aims to explore the dual vulnerabilities present in socio-ecological systems, particularly focusing on the interplay between urban morphology and geomorphology. Central to this framework is understanding how these forms intersect and overlap, leading to increased flood risks, social exposure, and socio-ecological vulnerabilities in the context of El Niño. At the heart of addressing these overlaps is the principle of coexistence with the El Niño phenomenon. This aspect will be developed through the lens of evolutionary resilience, encompassing strategies in flood management and the pursuit of social justice. The longue duree theory is then used as a tool to understand the enduring structures and forms, such as the geographical and urban configurations, over extended periods. This perspective allows for a more comprehensive examination of El Niño, not just as a meteorological event, but as a component of a broader temporal and spatial context. Similar, the urban form is analyzed through the lens of long-term patterns and developments in order to understand how historical, geographical and socio-economic factors influence the current urban landscape.

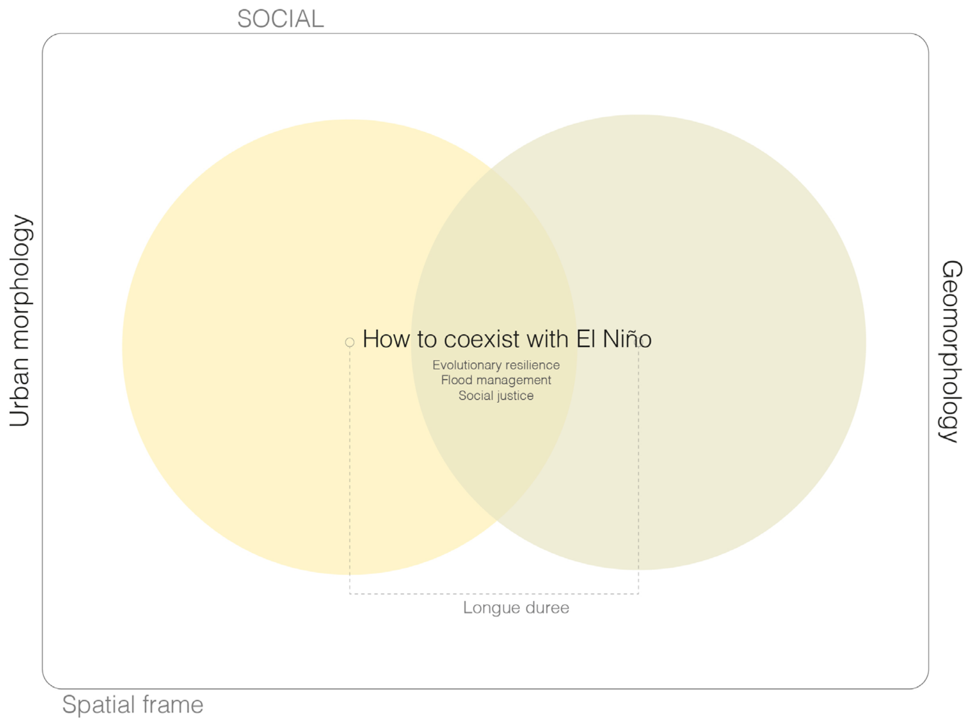


Figure 6: Conceptural framwork

4.4. Theoretical framework

In the context of socio-cultural-political factors, particularly concerning the identity and spatial development of the northern regions, the works of several notable authors are used. Maria Rostworoski (1999) provides insights into the pre-Hispanic cultures of Peru's northern regions, offering an understanding of the relationship between indigenous practices and the land. Jose Canziani's (2014) research into the territorial development of Piura, which accounts for the ecological and economic spaces shaping urban dynamics, is crucial in understanding why Piura has developed into a centralized dependency. This form of hierarchy in urban systems relies heavily on the city of Piura. The anthropological perspective of Matos Mar (1998) work is on the process of internal migration in Peru during the mid-60s and 70s, attributing it to broader causes. He adopts an optimistic stance on the urban expansions resulting from migrations from the Sierra to the Coast in pursuit of opportunities, advocating for the emergence of new cultural values. This perspective is highly valued in my research, as it aims to see further than informal and formal settlements

The social-cultural-political context gives rise to central dependencies, leading to the concept of spatial segregation. Muñoz, P., Hausleitner, B., and Dabrowski, M. (2020) offers and alternative view on spatial segregation in Peru. They focus on access to opportunities rather than a distinctive formal and informal view. Their paper advocates that by enhancing accessibility to social and economic activities, which are typically concentrated in central nodes, new opportunities can emerge. For further development of the concept of spatial segregation, Manuel Castells (1997) defines it as a process by which social groups are segregated into different geographic areas based on factors such as economic status, ethnicity, culture, or lifestyle choices. He links this segregation to broader socio-economic and cultural processes that reflect societal inequalities and power dynamics (Castells, M., 1997).

In the context of urban morphology, Karl Kropf's 2018 book "The Handbook of Urban Morphology" explains how spatial and activity patterns, shaped by societal actors' roles and intentions, contribute to urban formation. Kropf explains that urban patterns, encompassing networks of streets, plots, and building configurations, emerge not only from deliberate design but also as unintended outcomes over time. He introduces three key concepts: process, type, and hierarchy. The process reflects the interplay of deliberate and spontaneous actions in shaping the built environment, which Kropf describes as a transformation through human energy in building. Configuration and type refer to the replication of specific element arrangements, influenced by social and cultural factors, creating recognizable forms or 'types'. Hierarchy is related to the structured combination of individual elements, forming complex, organized spaces. Kropf also explores 'urban tissue', which is fundamental in contributing to local identity. (Kropf, K. 2018)

In the context of geomorphologies, specifically the Piura's characteristics, I delve into arid landscapes and fragile ecosystems. The author Sullivan, S (1996) provides an understand of the process of desertification in Piura by attributing it mainly to the deforestation, fires, poor water management, inappropriate use of land and overgrazing (Sullivan, S. 1996). The author uses definitions of desertification by the United Nations to Combat Desertification that defines it as the decline of dry lands that includes arid, semi-arid and sub-humid regions, that are attributed to various causes such as climate patterns and anthropogenic actions. (ONU, 1994).

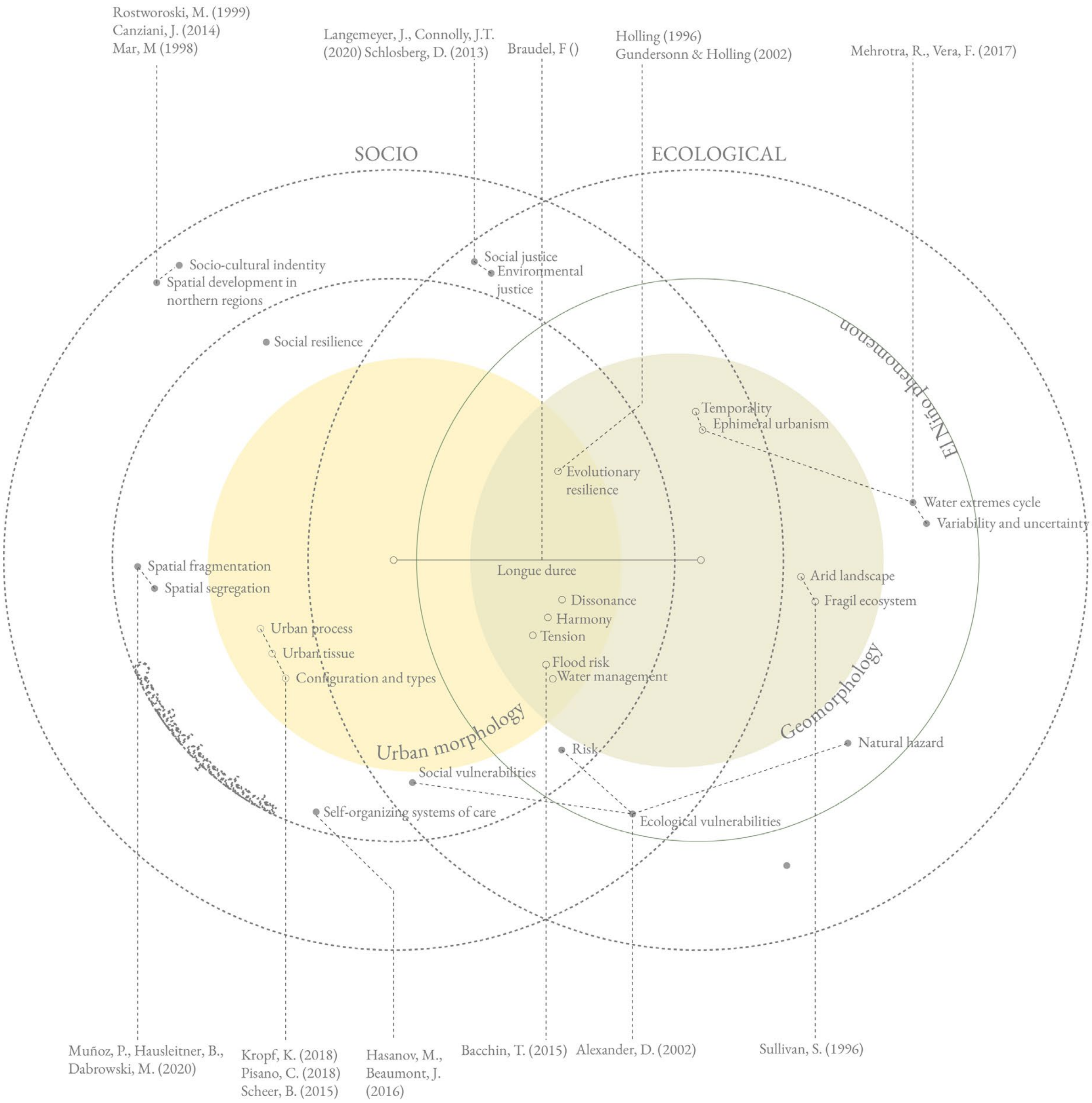


Figure 7: Abstract mapping of theoretical framework

There is three different types of conceptualizations whithin resilience: engineering, ecological and socio-ecological resilience (Gunderson & Holling, 2002). The concept of engineering resilience refers to the ability of a system to return to an equilibrium or steady state after a disturbance. It emphasizes efficiency, constancy, predictability, and focuses on how quickly a system can return to normal after being disturbed. (Holling, 1996 & Gundersonn & Holling 2002). The concept of ecological resilience suggests that ecosystems have multiple equilibria and can shift between them. It is concerned with a system's capacity to absorbed change and persist, with an emphasis on persistence, change and unpredictability. (Holling 1996). This type of resilience considers not just how long it takes for a system to bounce back, but also how much disturbance it can handle before it transforms into a different state. (Holling, 1996 & Gundersonn & Holling 2002).

The social-ecological resilience, what it known as evolutionary resilience (Simmie, J & Martin, R, 2010), blends socio-ecological resilience with evolutionary thinking, moving beyond the idea of returning to a stable equilibrium (whether existing or new). (Davoudi 2012). It views resilience as the ability of complex social-ecological systems to change, adapt, or transform in response to stresses and strains. (Carpenter et al., 2005). The concept includes the idea of an 'adaptive cycle', characterized by four phases: growth (rapid resource accumulation), conservation (resource storage and system maintenance), creative destruction (chaotic collapse and release of capital), and reorganization (time of innovation and restructuring). (Holling 1986 & Gundersonn & Holling 2002). The adaptive cycle is visualized as a series of nested cycles, known as 'panarchy', occurring at different scales and speeds. This implies continual interactions and self-organization between smaller and larger systems, and slow and fast processes, allowing systems to maintain resilience. (Gunderson & Holling, 2002)

Braudel, F (1980) defines the concept of longue duree as a historical approach that focuses on the long-term social, economic and geographical structures and trends. The author advocates to study history over long periods of time in order to understand deeper and more persistent forces that shape societies. This view opposes just concentrating in short-term events or in the individual experiences, and focuses in the slow and underlying processes and structures that have influence in historical change. (Braudel, F, 1980). Braudel's theory of the longue duree can be related to the El Niño-flood cycles by focusing on the long-term environmental and climate patterns that influence these events. This recurring climatic pattern, that is El Niño, fits into Braudel's concept of enduring structures that shape historical events over time. And by understanding the long-term climatic trends and their impact on societies and landscapes, Braudels approach comes in play by studying the deeper and more persistent forces in history. Regarding the urban expansions occurring in Piura, the longue duree theory can be applied to understand the underlying socio-economic structures and medium-term processes that drive such expansions. This perspective considers a the broader historical, economic and social context that contribute to the urbanization patterns. By looking at the longue duree, one can analyze the enduring factors such as the economic disparities, internal migration from the Sierra to the Coast and the historical and cultural factors that shaped the urban form.

4.5 Expected outcomes

The aim is to establish a framework for design proposals by providing context-specific guidelines. These proposals are grounded in the positioning outlined in Chapter 3, which were informed by the on-site visit and my learnings from the urbanism master track. The design proposals address three key scenarios related to the problem statement: El Niño floods, droughts, and day-to-day realities. Furthermore, how the designs are implemented over time and identify the actors involved in each phase of the process.

4.6 Summary

RESEARCH QUESTION

How to build Piura's evolutionary resilience towards El Niño induced water extremes, taking into account the realities of the place, where informal and formal activites are present?

RESEARCH SUBQUESTIONS

Contextual (what?)

A. What are the dimensions of resilience that contextualize the El Niño phenomenon?

B. What is understood as informality in the context of Piura?

Analytical (why?)

C. Why are social, environmental, and economic vulnerabilities from El Niño water extremes prevalent in the city of Piura? What variables contribute to the cycle of disaster-flooding?

D. What historical urban development patterns influence Piura's vulnerabilities to El Niño induced water extremes?

Propositional (how?)

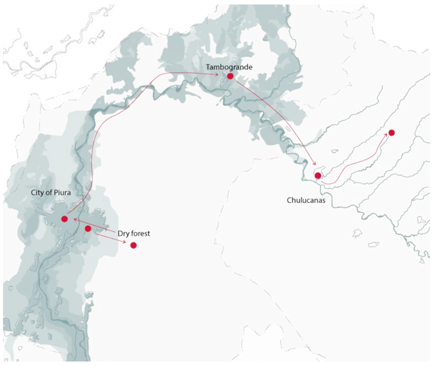
E. How to harmonize both urban morphologies and geomorphologies to reduce Piura's social and ecological vulnerabilities? To what extent can the urban form adapt and how can design remanage and redistribute spaces to enhance the urban system flexibility?

F. How can Piura design just and equitable spaces that are evolutionary resilient to extreme water events?

G. How do policy, governance structures and socio-cultural factors in Piura influence community responses and adaptability to El Niño induced water extremes?

METHODS	OUTCOMES
A.B. Literature review and case study A.B. Perception of people gathered through fieldwork interviews B. Historic review of the evolution, plans and responses to informal settlements.	A.B. Contextualize and create guideliness for the design proposal
C.D. Identifying and mapping of risk, daily system and local economies at different scales C.D. Mapping and quantifying flooding events and multidimensional risk assesment with case references	C.D. Design principles
E.F.G. Exploratory design E.F.G. Scenario as design evaluation	E.F.G Design proposal with scenarios

SECOND PART



Map 3: Routs made on-site

1. On-site perceptions

This chapter is about the on-site visit to the city of Piura. The main research question is how to builds Piura's resilience towards the effects of El Niño, considering the ground realities of the place, specifically informality. Nevertheless, there is a significant gap in accessing updated information and data online regarding several aspects. Therefore, an on-site visit was necessary to document through photos, videos and drawings the current state to gain a comprehensive understanding for the research and thesis project. Firstly, informal urban expansions towards hazard areas, specifically the dry forest and dry ravines. Secondly, the state of the dry forest which is being deforested by illegal logging, settlements and paved roads and plays a fundamental role in stabilizing the soils and water cycle during El Niño. Lastly, new informal constructions, typically small grey infrastructures, in the margin of the river for mitigating the floods during El Niño. Furthermore, engaging with local actors such as officials, specialist, communities and citizens is essential. Understanding their perceptions of water extremes will complement existing literature, covering topics from territorial development in the northern region, pre-Hispanic cultural identities, research in soil degradation in arid zones, and resilience to water extremes.

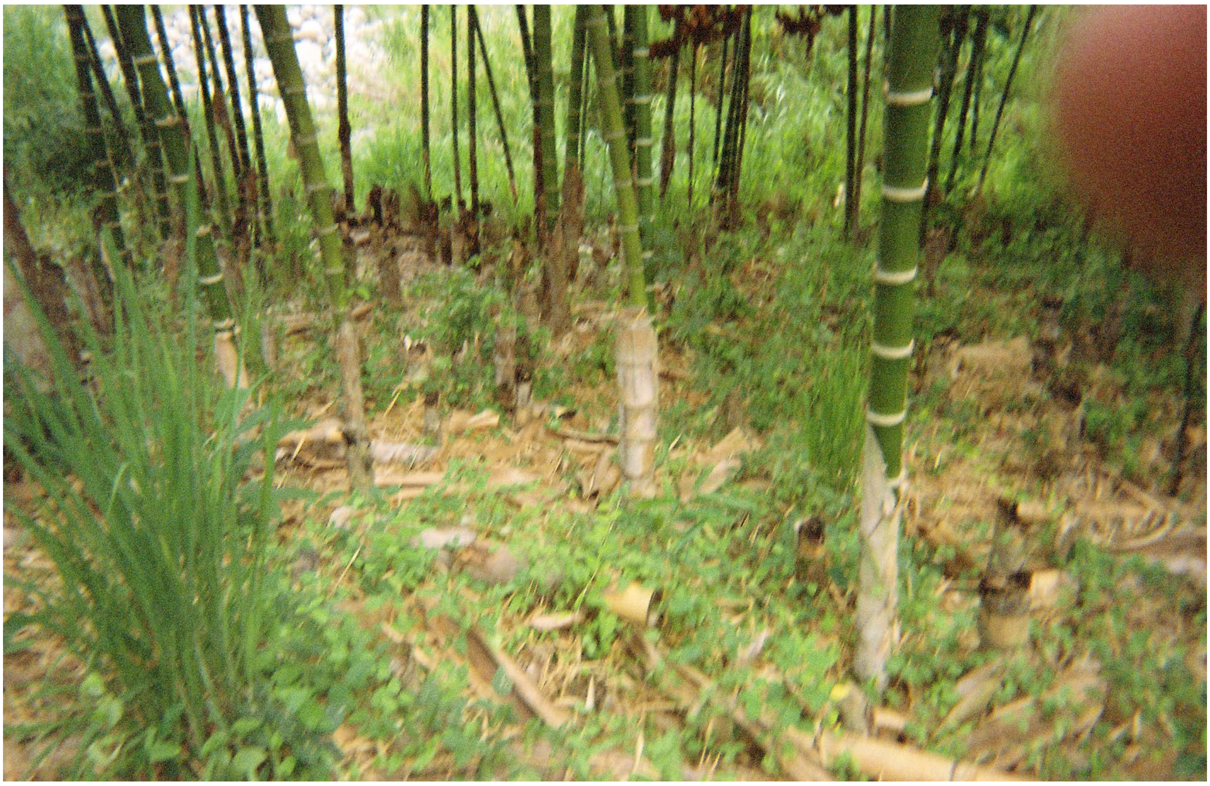
A two-week visit, preceding the anticipated El Niño event in late December 2023 and early January 2024, was conducted in collaboration with Blue Deal Peru, the National Authority of Water in Piura (ANA), and Proyecto Especial Chira-Piura, which focuses on water management in the region's main rivers. It involved interviews with various stakeholders, including members of the Proyecto Especial Chira-Piura, soil and ecology specialists, provincial-level representatives, community representatives from high-risk areas, and emergency response personnel.
Key areas visited during the expedition included blind basins such as Petroperú, El Chical, and La Primavera, the Santa Julia Lagoon, Piura River margins, El Gallo Ravine, informal settlements, the dry forest, and the upper part of the Piura River basin.

Central to the methodology was an attempt to understand the locals' perceptions of their landscape and the evolving climate. Participants were provided with digital cameras to capture their perspectives throughout the trip, allowing us to witness the journey through their eyes. This approach revealed nuances and details that might have escaped my notice as outsider, shedding light on what locals value and prioritize. Through this immersive experience, I gained invaluable insights into the intricate dynamics shaping Piura's resilience landscape. The findings underscore the importance of collaborative, community-driven approaches.


VILLA
LA ESPERANZA


IKER


VILLA
MERCEDES
90 MTS



2. Deconstruction of socio-ecological vulnerabilities

Variables (the partners) / Cycle and patterns (time and space) / Relations (the dance)

In the first part, the main problems of the city of Piura where identified: risk of natural phenomenon's such as El Niño, the underlying socio-political inherent vulnerabilities, and the disassociation between the the city's inhabitants and their local environmental dynamics. This chapter aims to deconstruct the different elements comprising socio-ecological patterns, contextualize them within specific temporal and spatial frames, and subsequently analyze their interrelations.

2.1 Variables (the partners)

This chapter systematically identifies spatially the variables that interact with the natural and urban systems. The main variables arise from diverse literature and are categorized in four groups, each comprising with several sub-variables: substratum, climate patterns, network and occupation.
The first two groups lean towards ecological aspects. Under 'substratum' encompasses sub-variables such as soil, topography, hydrology and vegetation and ecosystems, while 'climate patterns' include wind, precipitation, and temperature. The latter two groups, 'network' and 'occupation', focus on social aspects. 'Network 'covers aspects like transport, local economies, water infrastructure. 'Occupation' addresses factors such as urban developments, state of consolidation, built form, land use, location in flood-prone areas and location in heat zones.

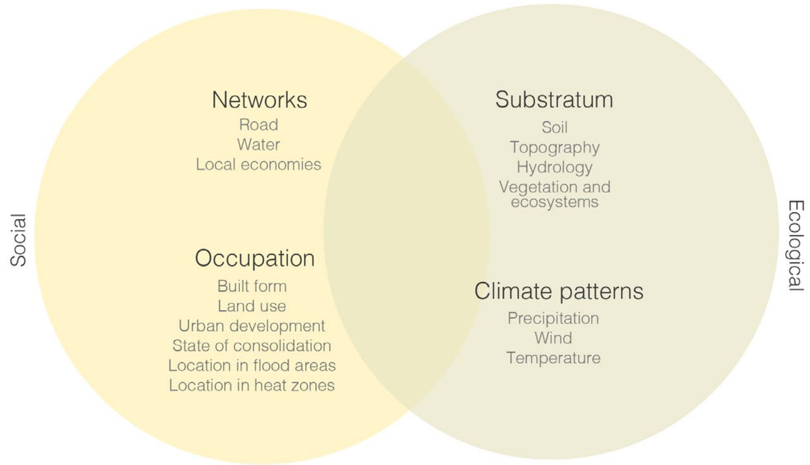


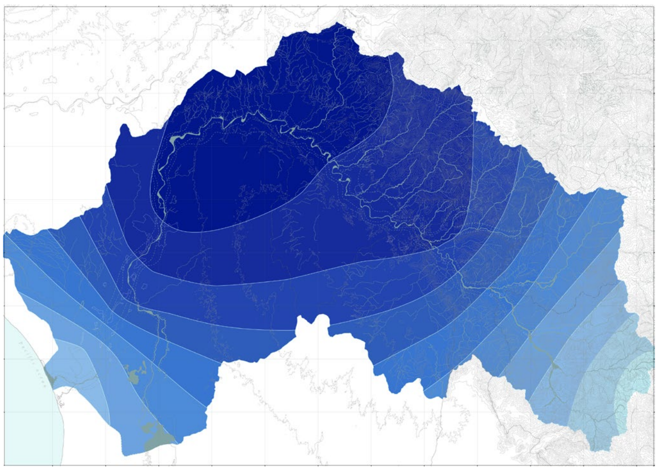
Figure 8: Dissasociated variables withing the conceptural framework

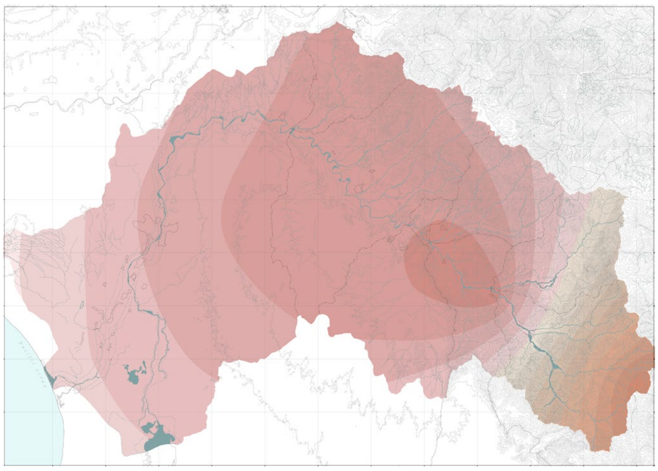
· Climate aspects: wind, precipitation and temperature

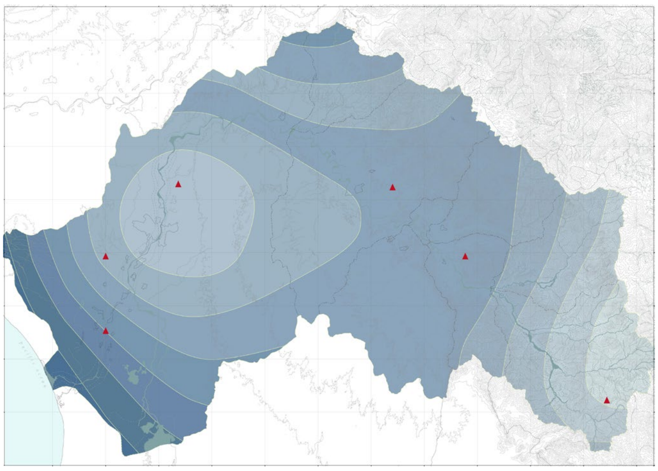
The precipitation is characterized by its exceptionally arid climate, resulting in very low annual precipitation. The city typically experiences less than 50 mm of rainfall per year, with most of this occurring during the austral summer months (December to March). This seasonal rainfall is primarily influenced by the El Niño phenomenon, which can reach up to 3000 mm.

The city of Piura experiences a unique wind pattern predominantly influenced by its desert-like climate. The winds here are generally characterized by their mild to moderate strength, blowing primarily from the south or southeast. Due to the city's proximity to the Pacific Ocean and its location within a coastal desert, these winds often carry a level of humidity, which can provide a slight relief from the typically high temperatures of the region. However, during certain times of the year, notably in the Peruvian summer (December to March), the winds can become more intense and variable, sometimes bringing warmer air from inland areas.

The city has a warm temperature, semi-arid climate, leading to high temperatures throughout the year. The city experiences minimal temperature variation seasonally, with average highs typically ranging between 30°C to 35°C (86°F to 95°F). The warmest months are usually December through April, coinciding with the southern hemisphere summer. During this period, temperatures can occasionally peak even higher.







Precipitation, wind and temperature
Basin scale
Data source: PEIHAP, 2019

Direction of the wind

Intensity of speed

Intensity of precipitation 2017
per hour (mm)

50
75
150
200
250

Average temperature

City of Piura

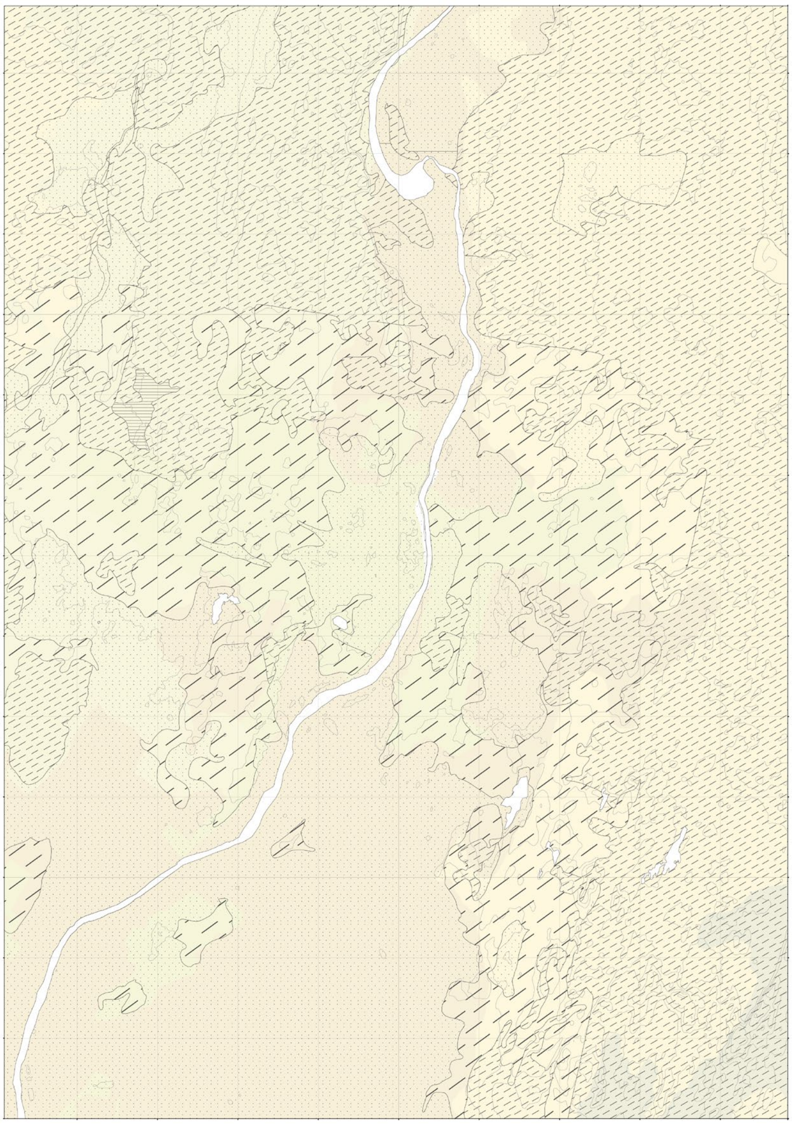
0 10 20 km N

Image 8: Arid landscape
Source: PEHIPAP 2019

Image 9: Arid landscape
Source: PEHIPAP 2019

· Substratum: soil

The city of Piura, is characterized by its predominantly alluvial soil, influenced by the presence of the Piura River. This soil is rich in sediments such as sands, silts, and clays, which have been deposited over thousands of years due to periodic flooding and the constant flow of the river. The varied texture of the soil provides a drainage capacity that ranges from moderate to high.



Soil composition_City scale
Data source: PEIHAP, 2019

Torrisament

Ustilfluvents

Salortids

Lotosoles

Conglomerate deposits, sand deposit, clay deposit

Conglomerates, Outcrops of shales, beds of quartzites, sand beds, muds covered by wet sands

Sandstonnes, shales and conglonerate

Litharenite conglomerate with poorly consolidated coquinas in an arcose sandstone matrix

Antropogenic soil

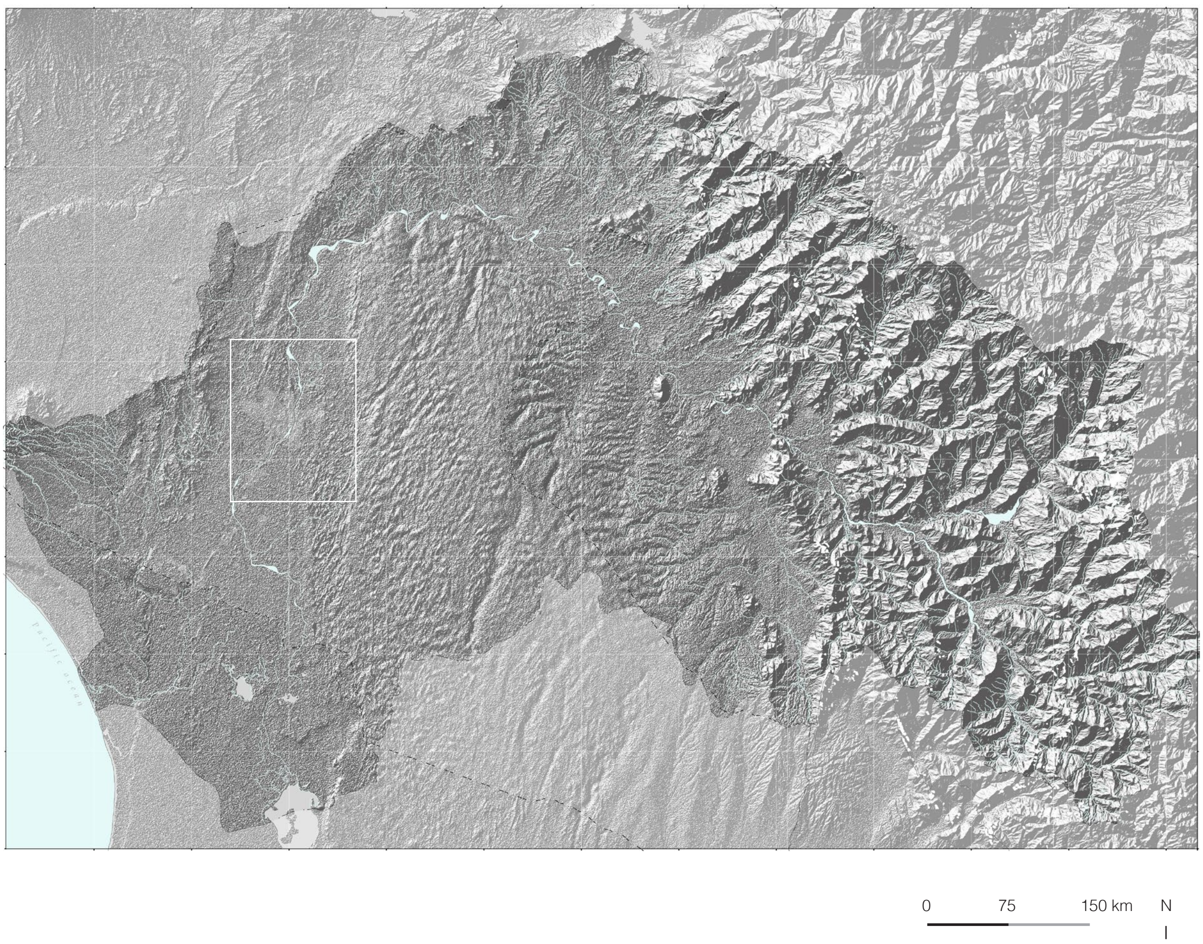
River Piura

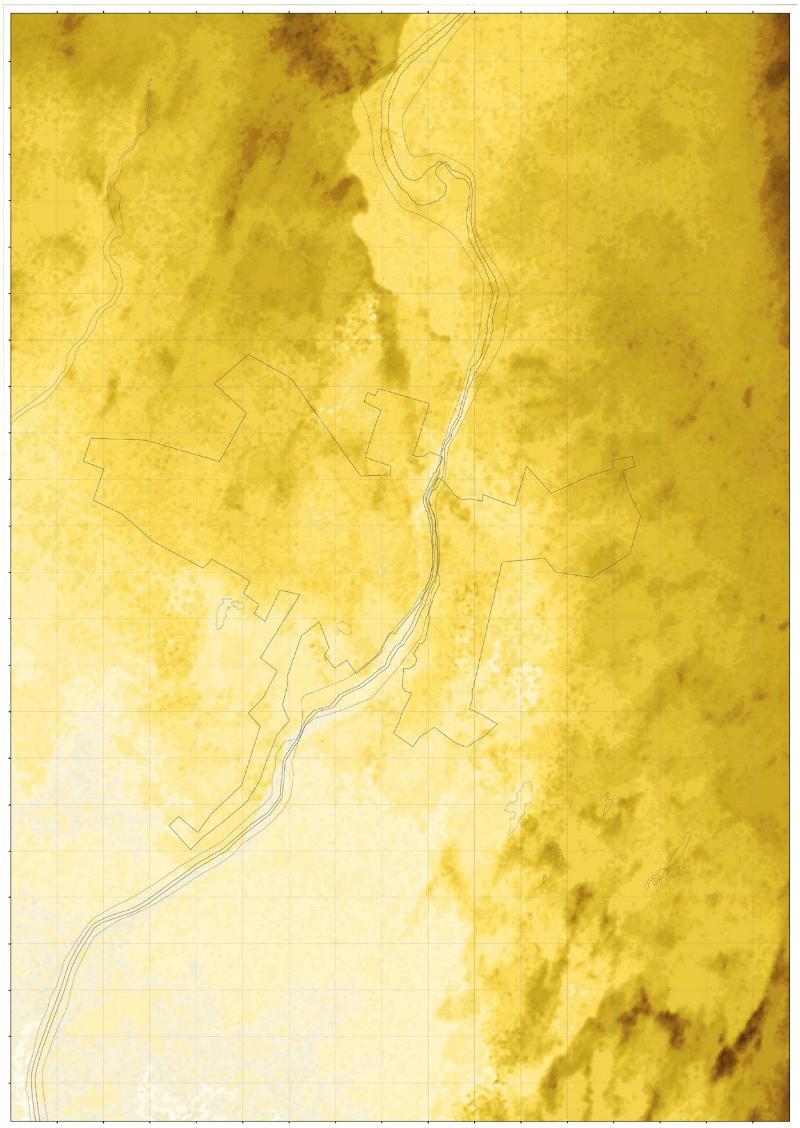
Countour lines every 10m

0 .75 1.5 km N

· Substratum: topography and land form

The city of Piura is located in a predominantly flat and gently undulating topography. Characterized by its location within the lower Piura River valley, the city's landscape gently slopes, with gradients generally not exceeding 5 degrees. This subtle incline is more pronounced along the river's course, where the terrain subtly dips towards the riverbed, aiding in natural water drainage. The flatness of the area, combined with its low elevation, makes Piura susceptible to flooding, especially during heavy rain events.





Topography
Basin scale (left) / City scale (right)

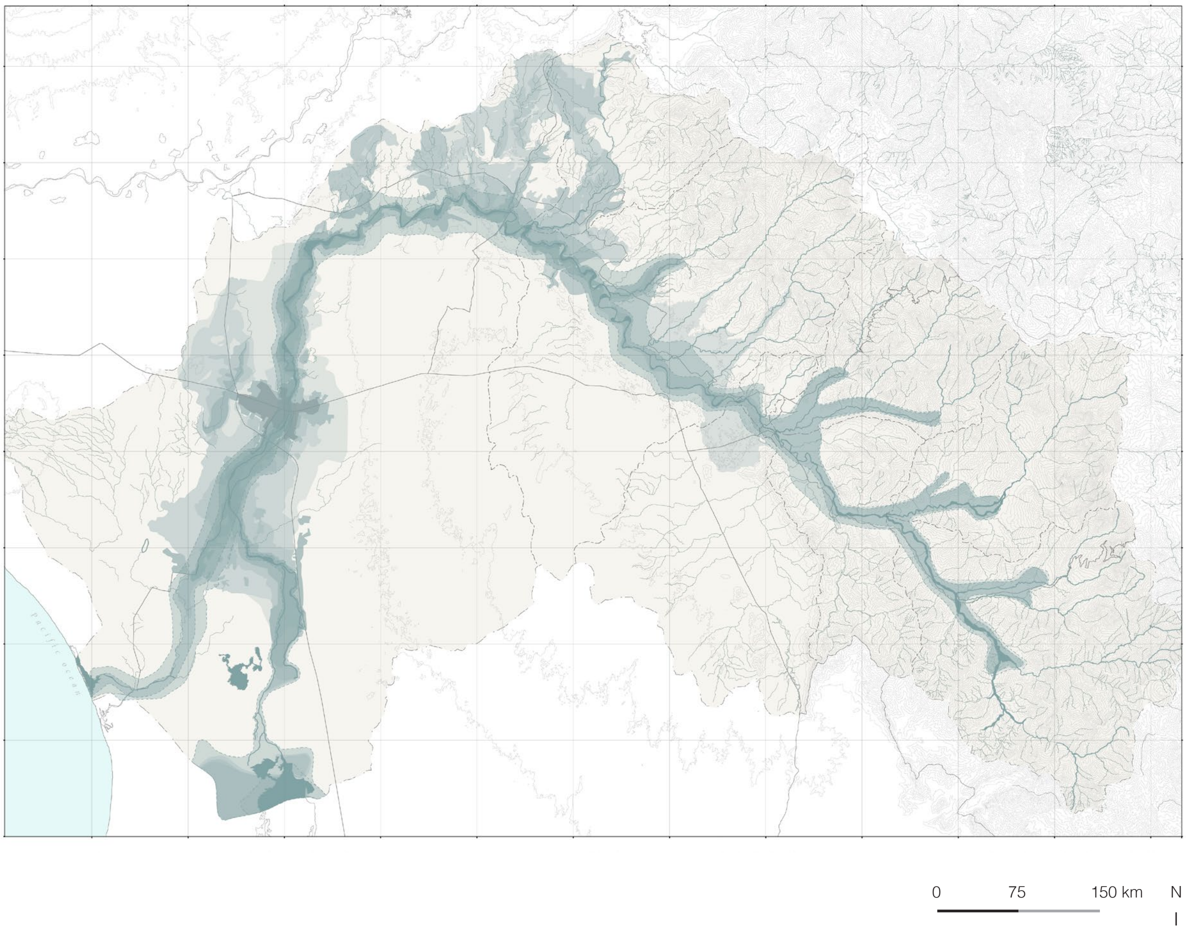
Highest
Lowest
River Piura
Urban areas

0 75 150 km N

Image 10: Natural ravines
Source: image taken by the author

· Substratum: hydrology

The area's aquifers are primarily composed of unconsolidated porous materials, such as sandy gravels, silts, and clays, offering good porosity and high permeability for efficient underground water storage and circulation. Unconfined aquifers are directly recharged by water infiltration through their permeable upper layer, subject to atmospheric pressure, which causes the water level to mirror the water table. In other words, these are like sponged lying under the ground. They soak up rainwater easily. Since they are open to the air at the surface, the water level in them goes up and down just like the water table (the top level of groundwater). In contrast, confined aquifers are sandwiched between impermeable layers and contain water under pressure greater than the atmospheric, leading to a rise in water level above the aquifer when a well is drilled. These confined aquifers are like water-filled balloons, trapped between layers of clay or dense rock. They are squeezed under pressure. When you drill into them, the pressure can punch the water up, sometimes even above the ground level. This is important because both types of aquifers are really good at holding and moving water underground. However, in some places, the water in these aquifers can have a lot of salt, making it not so good for watering certain crops. During droughts, its important to make sure these underground water sources keep getting refilled naturally. (PEIHAP, 2019)



Hydrology
Basin scale (left) / City scale (right)
Data source: PEIHAP, 2019

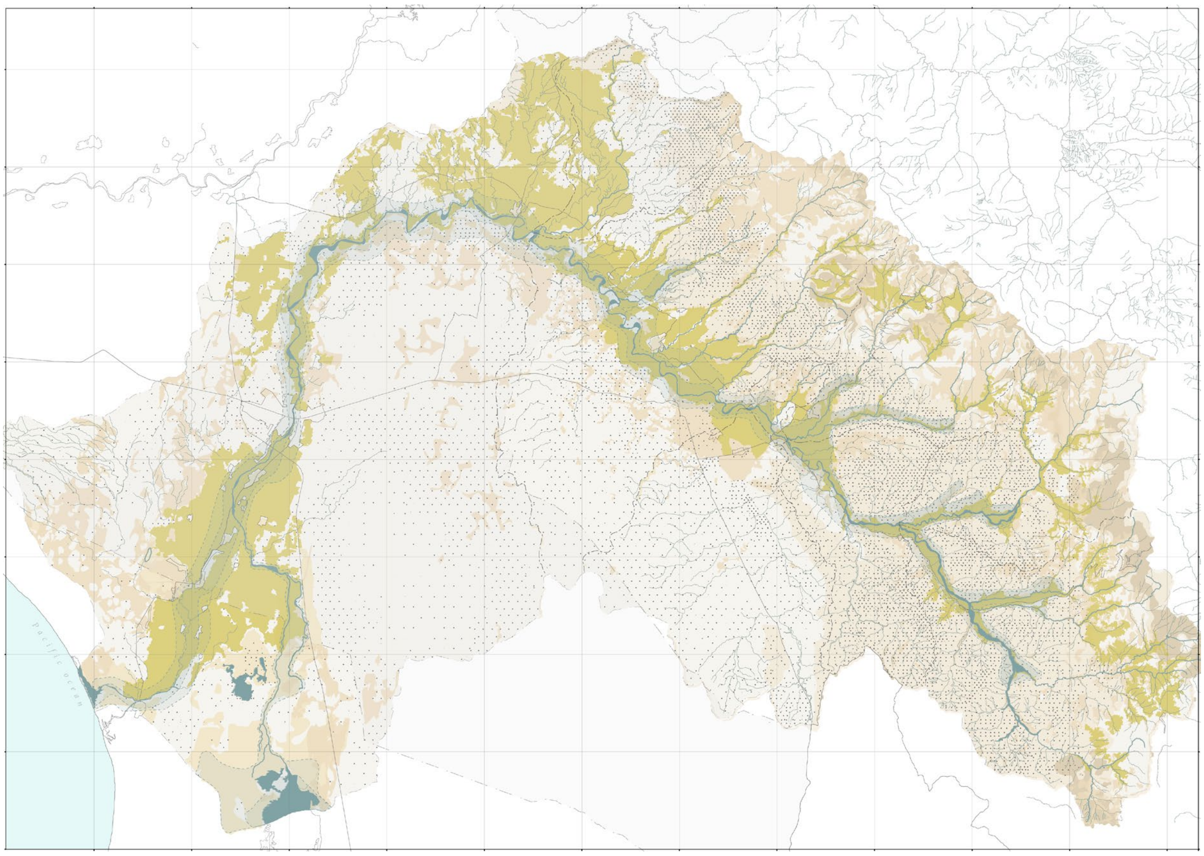
- Natural drainage system
- High level permeability to aquifer
- Low permeability to aquifer
- Lakes
- Retention lakes
- River Piura
- Countour lines every 10m

0 75 150 km N

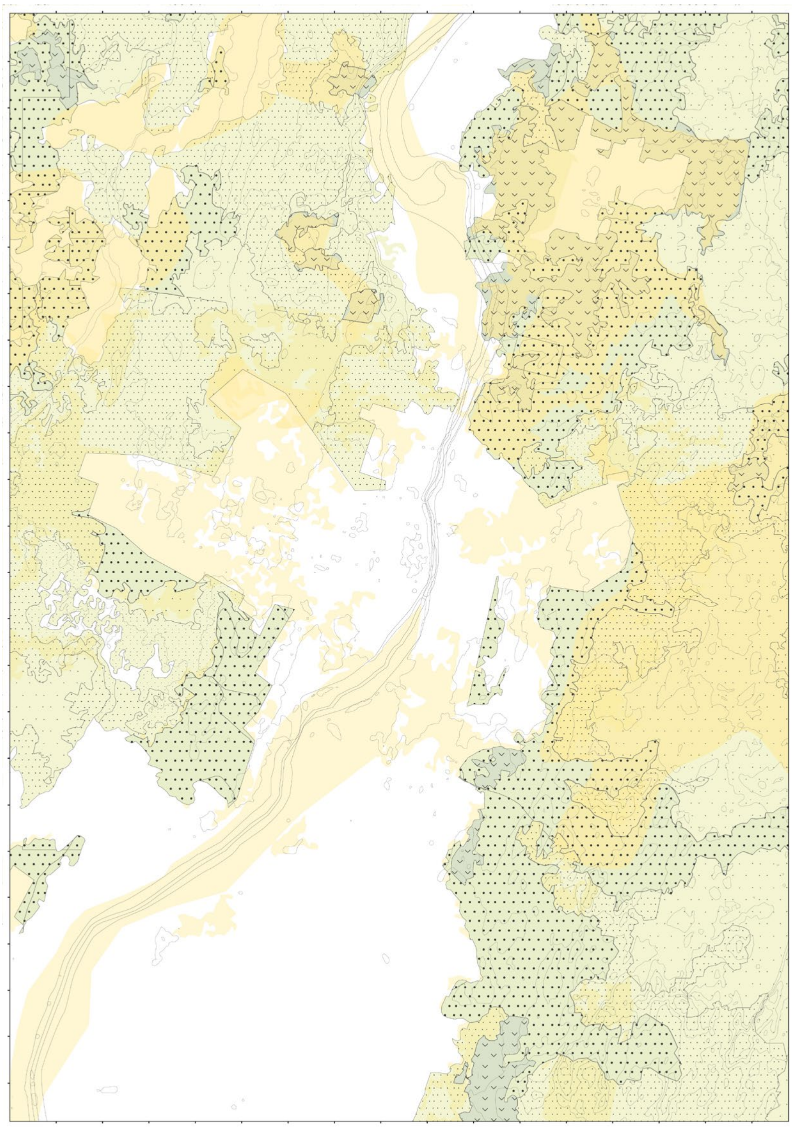
Image 11: Algarrobo tree
Source: PEHIPAP 2019

· Substratum: vegetation, habitats and ecosystems

The city of Piura is surrounded by a landscape characterized by arid and dry desert conditions. The vegetation in and around Piura is typical of a desert climate, consisting mainly of drought-resistant flora. You'll find a variety of cacti and scrub bushes, which are well adapted to the low rainfall and high temperatures of the region. These plants have developed unique adaptations like deep root systems and the ability to store water, enabling them to survive in the harsh desert environment. In addition to these, there are areas with sparse grasses and hardy trees, such as the algarrobo tree (Prosopis pallida), which is not only a common sight but also an important part of the local ecosystem and culture. The vegetation, although limited in diversity due to the dry conditions, plays a crucial role in supporting local wildlife and maintaining ecological balance in this desert landscape. (PEIHAP, 2019)



0 75 150 km N



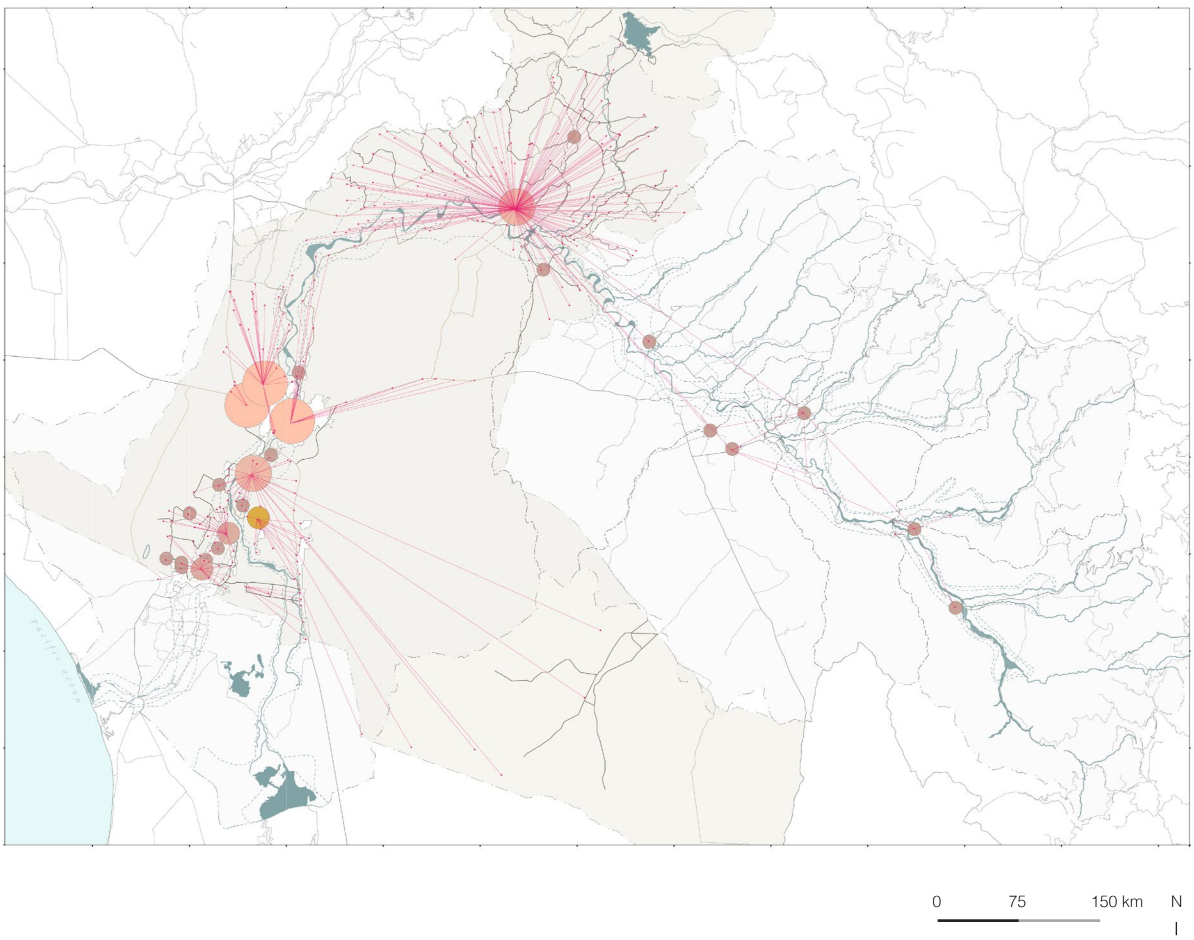
Vegetation
Basin scale (left) / City scale (right)
Data source: PEIHAP, 2019

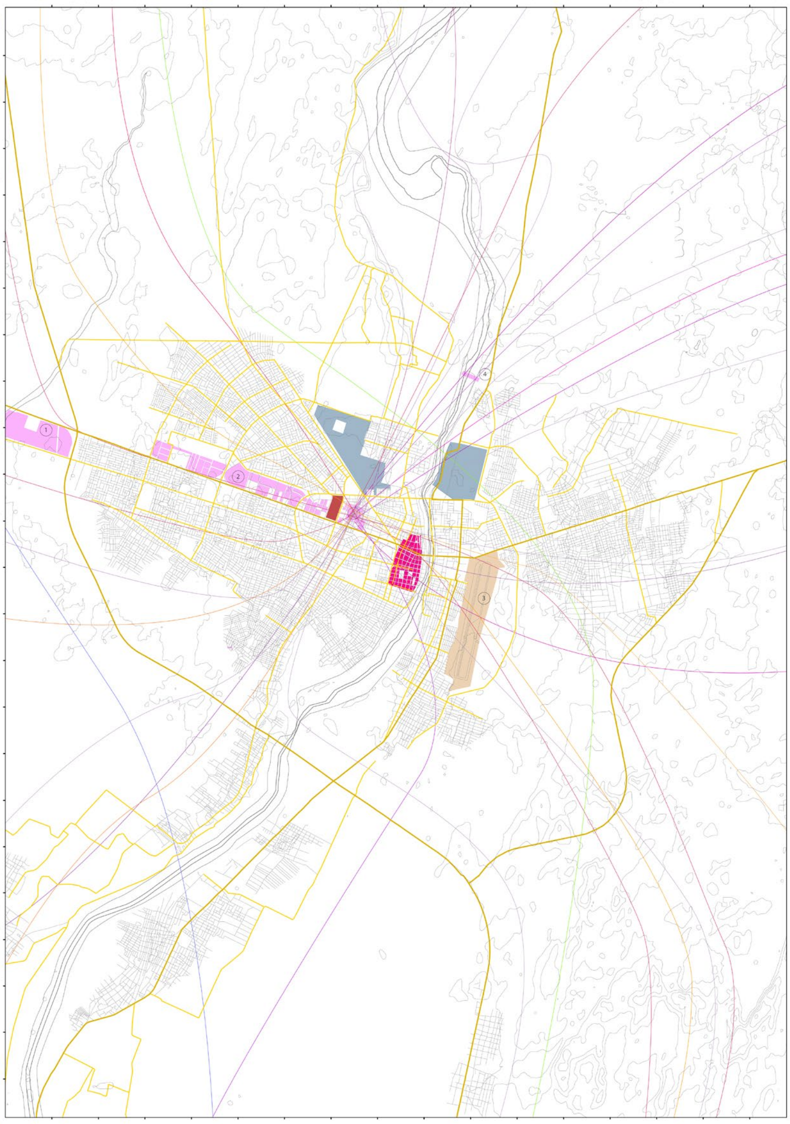
Dry shrubland
Xerophytic forest
Very sparse dry forest of plains
Sparse dry forest of plains
Semi-dense dry forest of plains
Dry forest
Deforested areas
River Piura
Countour lines every 10m

0 .75 1.5 km N

· Network: local economies and roads infrastructure

The most common form of public transportation in Piura is through buses and minibuses known as "combis." These vehicles operate on various routes throughout the city and its outskirts, providing an affordable means of travel, and Moto-taxis, which are small motorized tricycles, are also a popular and economical mode of transport for shorter distances within the city. As for the principal avenues in Piura, some of the most important ones that connect various parts of the city include: Avenida Sánchez Cerro: This is one of the main thoroughfares in Piura, connecting the city center with various neighborhoods and key areas. Avenida Grau: A major avenue that runs through the heart of the city, Avenida Grau is a vital link for both commercial and commuter traffic. Avenida Cáceres: This avenue is another significant route, facilitating movement across different parts of Piura. Avenida Loreto: It is an important road that connects with various sectors of the city. (PAT 2019). Piura's economy relies on several key infrastructures. The National Airport boosts travel and trade, cement industries support construction, hydroelectric plants provide energy, motor industries enhance manufacturing, and local markets drive small business growth.





Local economies flows and transportation
Basin scale (left) / City scale (right)
Data source: PAT 2019

Economic infrastructure:
3 National Airport
1 Pacasmayo Cements
3 Industrial park
4 Los Ejidos Dam
5 Piura supply market
Main roads
Secondary roads

Economic flows:
Agricultural products (mainly wheat, potato, rice, orange, cocoa, sugar cane, lemon, mango, fish and seafood)
Textiles, oil, soap, cattle
Petroleum, gas
Hydrobiological products
Turustic services
Informal mining (gold nuggets)
Centralities
Conections

0 .75 1.5 km N

Image 12: Sewage box
Source: Image taken by the author

Image 13: Current state of rain drainage
Source: Image taken by the author

Image 14: Current state of the canal
Source: Image taken by the author

· Network: water and accessibility

The sewage and potable water infrastructure in Piura fails to encompass the entire city, particularly affecting informal settlements. Initially, these areas lacked essential connections to electricity, sewage, and water services. Although many have since transitioned into formalized neighborhoods, the expansion of the necessary network to these regions has not kept pace. Consequently, residents in these areas still lack access to adequate drainage and sewage systems (PAT 2019)

Water infrastructure and accessability
City scale
Data source: PAT 2019

Contour lines every 10m
Urban areas without accessability
River Piura
Rain drainage
Canal
Smal canals for irrigation
Oxidation lakes
Pumping chamber
Primary collector
Transmitter
Line drive
Secondary collector

0 .75 1.5 km N

Image 15: Low elevation street, hard limits
Source: Google streets

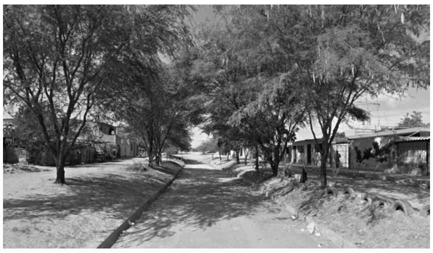


Image 16: Low elevation street, soft limits
Source: Image taken by the author

Image 17: Low elevation street, soft limits
Source: Google streets

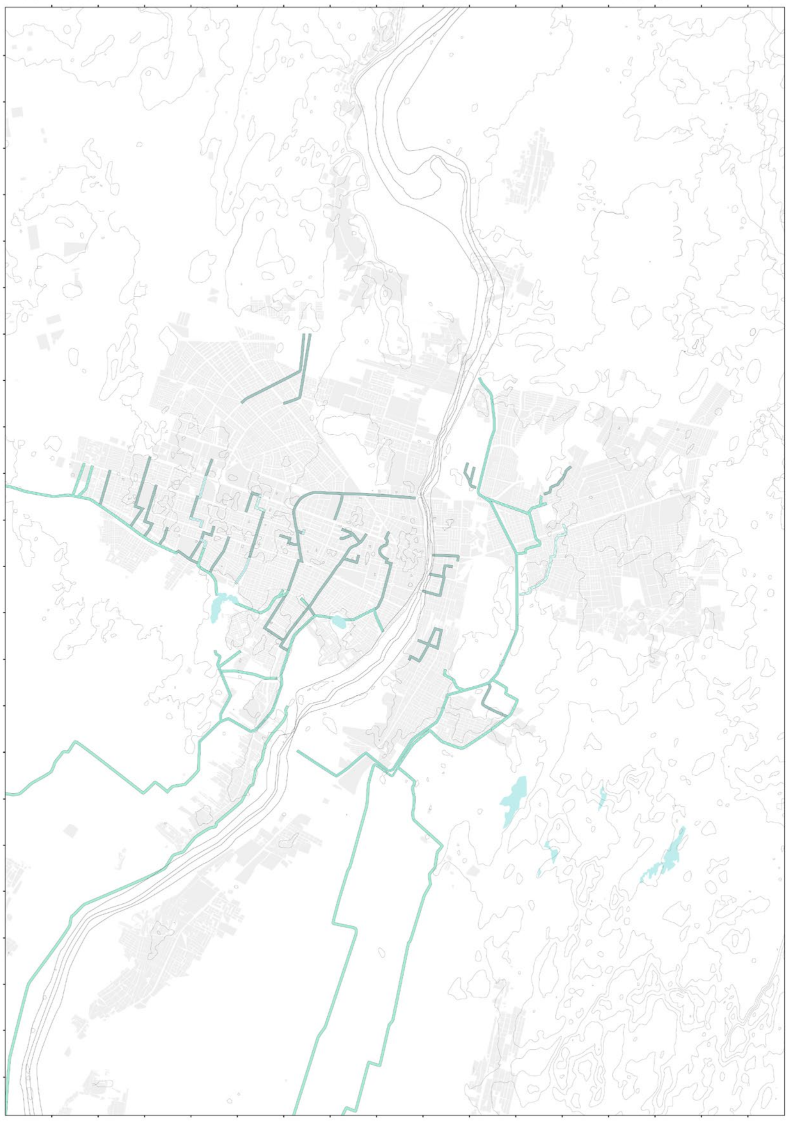
Image 18: Exposed water channels, hard limits
Source: Google streets

Image 19: Exposed water channels, soft limits
Source: Image taken by the author

· Network: drainage systems

The city's rain drainage system is notably inadequate, struggling even under minimal rainfall. Originally designed for agricultural use, it was later repurposed to manage urban rainwater. However, this adaptation has proven insufficient due to a lack of regular maintenance and poor connectivity. The system is fragmented and fails to cover the entire city, leading to inefficiencies and ineffectiveness in water management. During the intense downpours of El Niño, the drainage system quickly becomes overwhelmed, reaching its maximum capacity. In desperate attempts to drain the stagnate water, residents often resort to opening sewage system covers, inadvertently causing rainwater and sewage to mix. This occurs not only due to human intervention in lifting street drainage covers to relieve stagnant water but also due to the system's deterioration and inadequate maintenance. Such mixing of waters leads to severe contamination, posing significant health risks to the population (PAT 2019) .

The maps of the drainage systems shows it as homogenous here is says there is the drainage system. But a close look at it actually shows that there are different types of drainage systems. Therefore, this project categorizes it within three groups: lower elevation streets, exposed water channels and nothing above ground. These categorize can have soft limits, which means that there is not a defined barrier, or hard limits, meaning that there is physically a defined barrier of the sewage systems made by concrete or cement



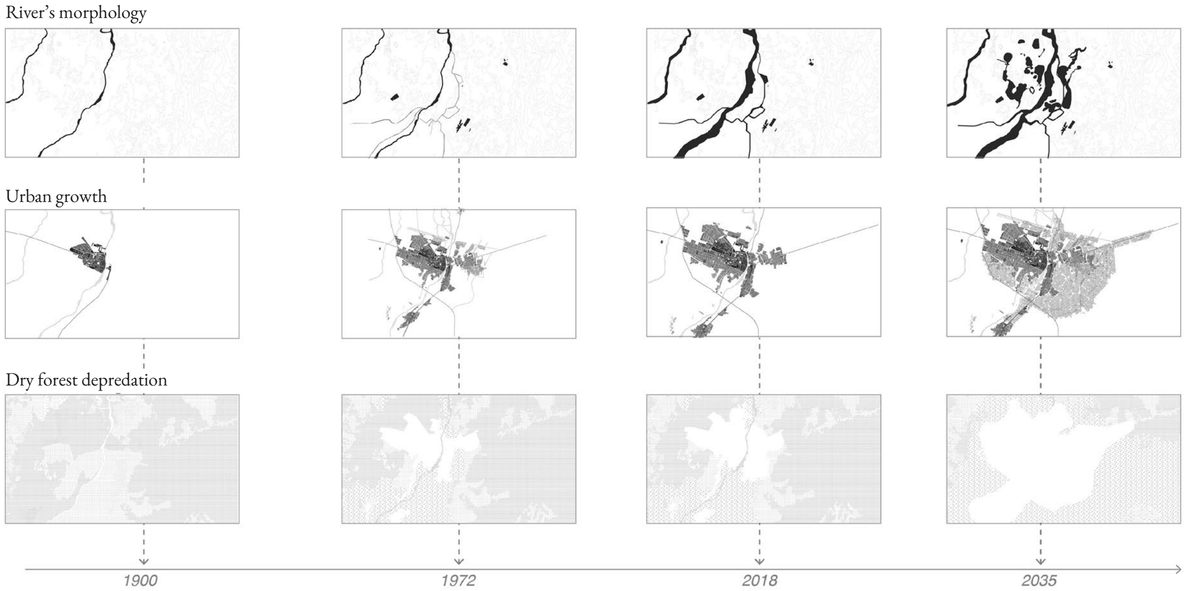
Water infrastructure and accessability
City scale

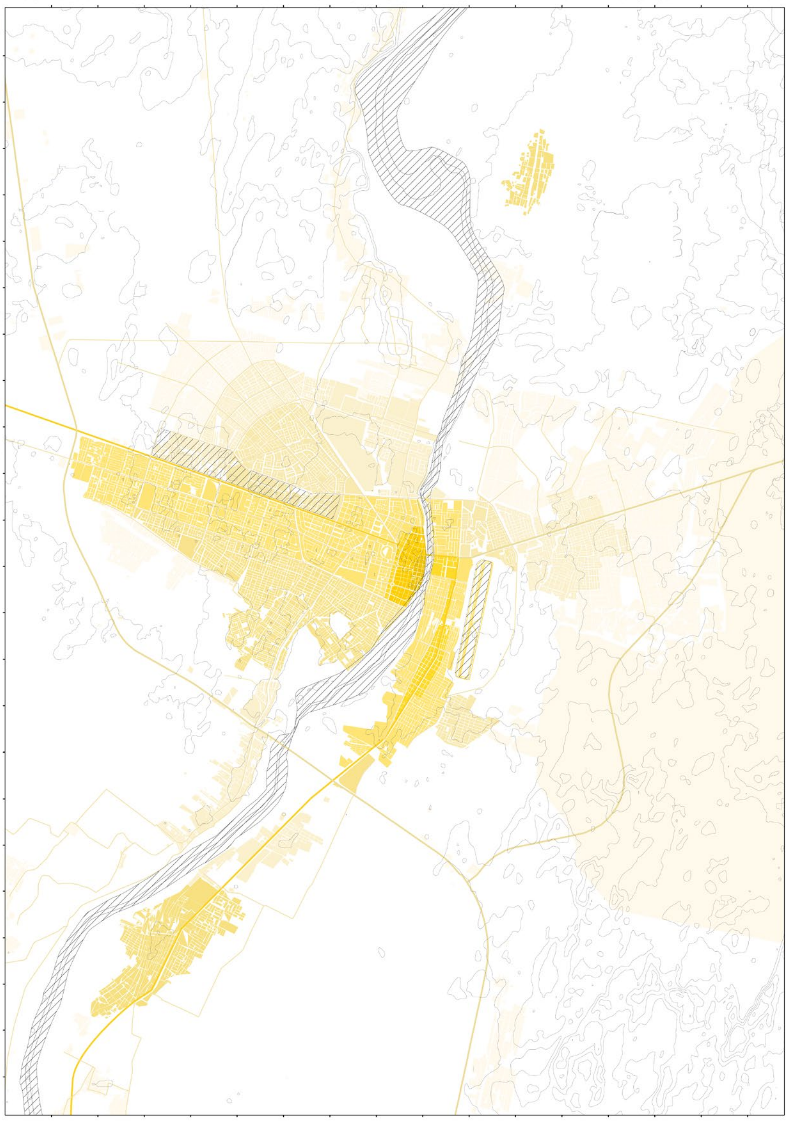
Contour lines every 10m
Urban areas without accessability
River Piura
Rain drainage
Canal
Smal canals for irrigation
Oxidation lakes
Pumping chamber
Primary collector
Transmitter
Line drive
Secondary collector

0 .75 1.5 km N

· Occupation: urban development and spatial fragmentation

The urban expansion of Piura and the Castilla district from 1588 to 1980 shows dynamic growth. Beginning with its foundation in 1588, Piura saw initial development, followed by the expansion of its central core until 1850. Key infrastructural developments like the first iron bridge in 1887 and the Paita-Piura railway in 1900 marked significant milestones. The 20th century saw further consolidation of Castilla and the start of Guillermo Concha Ibérico Airport between 1920 and 1921. Later growth included the expansion and settlement of new neighborhoods and young towns, reflecting population growth and migration from rural areas, particularly between 1997 and 2001.





Occupation: Urban development and spatial fragmentation
City scale

Urban development

1783

1900

1920-1930

1960-1980

2000

2023

0 .75 1.5 km N

Image 20: Informal expansions
Source: Google streets

· Occupation: state of consolidation

- State of consolidation: Informality typically responds to a multifaceted and unclear progression of growth that occurs beyond the norms. This process often involves construction activities that do not respect the building regulations nor other norms of urban development (Herrle & Fokdal, 2011). Consolidated areas or buildings in urban development typically refer to regions or structures that have undergone formal planning, regulation, and development. These areas often have established infrastructure, services, and legal recognition. On the other hand, non-consolidated areas or buildings are those that lack formal planning, regulation, and infrastructure. They may have informal settlements, inadequate services, and uncertain legal status.

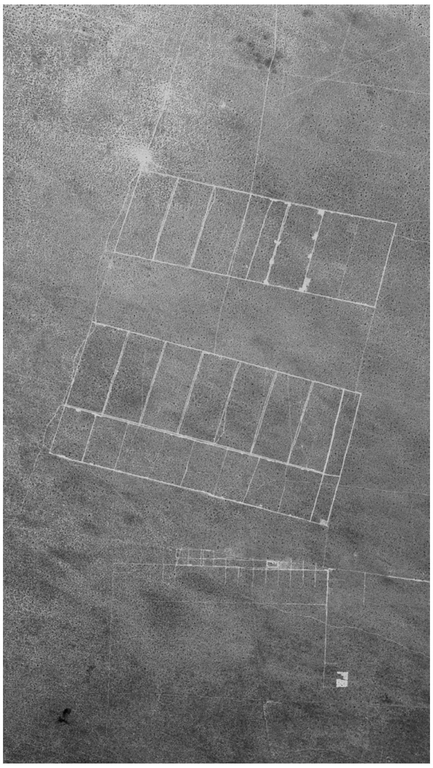
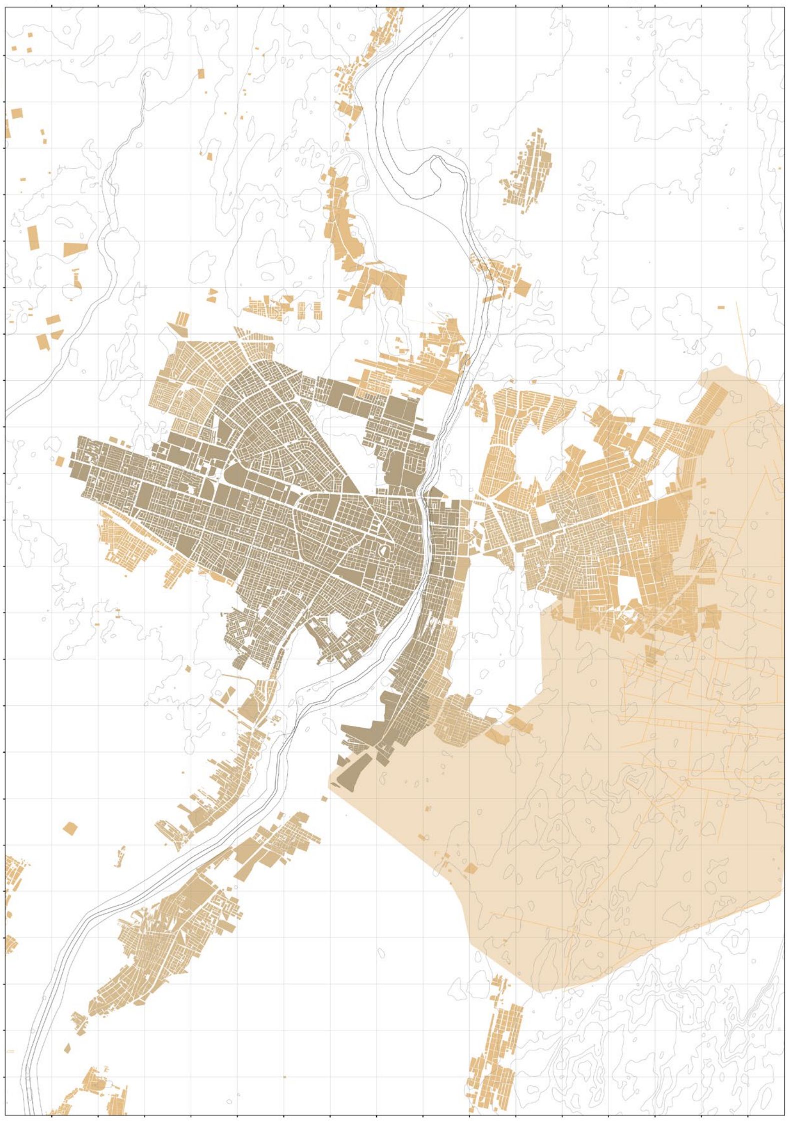


Image 21: Informal expansions
Source: Google earth



Occupation: State of consolidation
City scale

Consolidated

Semi consolidates

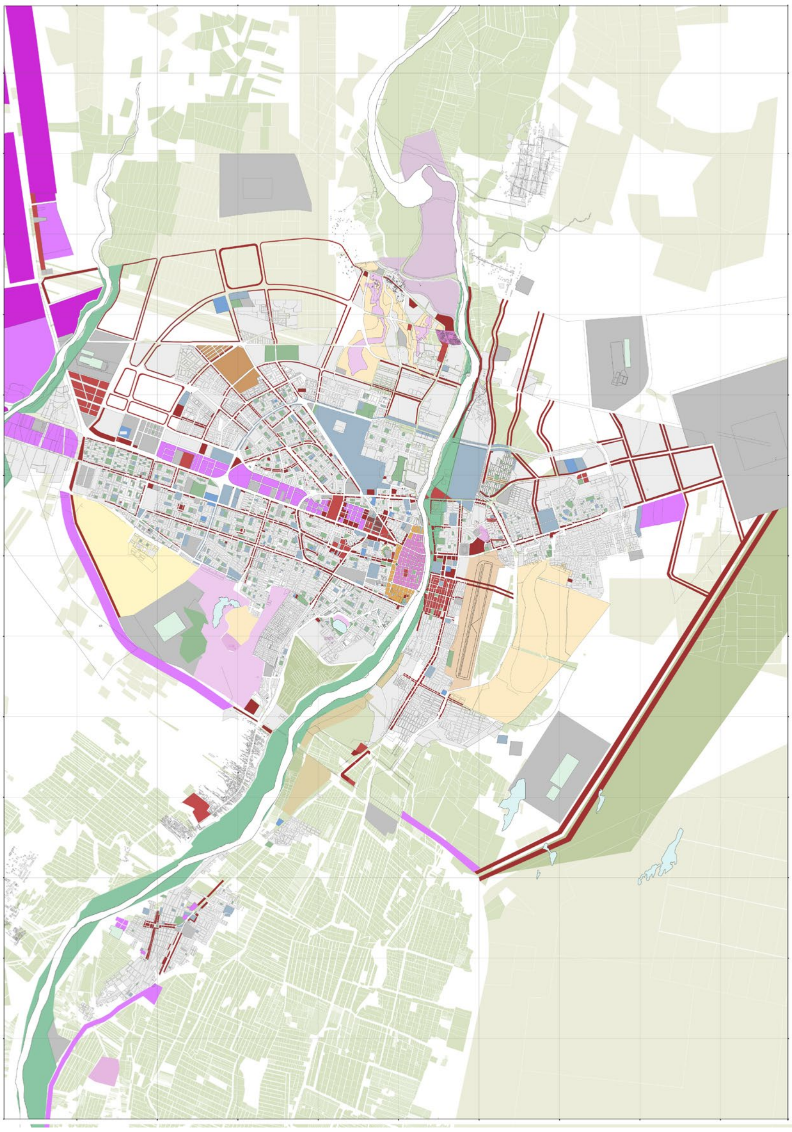
Not consolidated

Trend of new informal expansions

0 .75 1.5 km N

· Occupation: land use

Outside the urban area of Piura, intensive agriculture is the main land use. Within the city, an industrial corridor stretches from the urban core to the eastern edge. Near the district of Castilla lies the national airport, surrounded by smaller-scale agricultural fields, reflecting the city's expansion. Additionally, there is a single metropolitan park in the south of the city and a large open area belonging to the University of Piura, located central.



Land use
City scale
Data source: PAT 2019

Housing
Public Recreation Zones
Special Uses
Monumental zone
Heavy industry zone
Commercial
Protection area

Agricultural zone
Special regulation zone

0 .75 1.5 km N

· Occupation: location in heat zones

SENHAMI data from 2017 highlights that areas near industrial zones and the airport consistently experience the highest temperatures. Industrial activities and limited vegetation exacerbate heat levels, creating urban heat islands. These temperatures also pose significant health risks, including heat exhaustion, heatstroke, and exacerbation of respiratory and cardiovascular conditions, particularly among vulnerable populations.

Occupation: Urban heat island effect
City scale
Data source: Senhami 2020

Record high temperatures centigrade (2019)

35-40

0 .75 1.5 km N

Image 22: Occupation in flood-prone area
Source: Image taken by the author

Image 23: Advertaisment on free-flood areas
Source: Image taken by the author

· Occupation: location in flood-prone areas

The horizontal expansion of Piura's city, coupled with inadequate planning and zoning regulation, has led to informal settlements being established in dry ravines. Additionally, formal areas, including the urban center, are located near the river, making them vulnerable to flooding. This vulnerability is exacerbated during El Niño events, with the majority of the city's urban area experiencing inundation. Specific locations facing increased flood risk include the Petroperu blind basin, characterized by frequent flooding due to intensity rainfall; the permanent flood zone of Laguna Santa Julia; the main channel of the Piura River, subject to flooding, erosion, and sedimentation; and the right bank of the Piura River downstream of the Bolognesi Bridge, where there is danger of river overflow. Moreover, areas where the flow of the El Gallo stream infiltrates crop lands pose significant risk, as the stream serves as the primary drain for several human settlements and can rapidly be damaged during lower intensity rains. Topographic depressions and blind basins, such as those in La Primavera settlement and El Chilcal, are at risk of flooding, with historical flood levels reaching up to 2 meters during the El Niño event of 1998.

Location in flood-prone areas
City scale
Data source: PAT 2019

Contour lines every 10m

Urban areas without accessability

River Piura

Flood areas by overflow of the river

Flood areas by activation of dry ravines

Dry ravines

1 Laguna Santa Julia

2 El Chilcal

3 Petro Peru

4 El Gallo

0 .75 1.5 km N

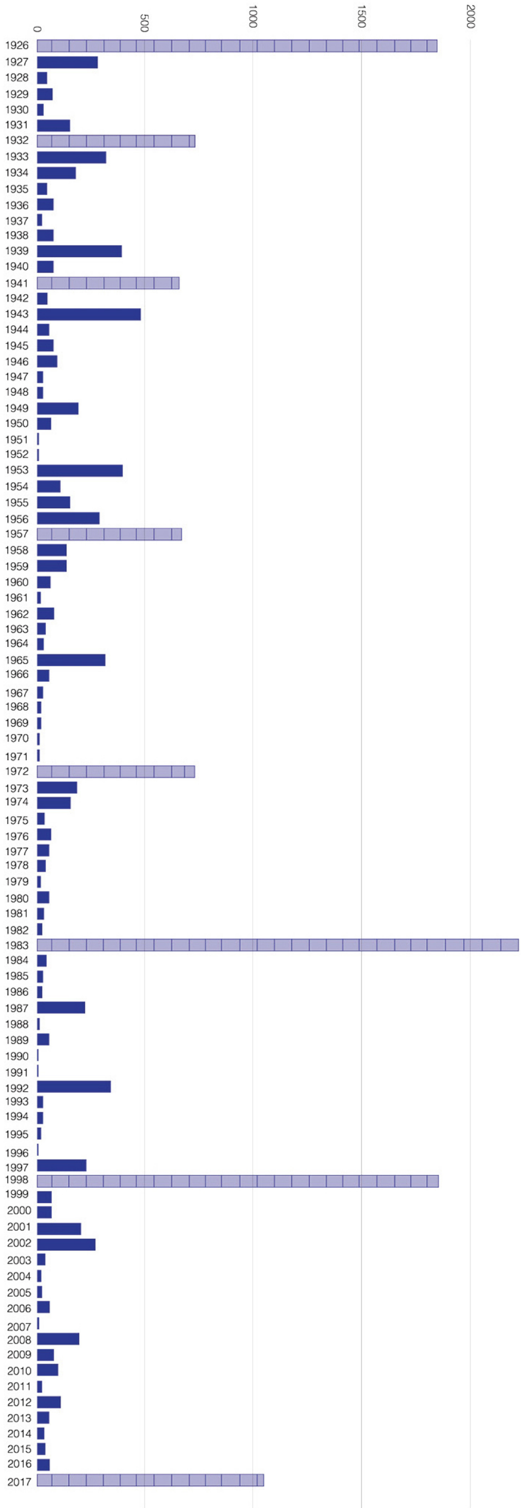


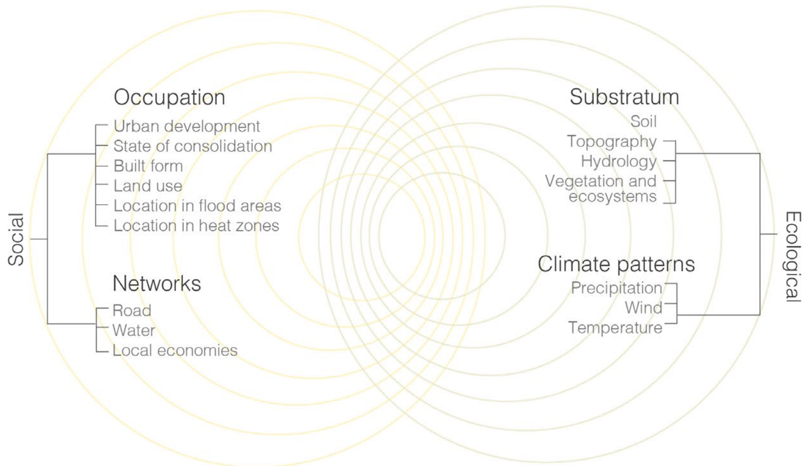
Figure 3: Anomalies of precipitation in Peru over the years
Source: Senhami (2017)
Graphic: Made by author

2.2 Cycle and patterns (time and space)

The interactions of the main variables and sub-variables follow the rhythms of cyclical patterns. In this context, the theory of longue duree comes into play. While analyzing the rhythm of El Niño-flood cycle, there is a focus in the long-term environmental and climate patterns that lead to persistent structures. In the realm of the urban systems, the longue duree framework help in understanding socio-economic structures in the medium-term processes, such as accessibility, disparities, local economic activities and flows.

The first cycle is defined by the El Niño events and are characterized by long-term cycles and irregular occurrences. Despite being a regular event, El Niño does not follow to a predictable pattern. Historical evidence shows variability in both frequency and intensity. This variability in the El Niño cycle is evidenced through diverse sources, ranging from paleoclimate records that trace back thousands of years (Brown, J. 2014) to changes observed in records from the Spanish colonies in the late 19th century and contemporary times (Seiner, L. 1999). The second cycle is defined by urban expansions in Piura, and it happens in a medium-term cycle, where each year sees a consistent increase in the rate of migration from rural to urban areas. This steady migration contributes significantly to the growth of urban expansions and the emergence of informal settlements in the peri-urban regions (Da Cunha, J.M & Vignoli, J.R 2009).

Furthermore, additional patterns influencing these cycles include the effects of deforestation, water demands, and urban growth, intertwined with the unpredictability of temperature and precipitation over recent decades. These factors contribute to the dynamic interplay of variables shaping the cyclical nature of Piura's socio-economic and environmental landscape


Occupation
Urban development
State of consolidation
Built form
Land use
Location in flood areas
Location in heat zones
Networks
Road
Water
Local economies
Social
Substratum
Soil
Topography
Hydrology
Vegetation and ecosystems
Climate patterns
Precipitation
Wind
Temperature
Ecological

Longue duree

Long-term — Medium-term — Short-term

- soil conditions (deterioration, erosion, contamination, acidification)
- topography
- dry ravines (dry ravines are occupied, filled, transformed, but they persist)
- aquifer (excess use during droughts, specially for farming)
- river Piura (neglected mostly throught the year, contaminated, tried to be closed off and delimitado)
- precipitation (more extreme, more intense during summer, less intense during winter)
- wind
- temperature (more extreme, more intense during summer)
- dry forest (very important to regulate the ecosystems, deforested faster and faster with time, not enough water in the aquifers to sustain it during droughts, wood used as contraband and for chicken cooking)
- algarrobo tree
- lakes (neglected mostly throught the year, contaminated, tried to be closed off and delimitado)
- housing (not enough houses with basic supply for the people of Piura, rate of self-building informal housing on the rise)
- national airport (used mainly for people traveling to Mancora and +, X amount of people per year, contamination of X)
- pacasmayo cements
- industrial park (how it contributes? what are the impacts?)
- waste areas
  the amount of waste produced in the city per year is X ton, how much space are these waster areas occupying?
- religious spaces (play an important role within the communities)
- Los Ejidos dam (almacena Xm3 per year)
- local commerce
- metropolitan commerce
- Piura supply market
- main roads
- local roads
- drainage system
- sewage system
- agriculture areas in urban areas
- agriculture areas
- arqueological areas
- open public spaces
- health and education centers
- monumental area
- sport areas
- communal spaces

2.3 Relations (the dance)

The specific variables are related because they are closely interconnected and have significant implications for Piura's vulnerability to climate variability and extreme weather events.

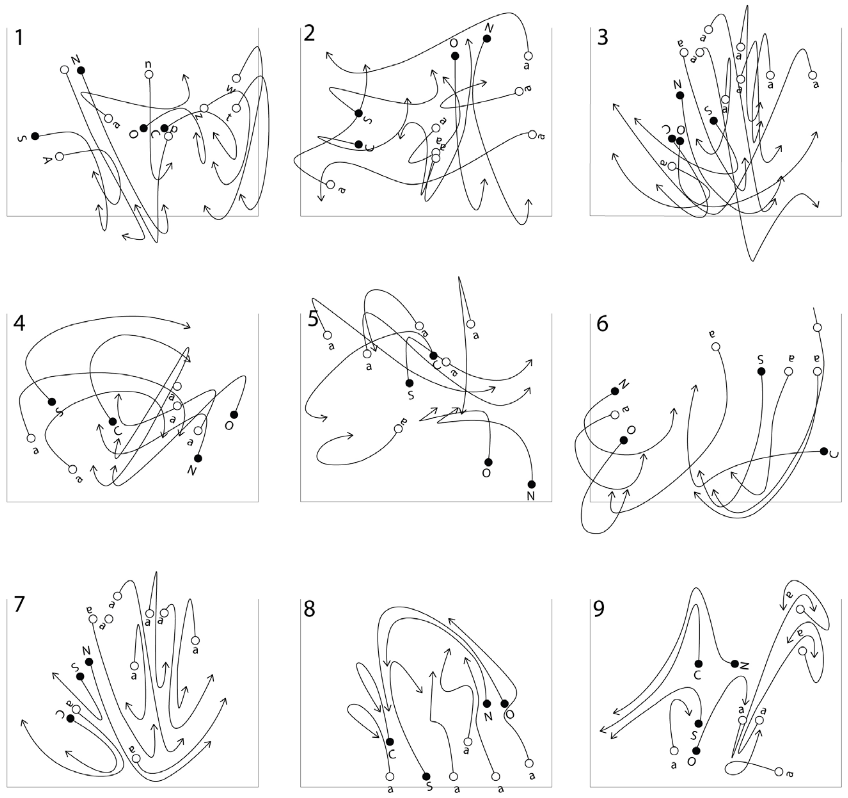
Precipitation and Soil Hydrology: The low annual precipitation in Piura, primarily influenced by the El Niño phenomenon, directly affects soil hydrology. With less than 50 mm of rainfall annually, the soil's drainage capacity, consisting of sands, silts, and clays, is crucial for managing water infiltration and runoff during sporadic heavy rainfall events. The variability in precipitation patterns, intensified by El Niño cycles, can lead to fluctuations in soil moisture levels, impacting groundwater recharge rates and aquifer storage capacity.

Temperature and Vegetation Dynamics: The warm, semi-arid climate of Piura, characterized by minimal temperature variation, significantly influences vegetation dynamics. Drought-resistant flora, including cacti and scrub bushes, have adapted to survive in the harsh desert environment, relying on deep root systems and water storage capabilities. However, increased temperatures, exacerbated by urban heat islands near industrial zones, pose risks to vegetation health, contributing to habitat degradation and biodiversity loss.

Urban Development and Drainage Systems: The rapid urban expansion of Piura, driven by consistent rural-to-urban migration rates, directly impacts drainage systems and flood vulnerability. Informal settlements established in flood-prone areas lack adequate infrastructure, exacerbating drainage system deficiencies. Fragmented and poorly maintained drainage networks struggle to manage rainfall runoff, resulting in inundation and contamination of waterways during intense precipitation events, such as El Niño-induced floods.

Occupation and Land Use Planning: The occupation of non-consolidated areas in Piura, characterized by informal urban developments and inadequate land use planning, contributes to environmental vulnerability and socio-economic disparities. Informal settlements established in flood-prone zones face heightened risks during El Niño events, highlighting the importance of integrating formal land use planning measures to mitigate flood hazards and improve urban resilience.

Networks and Climate Adaptation: Piura's transportation networks and road infrastructure play a crucial role in climate adaptation and disaster risk reduction. Access to reliable transportation, particularly during extreme weather events, facilitates evacuation efforts and emergency response coordination. However, inadequate road connectivity and drainage infrastructure exacerbate vulnerabilities, underscoring the need for integrated climate-resilient infrastructure planning and investment.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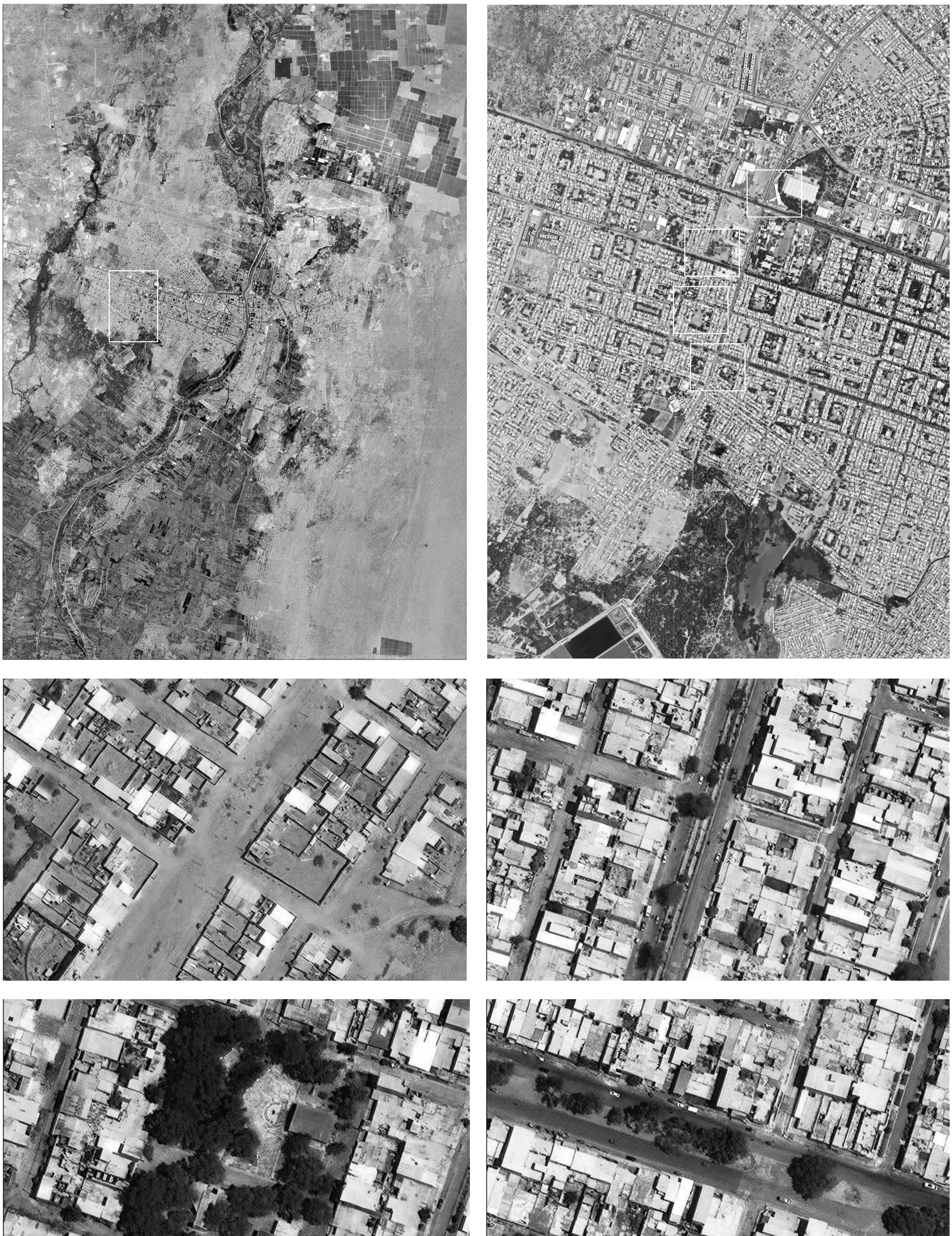
3. Learning space

This chapter is about strategically identifying spaces that can give in: its about making room for unpredictability and uncertainty. Specially, to understand how much the system can be flexible by design. Within the consolidated urban structures, local routines and habits, what spaces can be transformed to enhance Piura's overall resilience? Therefore, an understanding of the open space network, of the flexibility within the city, what remains and what not, and therefore the mediation spaces. learning on previous events that shape these spaces and above all, learning from past El Niño events.

From left to right:
City scale of Piura
District scale
Street scale 1 (unconsolidated area)
Street scale 2 (consolidates area)
Street scale 3 (residential park within urban area)
Street scale 4 (national avenuce)



3.1 Open space network

Open space, in relation to the built environment, is composed by various flows, including those of people, transport, water, soil, and plants. Analyzing open spaces at three different scales—city, district, and street—reveals distinct characteristics and ownership categories, whether public or private.

At the city scale, Piura, a developing city, is surrounded by dry forests and farmlands. Within its urban areas, the largest open spaces include the airport area, industrial zones with enormous plots and the expansive campus of the University of Piura (UDEP). The identified oversized streets at the city scale are: Av. Sanchez Cerro, Av. Grau, Av. Juan Velasco Alvarado, Av. Integradora, Av. Los Algarrobos, Pje. Qf, Av. Los Diamantes, Av. Las Americas, Av. Circunvalación, Av. Jose Aguila Santisteban, Av. San Josemaria Escrivá Balaguer, Av. Sullana, Av. Guillermo G, Av. Cesar Vallejo, Av. Marcavelica, Raul Mata La Cruz, C3, Av. 2, Av. Curumuy, Av. Luis Monntero, Andres Avelino Caceres, Av. Independencia, Av. Guardia Civil, Ramon Castilla, Av. Junin, Av. Jorge Chavez y Av. Sanches Carrion. At the district scale, a more detailed examination reveals oversized streets, large industrial plots, and unused areas, highlighting opportunities for better space use. It also reveals the open space of the Kurt Burt park and the wetlands. At the street scale, there four types of streets that are the area of analysis. The consolidated street, the periphery street, a National road and a small scale park.

Open scale network
from right to left, City of Piura, District of Piura, Street scale

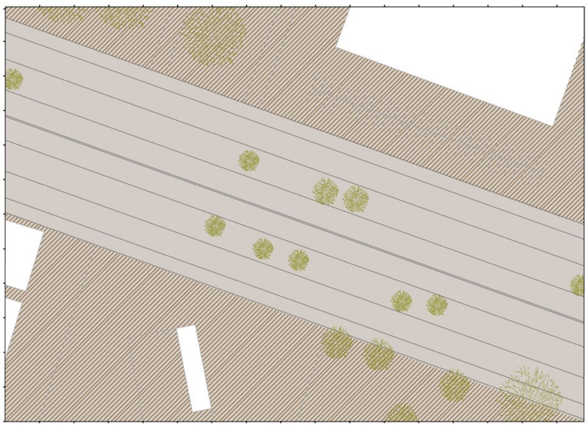
Public space

Private space

0 .75 1.5 km N





3.2 Flexibility

This chapter, grounded in on-site conversations with residents of Piura and building upon the positioning discussed in Chapter 3 of Part I, and with a more technical approach, examines the spatial elements of the area. It seeks to determine what can be changed, what is permanent, what is persistent, what can be removed, and what needs to be added.

Permanent elements are defined as those conditions that cannot be altered. Housing, for example, is permanent because locals view these structures as homes with personal significance rather than mere buildings. Hospitals are also permanent due to their essential role and complex infrastructure. The main avenues are considered permanent because they are integral to a larger network vital to the region's economic activities. Water bodies such as canals, wetlands, and the river must be protected and respected, making them permanent elements. Similarly, the dry desert landscape is seen as permanent due to the need for its preservation as well as all the existing vegetation.

Persistent elements are those that can adapt to change. For instance, recreational open spaces like urban parks are flexible and can be temporarily adapted for other functions.

Subtraction involves the removal of certain elements. Oversized spaces in the roads, parking lots, and waste areas in specific locations can be relocated or repurposed. Large industrial lots, due to their central location and potential for contamination, can be moved to better utilize the valuable space and address environmental concerns. Some water treatment plant may also be removed because of their vulnerability to floods and contamination.

Addition means to introducing new elements. This includes grey infrastructure for connecting drainage systems and retaining water, both under and above pavement, to enhance accessibility. Vegetation can be added to control erosion, stabilize the ecosystem, and improve the atmosphere. Additionally, rainwater wells can be installed to manage water resources effectively.

Flexibility
from right to left, City of Piura, District of Piura, Street scale

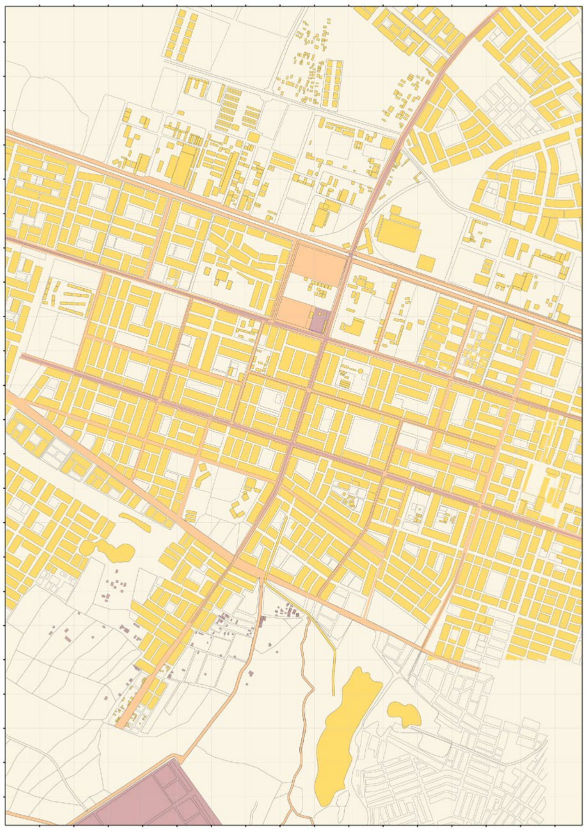
Permenent

Persistent

Substraction

Addition

0 .75 1.5 km N



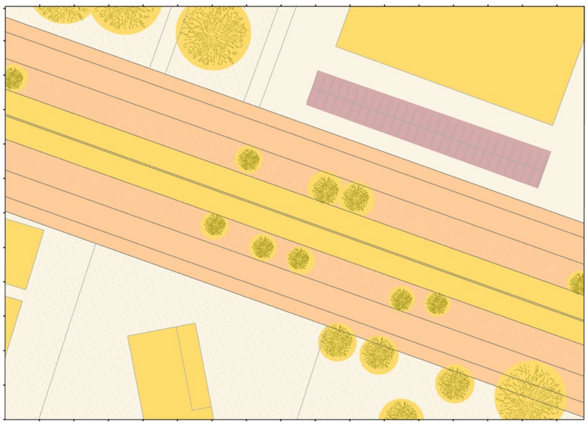


Image 24: Mediation spaces
Source: Image taken by the author

Image 25: Mediation spaces
Source: Image taken by the author

Image 26: Mediation spaces
Source: Image taken by the author

3.3 Mediation spaces

· City scale

Mediation spaces are crucial areas to act on spatially, found within both private and public plots. These spaces, which consist of persistent, subtracted, and additional areas, serve to reconcile the dissonance between climate patterns, substratums, occupations, and networks. They play a vital role in mitigating the impacts of floods caused by El Niño, addressing droughts, and reducing the urban heat island effect. Additionally, they function in everyday life and informal settings.

At the city scale, mediation spaces form a network. Key open spaces include oversized streets, southern farmlands, and agricultural zones in Castilla's district, which are particularly vulnerable due to their topography. The water treatment plant in the south poses a significant health risk during El Niño, as its low elevation leads to flooding and contamination from overflow. Similarly, the airport, located next to the farmlands in Castilla's district, is prone to flooding due to its low-lying position. Current policies are considering relocating the airport outside the city to mitigate these flood risks.

Mediation space on a city scale

0 .75 1.5 km N

Image 27: Mediation spaces
Source: Image taken by the author

Image 28: Mediation spaces
Source: Image taken by the author

Image 29: Mediation spaces
Source: Image taken by the author

Image 30: Mediation spaces
Source: Image taken by the author

· District scale

At the district scale, mediation spaces include Kurt Burt Park, which features water treatment plants and wetlands. Located in the southern part of the city, this area is highly vulnerable during El Niño events due to its low topography. Despite recent consolidation, many streets here lack pavement, with only a thin layer of sand covering the soil. Informal expansion towards the park and wetlands is deteriorating the soils. Other mediation spaces in the district are the parks within the urban tissue and the small streets that connect them, as well as the open spaces within large industrial plots.

Mediation space on a district scale

0 .75 1.5 km N

Image 31: Mediation spaces
Source: Google street

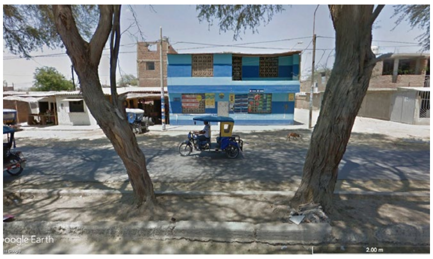


Image 32: Mediation spaces
Source: Google street

Image 33: Mediation spaces
Source: Google street

Street scale

On the street scale, Raul Mata la Cruz Street varies in width from 60 to 90 meters, despite having only two lanes in residential areas. This street exemplifies oversized streets. In the northern area, the built environment is more consolidated, and the pavement is asphalted. In the southern area, the built environment is still consolidating, and the roads remain unpaved. The mediation spaces are the road itself, but respecting the existing vegetation.

Mediation space on a street scale

0 .75 1.5 km N

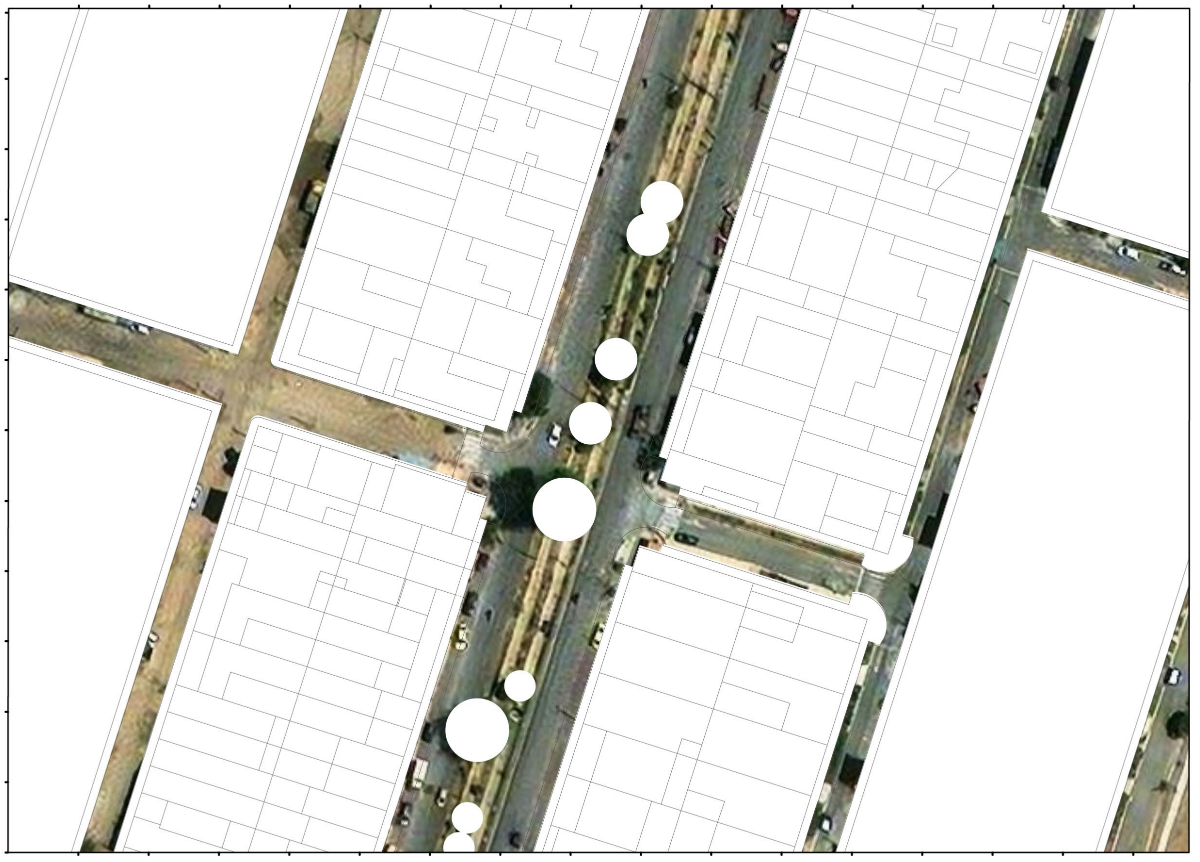


Image 34: Mediation spaces
Source: Google street

Image 35: Mediation spaces
Source: Google street

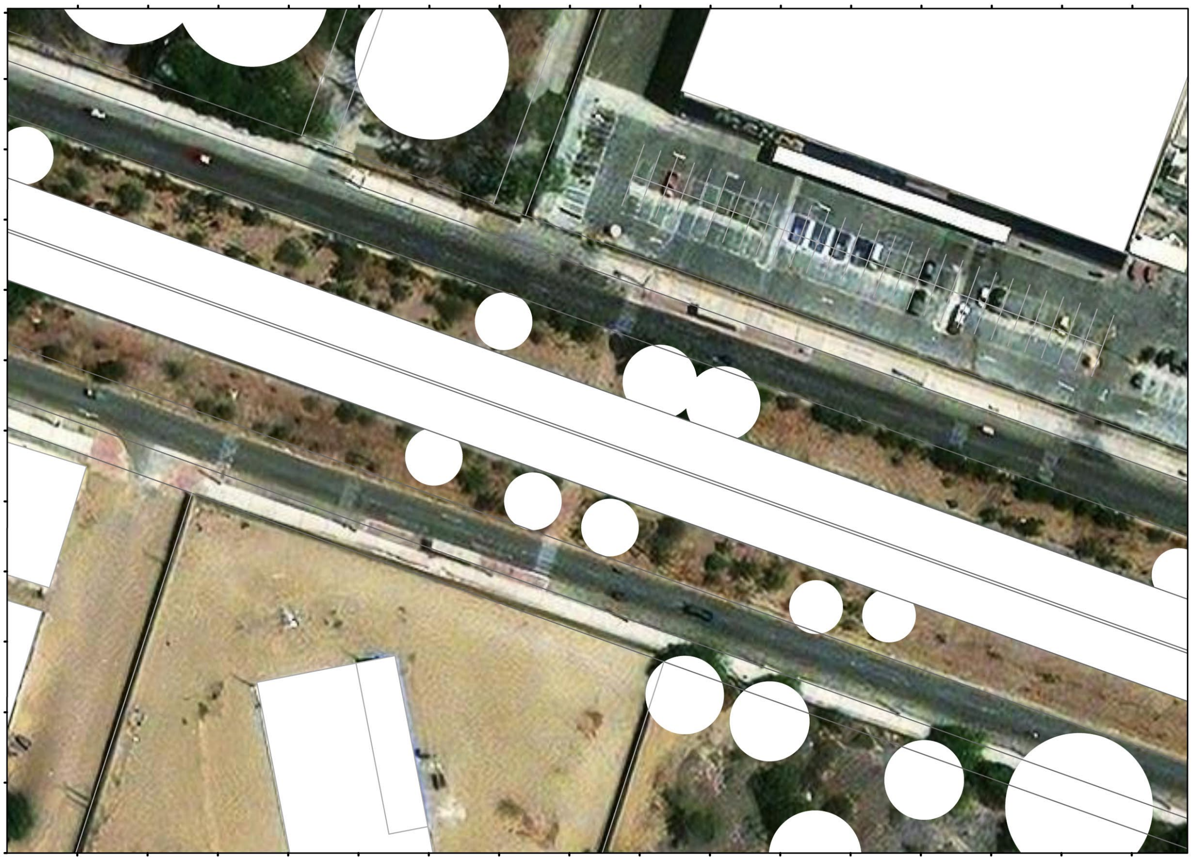
Image 36: Mediation spaces
Source: Google street

Street scale

Another example on the street scale is Sanches Cerro Avenue, one of the most important avenues in Piura. While the avenue itself is not part of the mediation spaces, its nearly 50-meter-wide margins are identified as such, including the surrounding parking lots and open spaces. In parks, mediation spaces encompass football fields and public spaces, highlighting their multifunctional role in both recreational and environmental management contexts.

Mediation space on a street scale

0 .75 1.5 km N



THIRD PART

1. Design proposal

The project is about finding the intersection where the urban structures can give in and what the territory allows to flow. It recognized that the main problem not just lies in the El Niño phenomenon nor in the social-political vulnerabilities, but the disassociation between them: the disassociation between the urban morphology and geomorphology. The project aims to understand the disassociated variables within the socio-ecological framework–substratum, climate patterns, networks and occupation—and their cycles and relations. Therefore, what the 'urban structures can give in and what the territory allows to flow' refers to these variables. Once these disassociation are understood, the project seeks to make space for these variables to coexist. The concept of 'finding the intersection where' implies identifying the space to act. Through the chapter of Learning Spaces, the project identifies the space to act. The analyzing of the open space network and its flexibility – considering what is permanent, persistent, subtracted or added— the project reveals the mediation spaces, or space for action. And learning from previous El Niño events, these spaces are identified as the learning spaces.

In the city scale, the geographical conditions of the mediation spaces are analyzed. These spaces are comprised by oversized roads, airport, wetlands, a water treatment plant and some farmlands. For the oversized streets, the geographical conditions are analyzed through sections to understand water stagnation during El Niño and soil types. This analysis reveals a pattern: a homogeneous slope from north to south, while the east-west slope is more heterogeneous. Similar analyses are performed for the airport, wetlands, water treatment plant, and farmlands, uncovering small depressions in the topography and clay and sand soil conditions. Specifically, these areas area alluvial deposits given the periodic flooding and sediment deposition

The design proposes using these small depressions as water retention areas, transforming the airport, water treatment plant, and wetlands into metropolitan parks. By utilizing clay from river margins in these depressed areas, they can become more semi-permeable and store water longer. The more permeable soil areas, such as the dry forest and other farmlands, will be used for runoff excess water once the parks reach their capacity. Stones and rocks from the upper basin will help with erosion control and space delimitation, along with local vegetation suited for high temperatures and low water resistance. The oversized streets are proposed to be transformed into blue and green corridors during El Niño events. The north-south corridors are primary as they carry water by gravity to the proposed metropolitan parks, while the east-west corridors catch and distribute water to the main corridors. Stagnant water is managed through grey infrastructure.

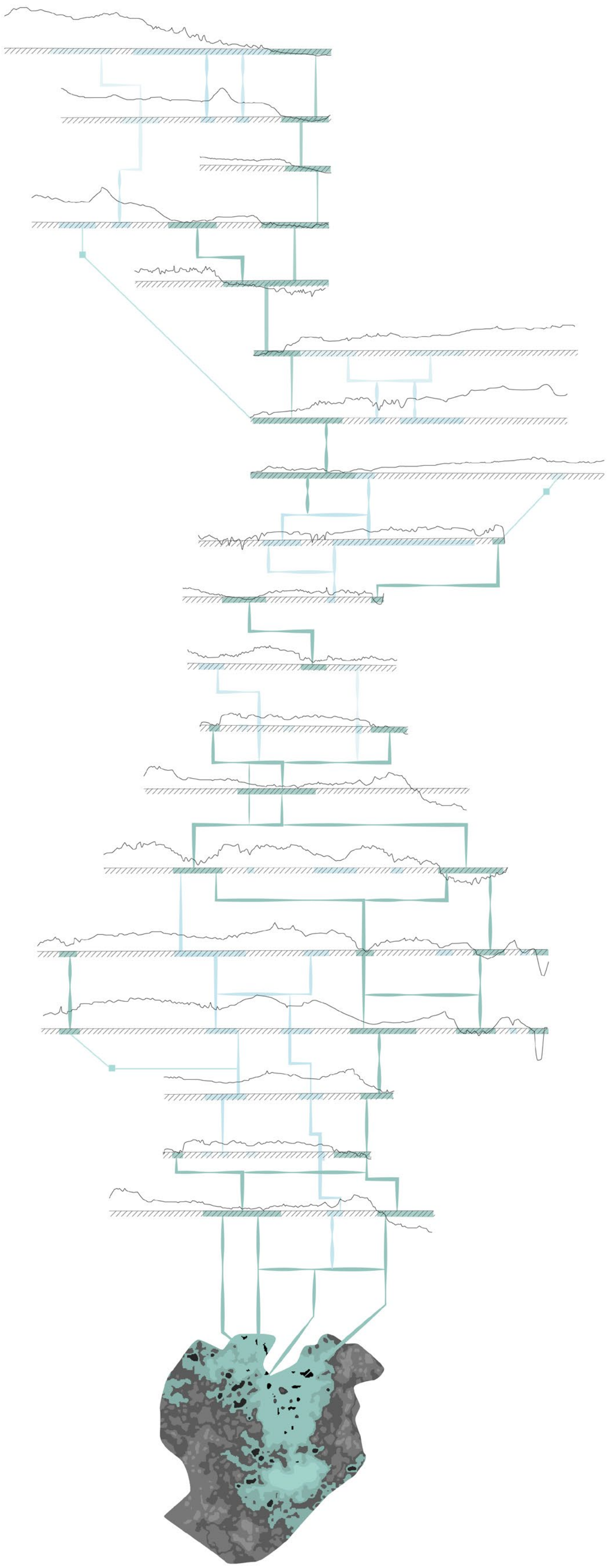
The proposed corridors and parks respond to different temporalities—rains, droughts, and normal periods—and form a hierarchical system. During normal times, metropolitan parks serve as recreational areas while maintaining their original character. Farmland areas that currently existing within the park can remain as agricultural area but with a community purpose. Areas next to residential areas have urban equipment that respond to their necessities. During El Niño events, the parks flood and retain water in the low depressions for future use.. In the aftermath, higher part become slowly habitable again. During droughts, the water from retention areas can be used. The corridors serve as recreational areas during normal times, providing safe spaces for activities such as selling hot meals and food from crops, which are currently done dangerously in the streets. By maintaining the existing vegetation, little islands are formed which gives different highs for recreational activities. During El Niño events, the corridor get flooded and in the aftermath, only the little islands can be used. During droughts, these spaces provide cooling area within the urban areas.

Thus, the idea of the project is to strategically identify the spaces that can be flexible by design. To use the current and local resources to enhance the ecosystem resilience, while integrating the existing grey infrastructure with the proposed blue and green. To create public spaces that highlight local characteristics, and ultimately, enhancing quality of life and providing stability in an uncertain environment.

Geographical understanding of the mediation spaces

- Lowest part of the street section
- Low inclination of the slope
- Street sections
- Natural depressions
- High areas
- Ustifluvents soil
- Salortids soil

0 .75 1.5 km N



Abstract representation of the interventions within the geographic understanding and mediation spaces.

Blue and green corridor system

Grey infrastructure

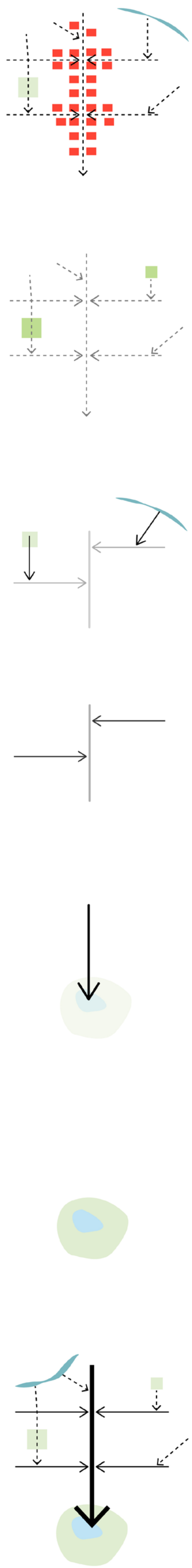
Street sections

wdepressions

High areas

Ustifluvents soil

Salortids soil



Built environment

- Regulations and reccomendations for the buildings in areas susceptible for flooding, such as hight of first floor, electric networks and materials of construction. (References from guidelines from VMM Netherlands)

Private open spaces

- Green pockets that are used to control the floods in urban areas.
- Permeable soil
- It can also capture and store water through grey infra-structure

Parks

- Green pockets that are used to control the floods in urban areas.
- Permeable soil
- It can also capture and store water through grey infrastruc-ture

Third corridors

- Its function is to join other elements to the first and second corridors.
- These elements can be existing parks, water bodies, infrastructure, water pumps, open spaces where stagnant water is found.
- Medium and short segments

Second corridors

- Heterogeneous slopes from East to West
- Its function is to capture and conduct water to the main corridors
- Long segments

Main corridor

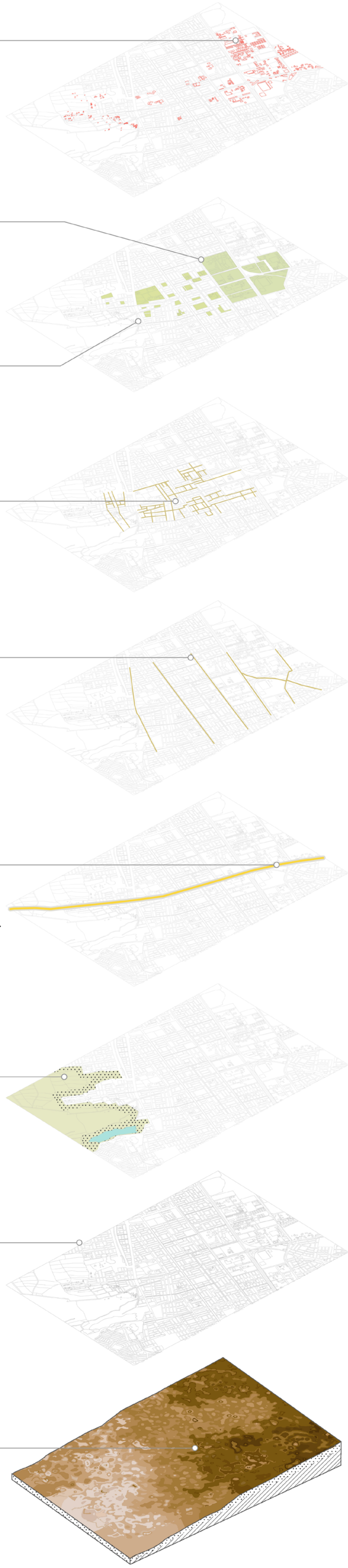
- Homogenous Slope from North to South
- Receives a greater flow of water.
- Its function is to conduct water quickly to the retention areas.
- Long segments

Metropolitan parks

- Water treatment plant is transformed into metropolitan park.

Urban

Territorial



Built environment

- The buildings in facing the corredors are more suceptible to floods. Take into consideration for norms and policies in the built environment.
- Retention of water in the roof-tops.

Private open spaces

- These open spaces are flooded and also retain water for further use.
- Retention of water underground

Parks

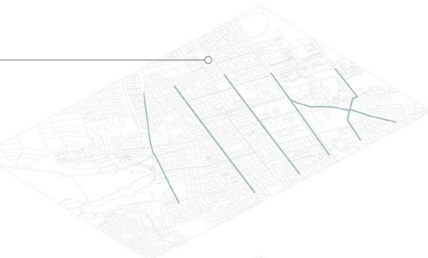
- The parks are flooded during El Niño events.
- Retention of water underground.

Third corridors

- The depth of the third corridors can be between 0.75m and 1m, given the size of the streets.

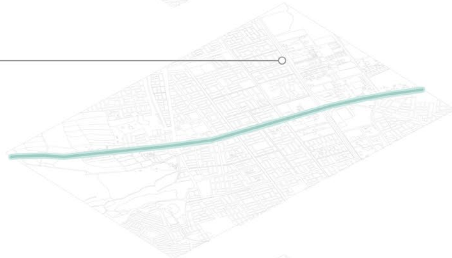
Second corridors

- The secondary corridors are flooded during El Niño events
- The depth of the secondary corridor can be between 1m and 2m, depending on the size of the street.
- It's capacity to flow water is 39.311 cubic meters



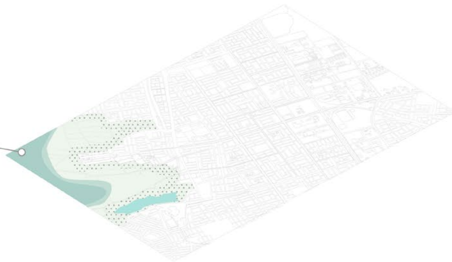
Main corridor

- The main corridors are flooded during El Niño events.
- The depth of the main corridor can be between 2m and 3m, depending on the ground water table level
- Its capacity on average is 96,674 cubic meters.



Metropolitan parks

- Park is flooded during El Niño events
- Area of the park is 11.8km2



Urban

- The total Storage Capacity of All Catchment Areas: 79,881,160 cubic meters
- The total Inflow Volume from Rainfall: 40,061,028 cubic meters

2. Scenarios

The design proposal responds to different scenarios and scales. It considers the day-to-day scenario, which means the socio-ecological vulnerabilities such as the urban expansions towards the dry desert to informal activities on a street level. El Niño flood scenario focus on the immediate imapact and the aftermaths. And the drough scenario, addressing challenges of water shortage. The proposal considers multiple scales. At a basin scale, it recognizes the relation of the upper and lower basin, especially in the scenario of El Niño. In the city scale, it highlits how it function as a system and network. At a district scale, as an example of how spatially the network looks, and at the street scale, how the design is implemented. For each scenario and scale, exposures, vulnerabilities and risk are identifies based of previous mapping and analysis, with corresponds to the strategies proposed.

2.1 Day-to-day

The main vulnerabilities that span the three scales include informal expansions, informal activities coupled with a lack of urban facilities, and a shortage of green spaces. To address these issues, the main proposals are to limit urban expansions, increase the availability of recreational and green open areas, and address socio-economic disparities. However, each scale explores these vulnerabilities and proposals in a unique manner, reflecting the specific challenges and needs pertinent to each scale.

At the city scale, several vulnerabilities impact the urban system. Informal expansions towards the dry forest in the East side of Castilla's district lead to deforestation, environmental degradation, loss of biodiversity, and droughts. Similarly, expansions towards river margins, Kurt Burt Park, and wetlands in the south side of Piura's district result in the loss of wetlands and environmental degradation. Economic disparities are evident with a reliance on semi-informal activities such as street food vendors and kiosks, particularly in Castilla, which heavily depends on Piura's economic activities and urban facilities, increasing its vulnerability during El Niño events. Additionally, the absence of metropolitan parks in both districts exacerbates exposure to environmental stresses and natural hazards.

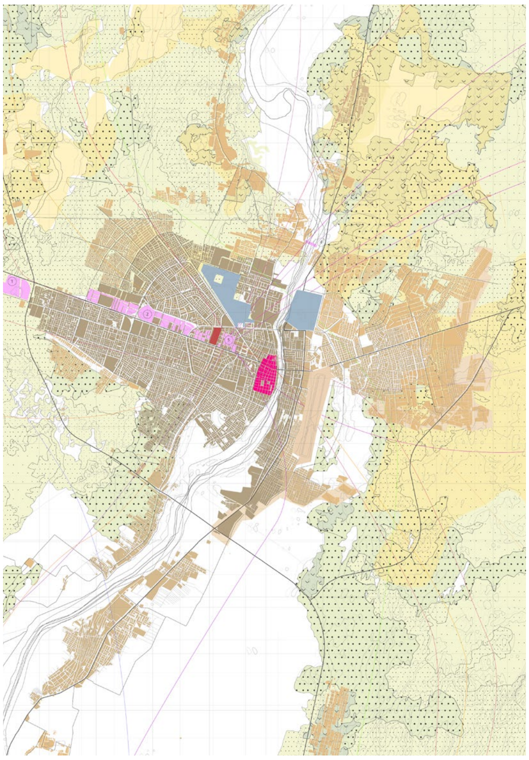
To address these issues, strategies include limiting urban expansions towards sensitive areas and implementing restoration, protection, and conservation measures for degraded regions. Restoration projects for the dry forest, wetlands, and river margins can help mitigate environmental degradation. Socio-economic disparities can be mitigated by ensuring equal access to opportunities and supporting semi-formal and informal commerce, such as selling food from crops and operating kiosks. Developing large-scale metropolitan parks would provide recreational, educational, and biodiversity benefits while adapting current land uses to local soil and water availability.

In the district of Piura, the urban fabric faces specific vulnerabilities. Industrial pollution and spatial segregation are significant issues, with industrial areas producing pollution and creating spatial divides within the city. Scattered semi-formal and informal activities along avenues and streets pose safety risks, especially during El Niño events when street vendors lose their selling spaces. The lack of green and recreational areas negatively impacts the quality of life and community well-being.

Strategies at the district level focus on increasing social permeability by promoting inclusive spaces with mixed-use developments and participatory planning processes to enhance social interaction and reduce spatial fragmentation. Relocating industrial activities to the outskirts of the city would mitigate environmental contamination and health risks for residents while creating opportunities for urban core redevelopment. Designating areas for semi-formal and informal activities would support economic growth and future formalization. Developing more parks and recreational areas within neighborhoods would provide communal gathering spaces and enhance overall well-being.

At the street scale, vulnerabilities include inadequate accessibility in street design, with poorly designed pedestrian streets and crossings. Public spaces often lack proper urban furniture and lighting, reducing their usability and safety. Additionally, mixing bicycles, motorcycles, pedestrians, and cars in the same lanes creates significant safety hazards.

Summary of vulnerabilities



A. Informal expansions:
Towards the dry forest in the East side of Castilla's district. This results in deforestation, environmental degradation, loss of biodiversity, and droughts.
Towards river margins, Kurt Burt park and wetlands in the south side of Piura's district. This leads to the loss of wetlands, environmental degradation, and droughts.

B. Economic disparities:
Particularly relying on semi-informal activities such as selling food in the streets, vendors, and kiosks.

B. Dependency on Piura:
Castilla's dependencies on Piura's economic activities and urban facilities. This dependence increases vulnerability during El Niño events.

C. Absence of metropolitan parks:
The lack of green spaces leaves them more exposed to environmental stresses and natural hazards.

Strategies

A. Limit urban expansions:
Implement policies to restrict urban expansions towards the dry forest and wetlands in Kurt Burt park to prevent further environmental degradation.

A. Restoration, protection, and conservation measures:
Restoration projects for degraded and deforested areas, including the dry forest, wetlands, and river margins. These initiatives can extend into urban areas.

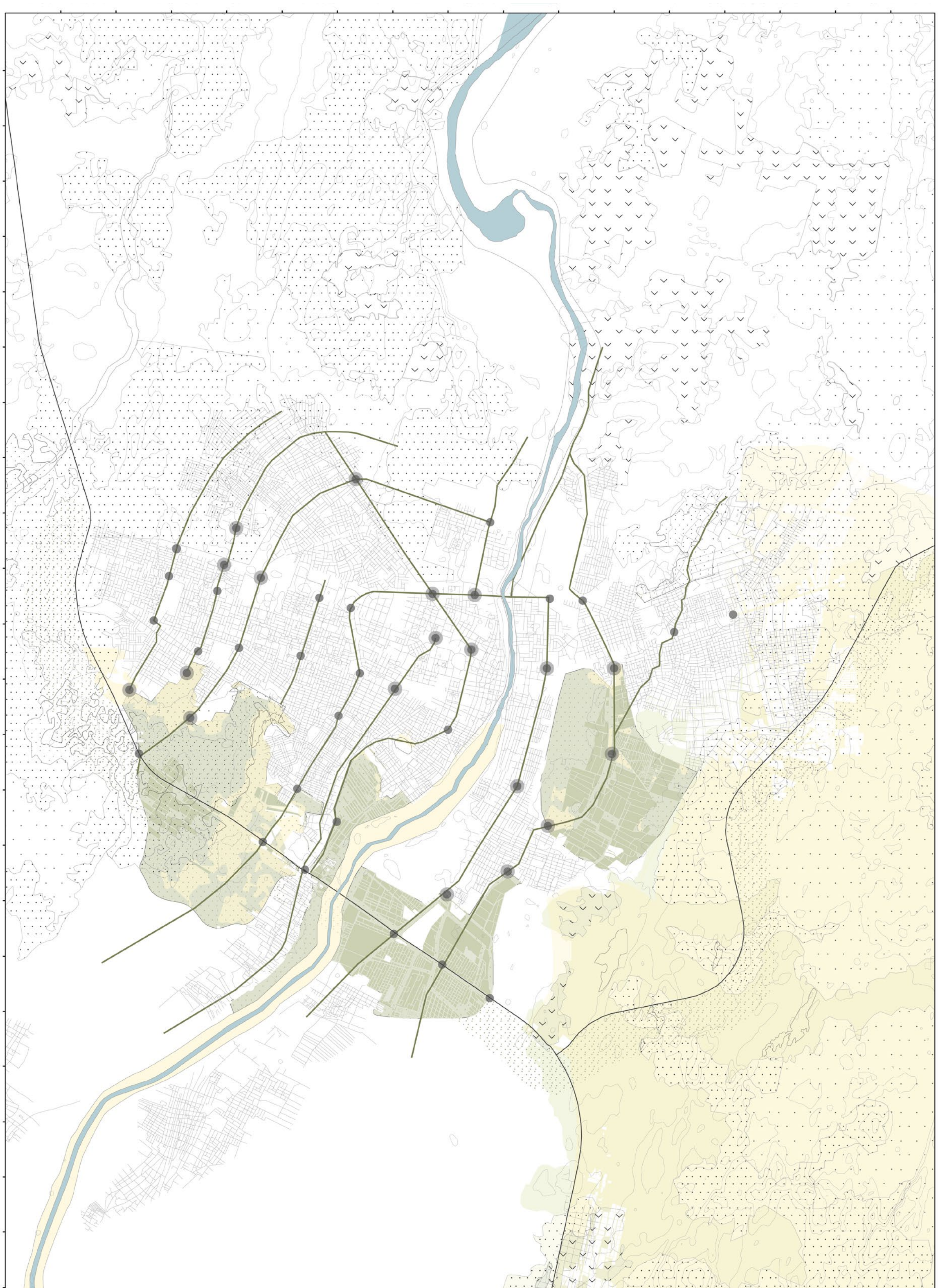
B. Address socioeconomic disparities:
Ensure equal access to opportunities for both Castilla and Piura by delineating areas for semi-formal and informal commerce. Support existing practices like selling food from crops, hot meals, and operating kiosks.

C. Develop large-scale metropolitan parks:
Large parks for recreation, leisure, environmental education, and biodiversity conservation. Adapt current land uses, such as agricultural practices, to the local soil and water availability.

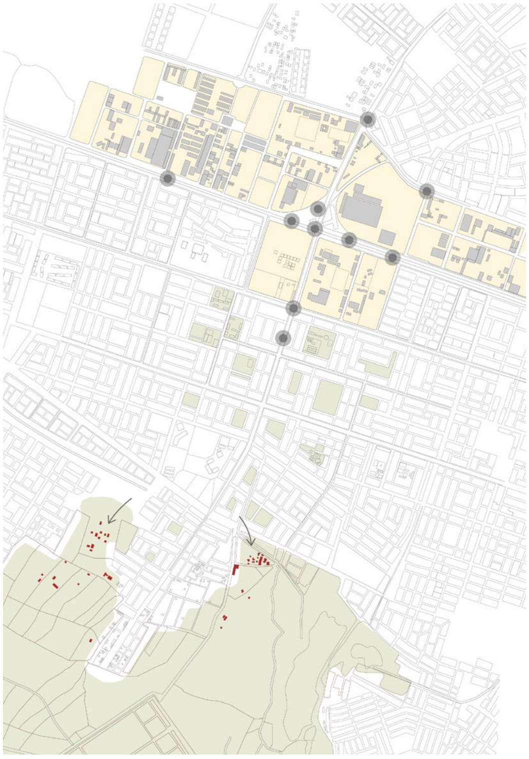
Proposal_City scale_Day to day scenario

- Existing avenues that limit urban expansions
- Protection of dry forest
- Green corridors
- Nucleos for formal and semi-formal commerce activities
- Metropolitan parks

0 .75 1.5 km N



Summary of vulnerabilities



A. Informal expansions towards wetlands:
This leads to the loss of wetlands, environmental degradation, and droughts.

B. Industrial pollution and spatial segregation:
The industrial area produces pollution and creates spatial segregation within the urban fabric.

B. Scattered semi-formal and informal activities:
Semi-formal and informal activities scattered along avenues and streets pose safety risks. During El Niño events street vendors lose their selling spaces.

C. Lack of green and recreational areas:
The absence of green and recreational areas negatively impacts the quality of life and community well-being.

Strategies

A. Limit informal settlements towards wetlands:
Add value to the wetlands. Transform area of the wetland into metropolitan park add restore vegetation.

B. Increase social permeability:
Promote inclusive spaces with mixed-use developments, participaroty planning processes that enhance social interaction and reducuce spatial fragmentation.

B.Relocate industrial activities:
Move industries away from residential areas to the outskirts of the city, mitigating environmental contamination and health risks for neighborhood residents while creating opportunities for redevelopment and revitalization of the urban core.

B. Designated spaces for semi-formal and informal activities:
Designate areas and provide economic growth and future formalization for current semi-formal and informal activities, like selling hot meals in the street and fruit crops.

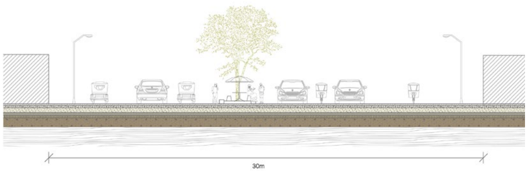
C. Develop recreational areas:
More parks, recreational areas and green spaces within the neighborhood to serve as communal gathering spaces and enhance locals overall well-being.

Proposal_District scale_Day to day scenario

Metropolitan park
New areas for developement
Centralities of formal and semi-formal activities
Urban equipment
Transport
Proposed dense vegetation
Existing parks
Private open spaces
Unpaved streets
Existing trees
'Islands'

0 .75 1.5 km N

Summary of vulnerabilities



B. Inadequate accessibility in street design:
Poor design of pedestrian streets and crossings.

B. Safety concerns from mixed transportation modes:
Mixing bicycles, motorcycles, pedestrians, and cars in the same lanes creates safety hazards.

C. Poorly designed public spaces:
Accessability, urban furniture and lights

Strategies

B. Improve street-level accessibility:
Improve pedestrian infrastructure with sidewalks, crosswalks, ramps, and dedicated cycle paths

B. Foster community participation:
Involve residents in the design, uses and maintainance of their public spaces to ensure social cohesion and added value.

C. Delimitate flows of transport:
Delimite modes of transportation for bicycles, motorcycles, pedestrians, and cars

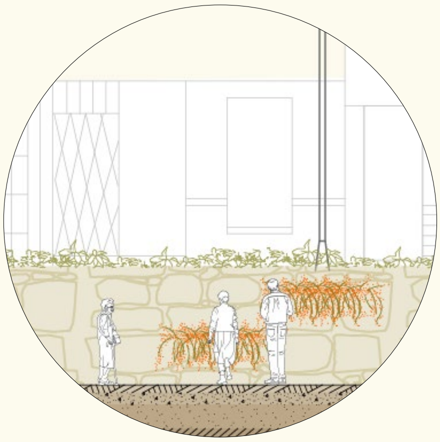
C. Improve public spaces:
Engage the community in the design and quality of the public spaces.

Proposal_Street scale_Day to day scenario

- Cycle lane
- Pedestrian lane
- Car lane
- Corridor (de-paved)
- Islands
- De-paved street
- Existing trees
- Proposed vegetation
- Accesibility

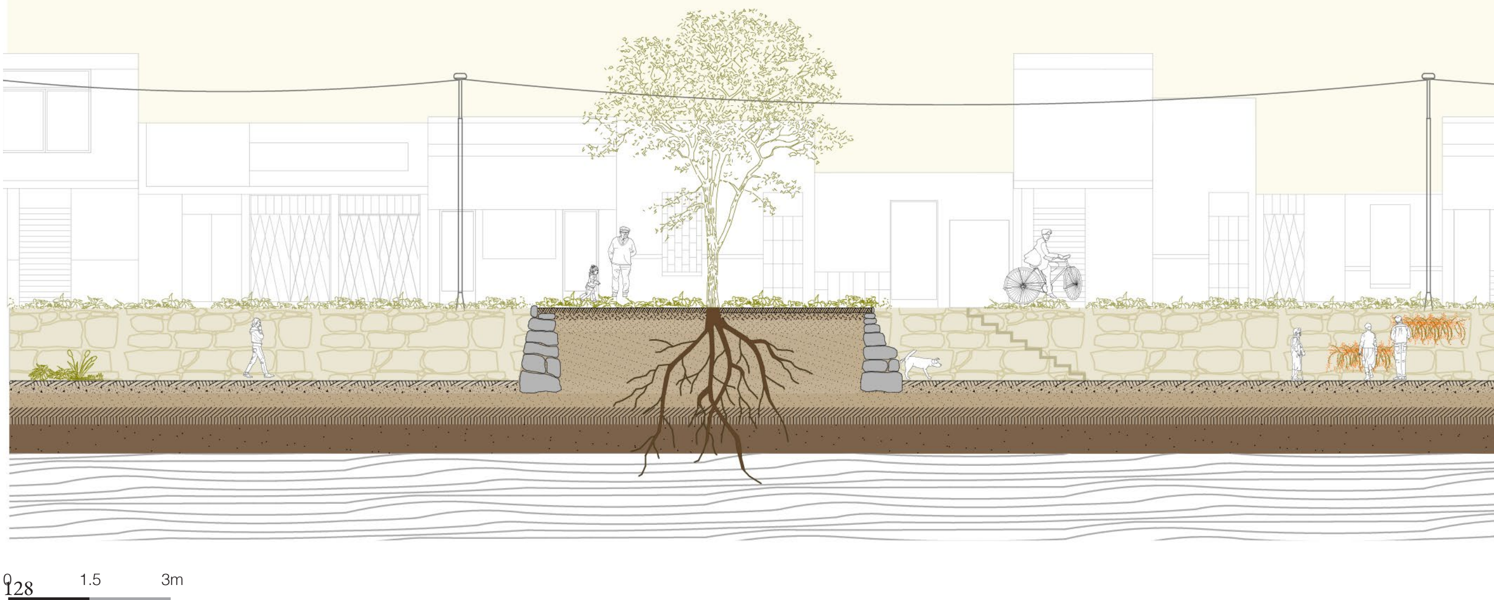
0 .75 1.5 km N

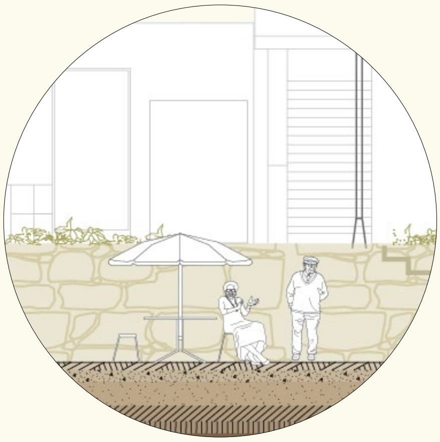

1.5m
2.6m
1.2m
18m
1.2m
2.6
1.5



Maintain existing vegetation:
Forming 'little islands' through the persevation of the roots, therefore, creating different levels in the public space.

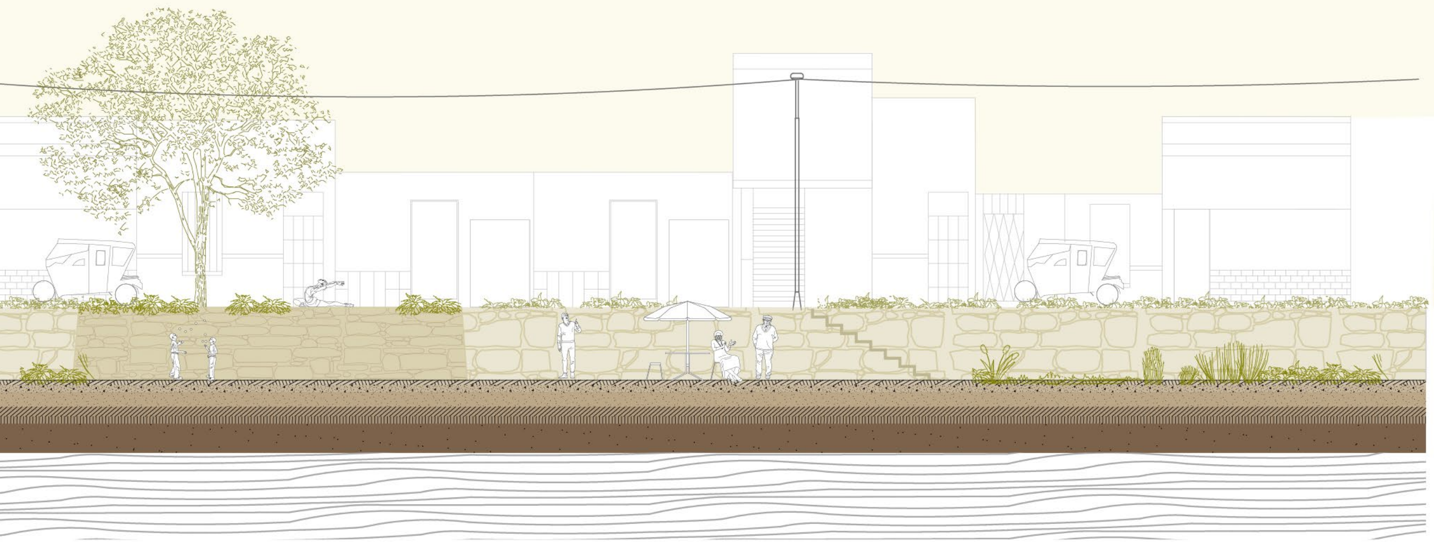
Community appropriation:
The activities and character of the public space within the corredor responds to the communities needs.





Semi-formal and formal activities:
Current activities, such as selling hot meals, food from crops and kioskos, have a place in the public space of the corridors, activating the space.

Accessibility and transport:
Delimitated spaces for diferent modes of transport and access to the lower part of the corridor every 100m through stairs and ramps.



2.2 During El Niño floods

The main vulnerabilities that span the three scales include a lack of connectivity and capacity in drainage systems, disruptions and impacts on transportation, economic networks, and the built environment, the 'loss' of valuable water resources, and a lack of integrated emergency response. To address these issues, key proposals have been put forward that target all three scales. These proposals include the development of blue and green corridors, the implementation of controlled floods, increasing the capacity for water capture, and enhancing flood preparedness. However, each scale explores these vulnerabilities and proposals in a unique manner, reflecting the specific challenges and needs pertinent to each scale.

The city faces several critical vulnerabilities. Occupation in flood-prone areas, such as riverbanks, floodplains, and dry ravines, exposes inhabitants to fluvial and pluvial floods. The drainage network's poor connectivity and insufficient capacity result in inadequate water runoff management, while the sewage network's low capacity leads to contamination as it mixes with runoff water. Health risks arise from flash floods that carry debris and contaminants. Transportation and economic networks are disrupted as floods block roads, collapsing transport systems, particularly impacting Castilla due to its dependency on Piura. Additionally, the city lacks sufficient metropolitan green open spaces to absorb runoff water and an integrated emergency response plan, leaving it unprepared for coordinated flood events.

To address these vulnerabilities, the city must develop a network of blue and green corridors to connect the drainage system and direct water to retention areas and open spaces by gravity. Building more capacity for water in proposed metropolitan parks and channeling excess water through blue corridors to agricultural fields and dry desert areas can help manage runoff. Enhancing groundwater recharge through land-use changes, soil restoration, and conservation of the dry forest is also crucial. Upgrading infrastructure to separate rainwater from sewage systems will prevent contamination. Transforming critical areas, such as oxidation lakes, farmlands, and the airport, into large-scale green open spaces can capture and manage water flow. A comprehensive flood preparedness plan, developed in coordination with local authorities and community organizations, should include evacuation routes and designated shelter facilities, ensuring critical infrastructure services, such as power and telecommunications, are maintained during floods.

At the district level, vulnerabilities include residential zones in low depression areas being highly susceptible to pluvial floods. Local drainage systems suffer from poor connectivity and insufficient capacity, with many streets lacking any drainage infrastructure. The local sewage systems also face low capacity, leading to contamination when mixed with runoff water. Health risks arise from physical accidents during flash floods and erosion. Community facilities and infrastructure, including housing, are often damaged by floods and erosion. Local transportation disruptions hinder daily life and emergency response efforts. Additionally, districts often lack clearly marked evacuation routes and designated safe zones, complicating evacuation and rescue operations.

To mitigate these vulnerabilities, districts should establish transitional spaces in high elevation areas within neighborhoods to serve as safety zones, located in parks or open spaces. Adapting streets into blue and green corridors will channel water flow while allowing for infiltration, directing it to retention areas and open spaces. Building more capacity for water involves capturing water for future use and channeling excess through blue corridors. Implementing controlled floods in green pockets, such as parks, parking lots, and agricultural fields, provides room for rainwater. Enhancing groundwater recharge with permeable surfaces, vegetation, and soil restoration is essential. Systems to separate rainwater from sewage should be implemented to prevent contamination and overflows during heavy rainfall.

At the street level, vulnerabilities include poorly designed street drainage, leading to flooding during heavy rainfall. Flooded streets cause significant damage to road surfaces, sidewalks, and public pathways, making them unsafe and unusable. Housing infrastructure deteriorates due to poor construction standards and locations in flood-prone areas. Flooded streets impede pedestrian and vehicle movement, complicating access to essential services. The impermeability of pavement exacerbates flooding by preventing water infiltration. High temperatures and a lack of permeable areas increase evapotranspiration, reducing soil infiltration and maintaining surface water.

Incorporating green infrastructure, such as rain gardens and increased vegetation, will enhance infiltration. Designating temporary transitional spaces for evacuation and safety, adapting parks and open spaces for emergency use, is essential. Enhancing soil permeability by replacing impermeable surfaces with permeable ones and restoring damaged soil will increase infiltration. Improving drainage infrastructure at the street level is crucial. Balancing evapotranspiration by planting tall trees like Molle or Algarrobos will reduce surface temperatures. Building more capacity for water includes installing green roofs and infrastructure in housing to capture rainwater. Reducing surface runoff by increasing vegetation cover and using permeable surfaces throughout the district is necessary for effective flood management.

Summary of vulnerabilities

A. Failure in drainage network:
Poor connectivity and insufficient capacity for water runoff

A. Mix run-off water with sewage network:
Low capacity and it gets mixed with run-off water, resulting in contamination

A. Lack of metropolitan green open space:
Insufficient permeable spaces for recieving the run-off water.

B. Disruption in transportation and economic network:
Floods block roads, collapsing transport networks. Castilla is particularly vulnerable due to its dependency on Piura. Grau's avenue is blocked. Very important road for goods.

B. Occupation in flood-prone areas: inhabitants in riverbanks, floodplains and dry ravines are more vulnerable to fluvial and pluvial floods.

C. Loss of Valuable Water Resources:
Failure to effectively store floodwater can result in significant water loss through evaporation or drainage into the sea, wasting a critical resource that could be used for future needs.

D. Lack of integrated emergency response:
The city lacks cohesive emergency response plans that coordinate between different agencies and sectors during flood events

Strategies

A. Blue and green corridors:
Develop a network of blue corridors to connect the drainage system, guiding water to retention areas and open spaces by gravity. This will increase the capacity for runoff, preventing the sewage system from being overwhelmed.

A. Separate rainwater from sewage:
Implement infrastructure upgrades or policy changes to separate rainwater and sewage systems.

B. Controlled floods:
Minimize critical infrastructure during floods.

B. Enhance groundwater recharge:
Land-use changes, for example to agricultural o recreatioal areas, restoration of the damaged soil for better permeability and conservation of the dry forest.

C. Build more capacity for water:
Capture water for further use in the proposed metropolitan parks. excess is channalized through blue corridors to agricultural fields and dry desert. Transformation of oxidation lakes, farmlands and airport in critical areas into large-scale green open spaces to capture and recieve water flow.

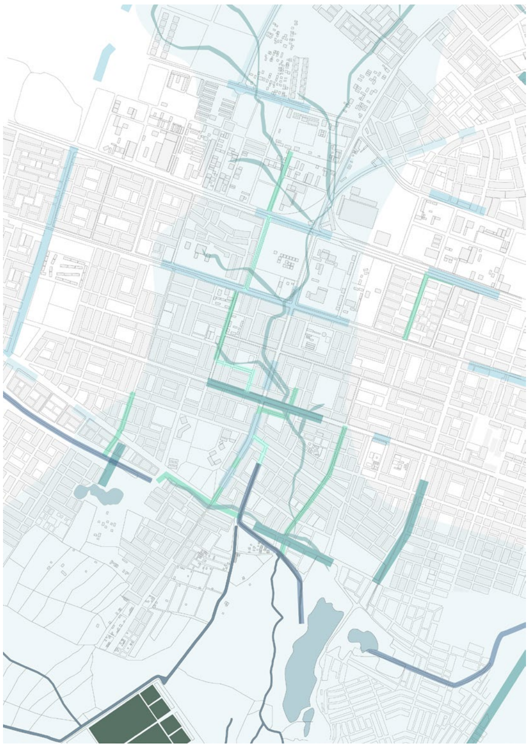
E. Flood preparedness:
Develop emergency response plan in coordination with local authorities, emergency services, and community organizations. This plan should include clearly defined evacuation routes and designated sheltering facilities.

Proposal_City scale_During El Niño events

Main corridor
Secondary corridor
Third corridor
Water retention areas
Less deep
More deep
Dry forest
Farmlands
Excess water
Direction of flow

0 .75 1.5 km N

Summary of vulnerabilities



A. Failure in local drainage systems:
Poor connectivity and insufficient capacity for water runoff, many streets lack any type of drainage systems

A. Failure in local sewage systems:
Low capacity and it gets mixed with run-off water, resulting in contamination

B. Damage to community facilities and infrastructure:
Damage to housing and urban facilities due to floods and erosion.

B. Local transoportation disruptions:
Blockages of transportation routes due to flooding disrupt daily life and hinder emergency response efforts.

B. Residential zones in flood-prone areas:
Inhabitants in low depression areas are more vulnerable to pluvial floods.

C. Loss of Valuable Water Resources:
Failure to effectively store floodwater can result in significant water loss through evaporation or drainage into the sea, wasting a critical resource that could be used for future needs.

D. No evacuation routes and safe zones:
Districts often lack clearly marked evacuation routes and designated safe zones, complicating evacuation and rescue operations.

Strategies

A. Blue and green corridors:
Strategic streets are identified and adapted into main, secondary and third corridors for chanalizing water to small retention areas within the urban tissue and to the metrpolitan park. excess water get chanalized to minimize floods in urban areas.

A. Implement systems to separate rainwater from sewage:
To prevent overloading the sewage infrastructure during heavy rainfall, reducing the risk of contamination and overflows.

B. Controlled floods:
Many housings are in flood-prone areas. Therefore, its necesarry to find room for the rain. By identifying green pockets in critical area within the urban area.these pockets can be existing parks, parking lots, waste areas.

B. Enhance groundwater recharge:
Use permeable surfaces, vegetation, and soil restoration to enhance recharge. this is specially for the green pockets and blue corridors.

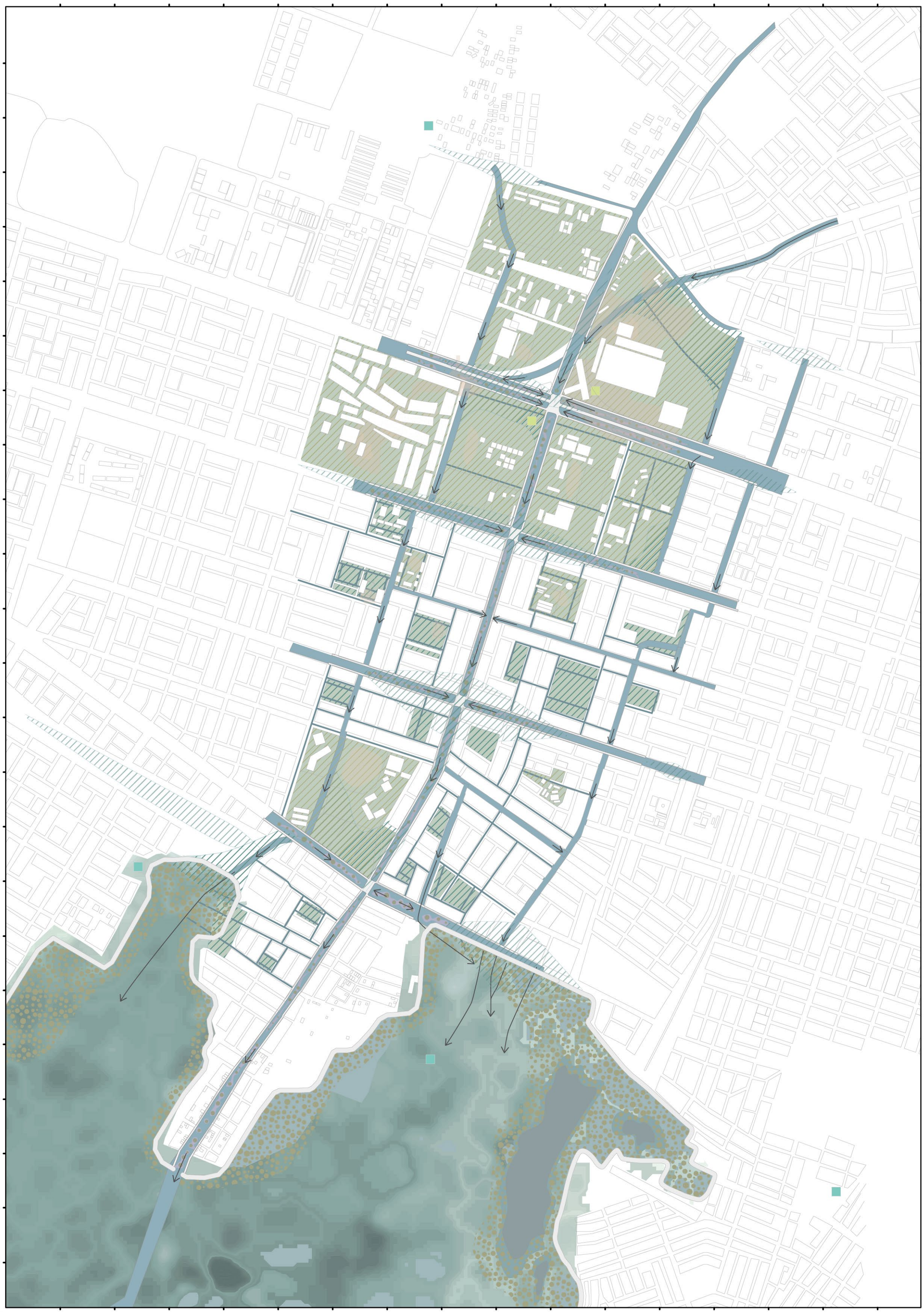
C. Water-retention parks:
Kurt Burt park to capture more water: this area is transformed into a metropolitan park with enough space to retain water during El Niño. Its a temporal park which can be flooded during El Niño events.

D. Safety Areas:
Identify low-risk zones for temporary use, create elevated areas in open spaces to provide safe refuge during floods.

Proposal_District scale_During El Niño events

- Park Kurt Burt, water retention area
- Main blue corridor
- Secondary blue corridor
- Third blue corridor
- Existing pumps
- Proposed pumps
- Flow of water
- Higher areas
- Areas vulnerable to water flow

0 .75 1.5 km N



Summary of vulnerabilities

A. Poorly Designed Street Drainage:
Sreets with inadequate or poorly maintained drainage infrastructure are prone to flooding during heavy rainfall events.

B. Flooded streets:
Floods cause significant damage to road surfaces, side-walks, and public pathways, making them unsafe and unusable.

B. Deterioiration in housing infrastructure:
Some buildings are vulnerable due to poor construction standards, while others are at risk because of their location in flood-prone areas.

B. Accessibility issues:
Flooded streets impede pedestrian and vehicle movement, making it difficult for residents to access essential services.

C. Impermeability of pavement:
The presence of impermeable or semi-permeable pavement, due to the material of the surface, soil saturation, and lack of vegetation, exacerbates flooding by preventing water infiltration.

C. Evapotranspiration:
The lack of permeable areas and high temperatures increases evapotranspiration, reducing the amount of water that infiltrates the soil and contributing to the persistence of surface water.

D. Safety areas and evacuation routes:
Lack of areas of safety and evacuation routs during the event.

Strategies

A. Blue and green corridors:
Margins or center areas of streets are transformed into corridors.

A. Green infrastructure:
Incorporate rain gardens and more vegetation for better infiltration

B. Enhance soil permeability:
Replace impermeable surfaces with permeable ones, and restore damaged soil to increase permeability.

B. Erosion:
Use different size of stones and rocks for retentioon walls and allow water permeability at the same time.

B. Reduce surface runoff:
By increasing vegetation cover and using permeable surfaces throughout the district.

C. Balance evotranspiration:
Increase shadow by using tall trees such as Molle or Algarrobos to reduce surface temperature, thereby decreasing evotranspiration.

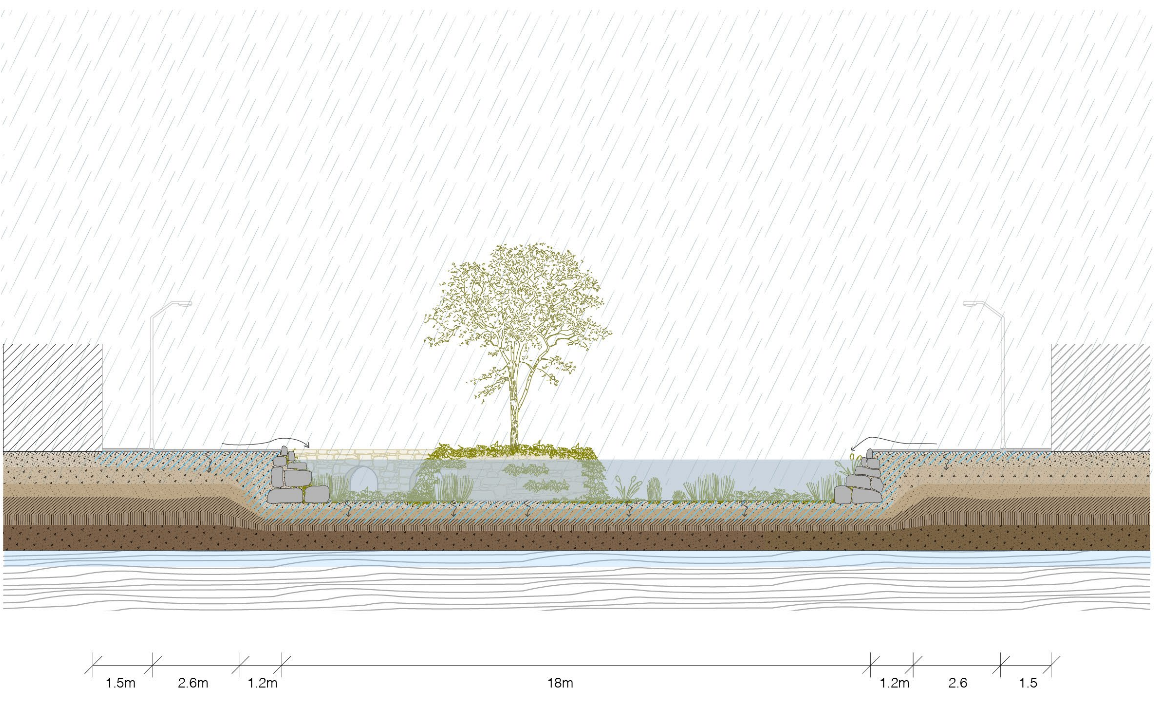
C. Build more capacity for water:
Green roofs and infrastructure in housing to capture water during rains.

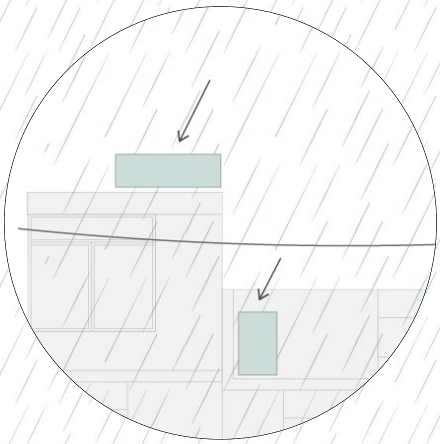
D. Safety areas:
Designate routed and safety areas

Proposal_Street scale_During El Niño

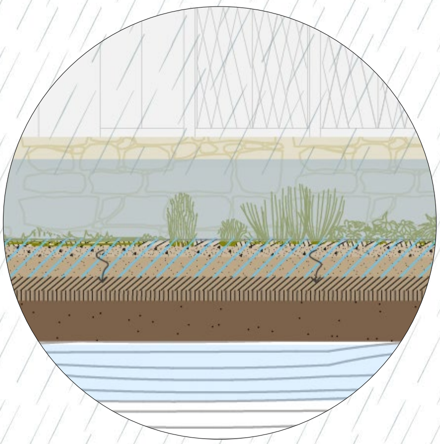
Cycle lane
Pedestrian lane
Car lane
Corridor (de-paved)
Islands
De-paved street
Existing trees
Proposed vegetation

0 .75 1.5 km N

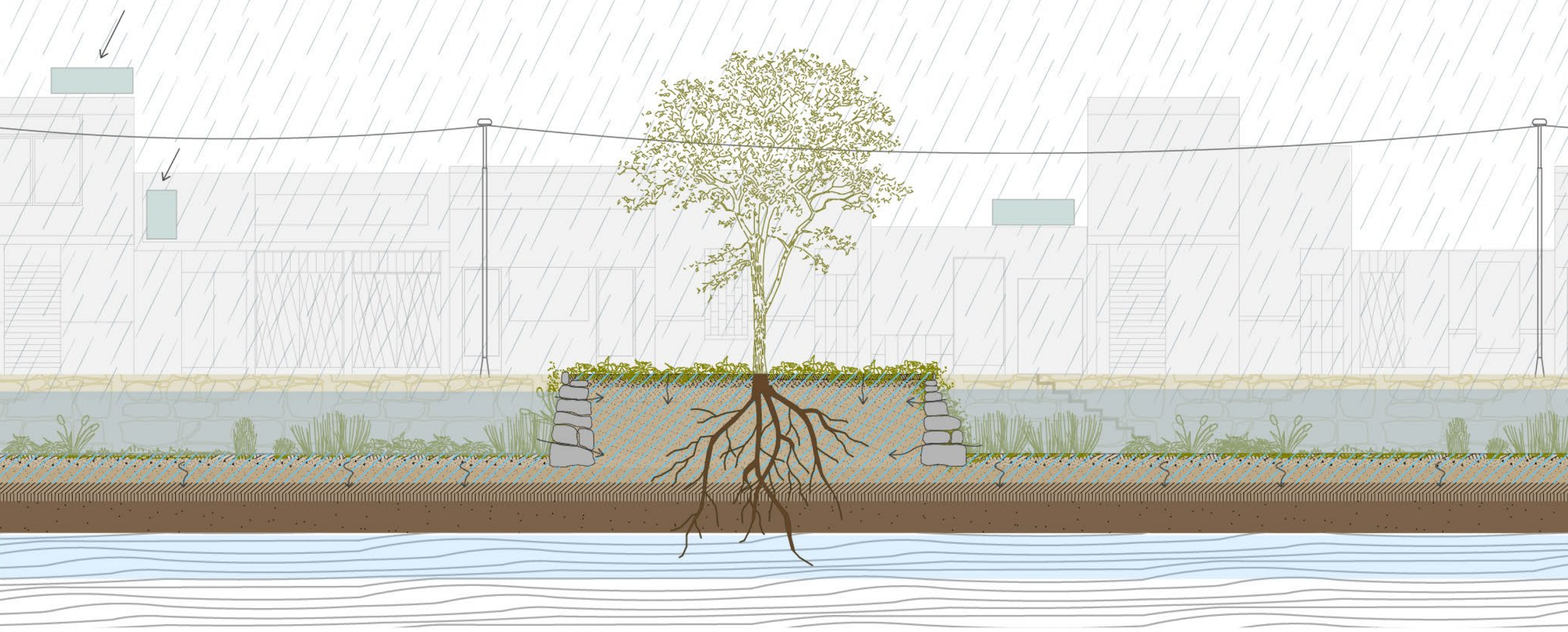

1.5m
2.6m
1.2m
18m
1.2m
2.6
1.5

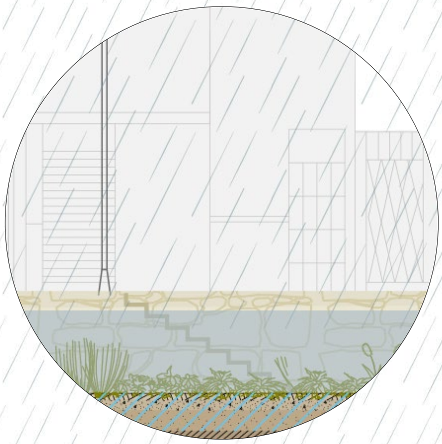


Capture water

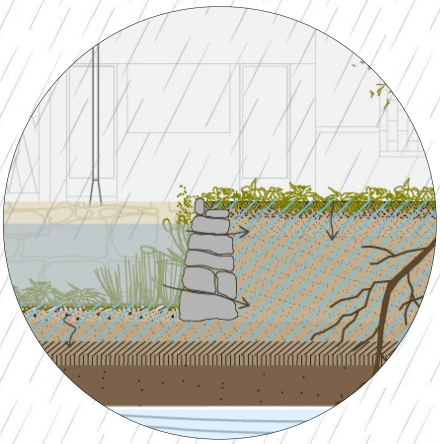


Permeable soil, mostly
sand, slope of 2%

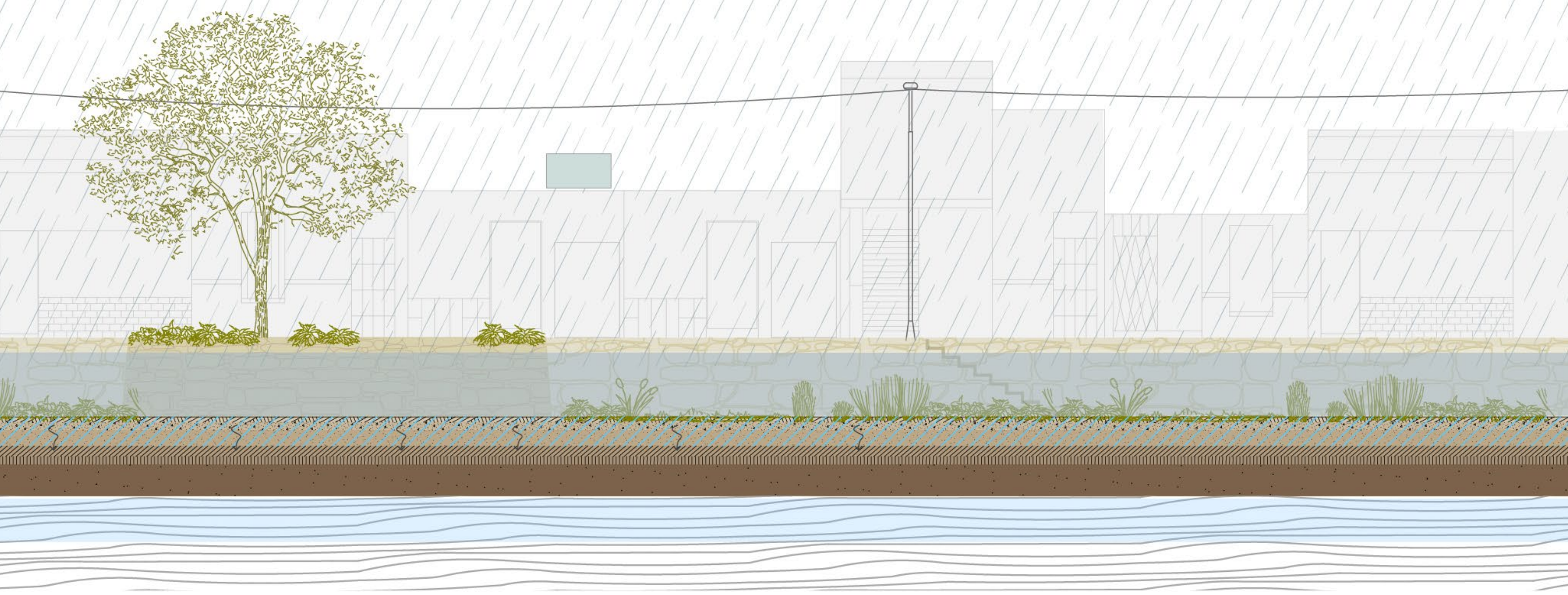




Area not accessible during rains



Retention wall made from stones and rocks from upper basin. Helps with erosion and water permeability



2.2 Aftermath of El Niño

The primary vulnerabilities that transcend the three scales include stagnant water, health risks such as dengue, damage to infrastructure, and the absence of recovery plans. To address these issues, several key proposals have been developed. These include effective water management through retention and storage, enhancing the flow of water and integration of vegetation, comprehensive maintenance and recovery initiatives, and the creation of temporal spaces to mitigate immediate impacts.

The city faces several critical vulnerabilities. Stagnant water, resulting from impermeable surfaces or deteriorated soils, creates breeding grounds for mosquitoes, leading to health risks such as dengue fever. Inadequate sanitation exacerbates these health risks. Transportation and economic activities are disrupted by damage and blockage of avenues due to improper drainage systems, impacting emergency services and supply chains, particularly agricultural. Infrastructure damage, especially in low-lying areas, affects buildings, power lines, and hospitals. The absence of response and recovery plans highlights the need for comprehensive disaster management, including evacuation protocols and community education programs. Additionally, the city faces the loss of valuable water resources due to the ineffective storage of floodwater, which often evaporates or drains into the sea.

To address these vulnerabilities, the city should implement strategies for water retention and storage using permeable and semi-permeable retention areas. Large retention ponds within proposed metropolitan parks can provide semi-permanent water storage, while temporary flooding in agricultural and dry forest areas can replenish aquifers. Improving water quality involves natural filtration systems with vegetation and controlled water flows, addressing contamination and vector-borne diseases. Blue and green corridors will manage water flow, with main corridors remaining functional the longest after El Niño events. Infrastructure upgrades should separate rainwater from sewage, treating any cross-contamination with vegetation or advanced treatment options. Ensuring the functionality of hospitals, schools, and urban equipment after floods, and adapting areas for temporary shelter, are crucial for maintaining essential services.

At the district level, stagnant water from impermeable surfaces or deteriorated soils poses health risks. Soil erosion from floodwaters degrades land quality, affects agricultural productivity, and damages critical infrastructure. Inadequate sanitation leads to health risks such as dengue fever outbreaks. Transportation is disrupted by damaged roads and streets, impacting connectivity. Infrastructure in low-lying areas, including buildings, power lines, and hospitals, is vulnerable to damage. Semi-formal and informal businesses on streets face significant economic disruptions. The lack of response and recovery plans necessitates comprehensive disaster management. Additionally, the district faces the loss of valuable water resources and blockages from sediments and waste carried by floods.

Strategies include designating transitional spaces for public use and recovery post-El Niño while water infiltrates or evaporates. Implementing water retention and storage with green roofs, rain gardens, and permeable pavements in urban areas is essential. Natural filtration systems with vegetation and controlled water flows will improve water quality post-flood, addressing contamination and vector-borne diseases. Blue and green corridors will manage water and sediment flow, though lower parts may be temporarily unusable. Infrastructure upgrades should separate rainwater from sewage to prevent contamination. Ensuring needed services in hospitals, education centers, and flexible shelter areas is vital. In cases of stagnant water, pumps will transfer it to corridors. Regular maintenance and inspections will prevent blockages. Community efforts for meeting and collection points will alleviate blockages and organize collective action.

Street-level vulnerabilities include open sewage boxes, as residents attempt to remove stagnant water, leading to sewage overflow and contamination. Flooded streets cause significant damage to road surfaces, sidewalks, and public pathways, making them unsafe. Accessibility issues arise as flooded streets impede pedestrian and vehicle movement. High temperatures and lack of permeable areas increase evapotranspiration, reducing soil infiltration and maintaining surface water. Impermeable pavements exacerbate flooding by preventing water infiltration.

Incorporating green infrastructure, such as rain gardens and increased vegetation, will enhance infiltration. Designating temporary transitional spaces for public use and recovery post-El Niño is essential. Enhancing soil permeability by replacing impermeable surfaces and restoring damaged soil will increase infiltration. Balancing evapotranspiration by planting tall trees like Molle or Algarrobos will reduce surface temperatures. Installing green roofs and infrastructure in housing will capture rainwater. Blue and green corridors will manage floodwater and sediments, with proposed islands remaining accessible for other uses. Incorporating recreational and educational elements will promote community engagement and awareness, aiding in water management and maintaining ecological balance.

Summary of vulnerabilities

A. Stagnet water:
Impermeable surface or deteriorated soils makes it harder to infiltrate water within the urban areas, making them areas for mosquitos.

B. Health risks:
Due to inadequate sanitation, stagnet water and disease outbreakes, like dengue fever.

C. Transportation and economic activities disruptions:
Damage and blockage of avenues due to improper drainage systems, impacting emergency services and supply chains, specially agricultural.

C. Damage in infrastructure:
Especially in buildings and critical infrastructure in low-lying areas, including power lines, housings, and hospitals.

D. No plans for response or recovery plans:
Currently, no plans exist for response and recovery efforts following flood events, highlighting the need for comprehensive disaster management plans, including evacuation protocols and community education programs.

Strategies

A. Water management (retention and storage):
Implement strategies for water retention and storage for further use. These can be temporary or semi-permenent water retention areas

A. Semi-permenent:
Large retention ponds within the proposed metropolitan parks with semi-permeable soil. (some because they are located in clay soil), given the amount of space and depht-.

A. Temporary:
In agricultural and dry forest areas, temporary flooding will allow water to infiltrate into highly permeable soils, replenishing aquifers.

B. Water quality:
Improve water quality using natural filtration systems involving vegetation and controlled water flows, along with fauna that help purify the water. Address concerns regarding contamination and vector-borne diseases like dengue

B. Minimize the mix of sewage and run-off water:
Treat any cross-contamination with vegetation or divert it with a pumping machine to advanced treatment options like biofiltration and constructed wetlands before reaching oxidation plants.

C. Quick recovery:
Controlled floods in critical areas makes it quicker to recover. For example, the national road.

C.D. Ensure needed services:
Adapt hospitals, schools and urban equipment to function after floods and areas that can be flexible for people who need shelter.

D. Temporal spaces in blue and green corridors:
In the aftermath of El Niño, the blue corridors will slowly become usable again. Because the main corridors are more deep, these are the last ones to “dry”. it created this temporality within the use of the corridors.

Proposal_City scale_After El Niño floods

0 .75 1.5 km N

Summary of vulnerabilities

A. Stagnet water:
Impermeable surface or deteriorated soils makes it harder to infiltrate water, making it stagnet within the urban areas and posing health risks.

B. Health risks:
Due to inadequate sanitation, stagnet water and disease outbreakes, like dengue fever.

C. Soil erosion:
Floodwaters can lead to soil erosion, degradading land quality, affecting agricultural prooductivity and damaging critical infrastructure.

C. Damage in infrastructure:
Especially in buildings and critical infrastructure in low-lying areas, including power lines, housings, and hospitals.

C. Blockage:
Sediments, waste and objects from floods block pedestrian pass and the dicharge of water

D. No plans for response or recovery plans:
Currently, no plans exist for response and recovery efforts following flood events, highlighting the need for comprehensive disaster management plans, including evacuation protocols and community education programs..

Strategies

A. Transitional spaces on a district scale:
In the aftermath of El Niño, designate temporary zones for public use and recovery while water infiltrates or evaporates.

A. Stagnet water:
In case of stagnet water that is not relieved with the proposed drainage systems, water-pumps will help transfer the water to to corridors..Implement a regular schedule for maintenance and inspections of drainage systems to prevent water from becoming stagnant.

A. Water management (retention and storage):
Implement strategies for water retention and storage for further use. These can be temporary or semi-permenent water retention areas:
Semi-permenent: kurt burt park given clay soil, semi permeable soil. grey infrastructure: in tanks under the pavement, this can be located in parks to serve the community.
Tempoprary: current parks and corridors, given the high permeability soil.

B. Water quality:
Post-flood, the water ofter carries sediments and drags everything in its way. Improve water quality using natural filtration systems involving vegetation and controlled water flows, along with fauna that help purify the water. Address concerns regarding contamination and vector-borne diseases like dengue

B. Minimize the mix of sewage and run-off water:
Any cross, should be treated with vegetation or divered to with a pumping machine and treated in the oxidation plants.

C.D. Ensure needed services:
In hospitals, education centers, and areas that can be flexible for people who need shelter.

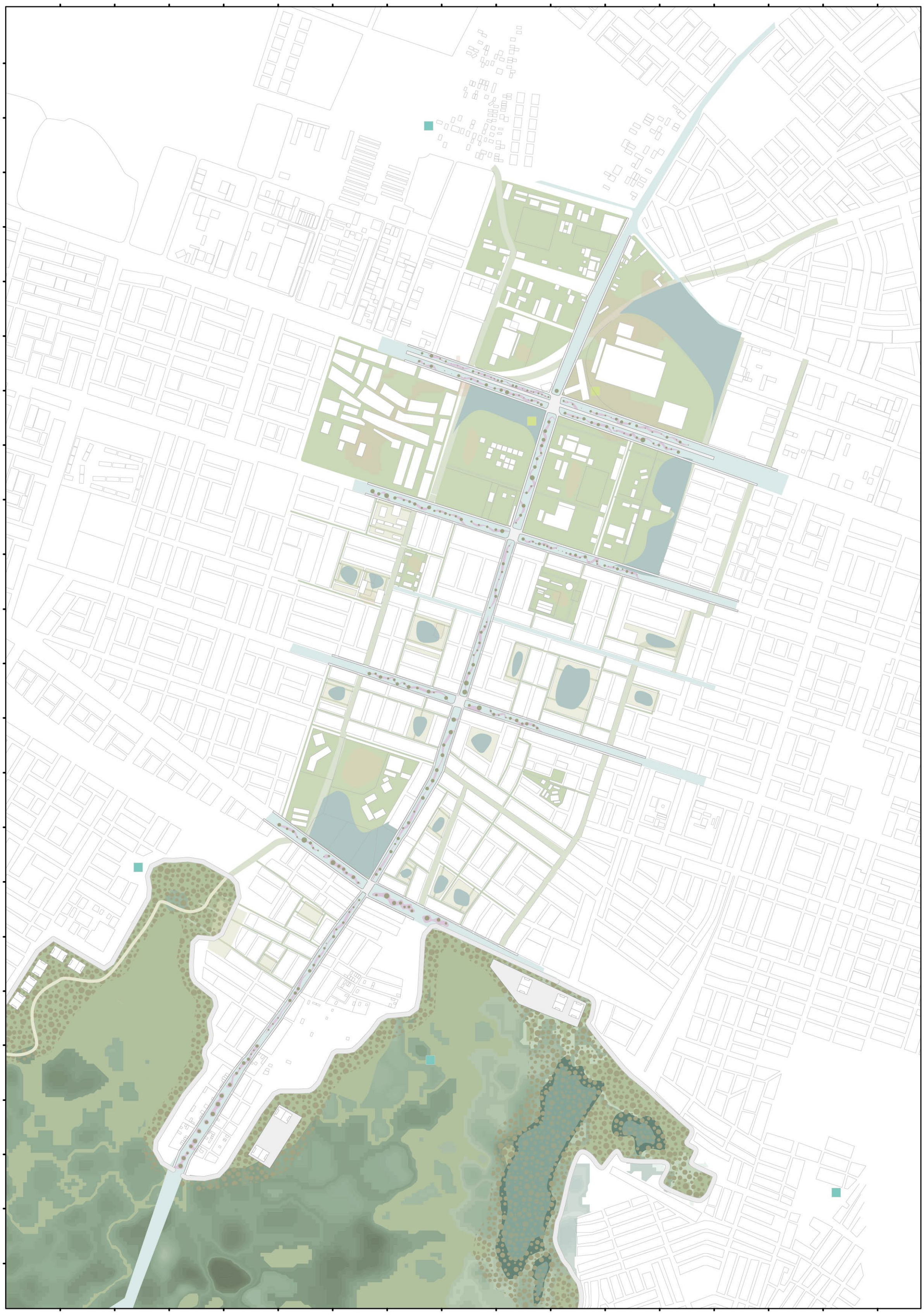
C.D Relieve blockage in the corridors:
Vegetation, sediments and objects from floods fill the street. delimitate space and routs for trucks to pick waste

D. Temporal spaces in blue and green corridors:
Main and secondary corridors still have water and sediments brought by the flood, lower parts temporarly cannot be used.

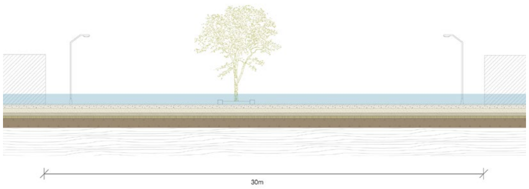
D. Meeting and collection points:
Community gatherings to aliviate the blockages from the floods in case more water will flow. collective action with the public and organize communities.

Proposal_District scale_After El Niño floods

0 .75 1.5 km N



Summary of vulnerabilities



A.B. Open sewage boxes:
Because the drainage system collapse, many residents open the sewage boxes to remove the stagnet water. Most of the times, the sewage systems reaches its limits and overflows in the flooded street, contaminating the water and posing health risk.

A. Evapotranspiration:
The lack of permeable areas and high temperatures increases evapotranspiration, reducing the amount of water that infiltrates the soil and contributing to the persistence of surface water.

C. Blockage of streets:
Floods cause significant damage to road surfaces, sidewalks, and public pathways, making them unsafe and unusable.

C. Accessibility issues:
Flooded streets impede pedestrian and vehicle movement, making it difficult for residents to access essential services.

D. No plans for response or recovery plans:
Currently, no plans exist for response and recovery efforts following flood events, highlighting the need for comprehensive disaster management plans, including evacuation protocols and community education programs..

Strategies

A. Green infrastructure: incorporate rain gardens and more vegetation for better infiltration

A. Retain and store: Through roof gardens or under the built environment as tanks

B. Enhance soil permeability: replace impermeable surfaces with permeable ones, and restore damaged soil to increase permeability.

B. Balance evotranspiration: increase shadow by using tall trees such as Molle or Algarrobos to reduce surface temperature, thereby decreasing evotranspiration.

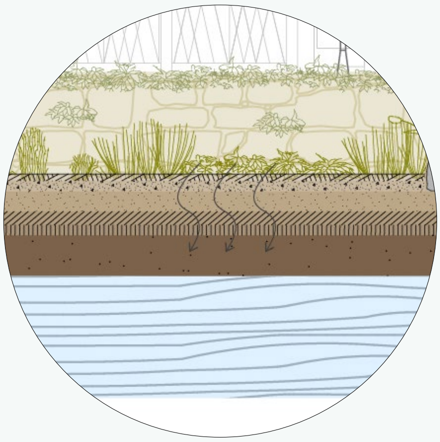
C.D. Temporal spaces in blue and green corridors: Designate temporary zones for public use and recovery while water infiltrates and evaporates. Main and secondary corridors still have water and sediments brought by the flood. However, the proposed islands remain accessible for other uses. Incorporate recreational and educational elements to promote community engagement and awareness, aiding in managing excess water and maintaining ecological balance.

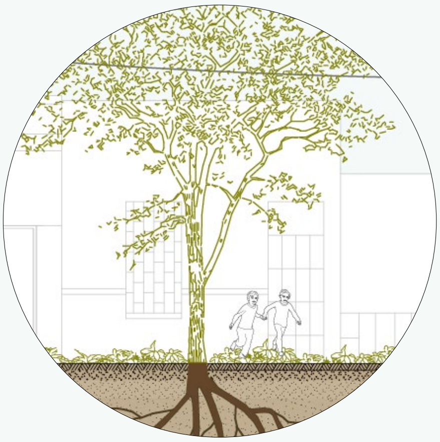
C.D Relieve blockage in the corridors: vegetation, sediments and objects from floods fill the street. delimitate space and routs for trucks to pick waste

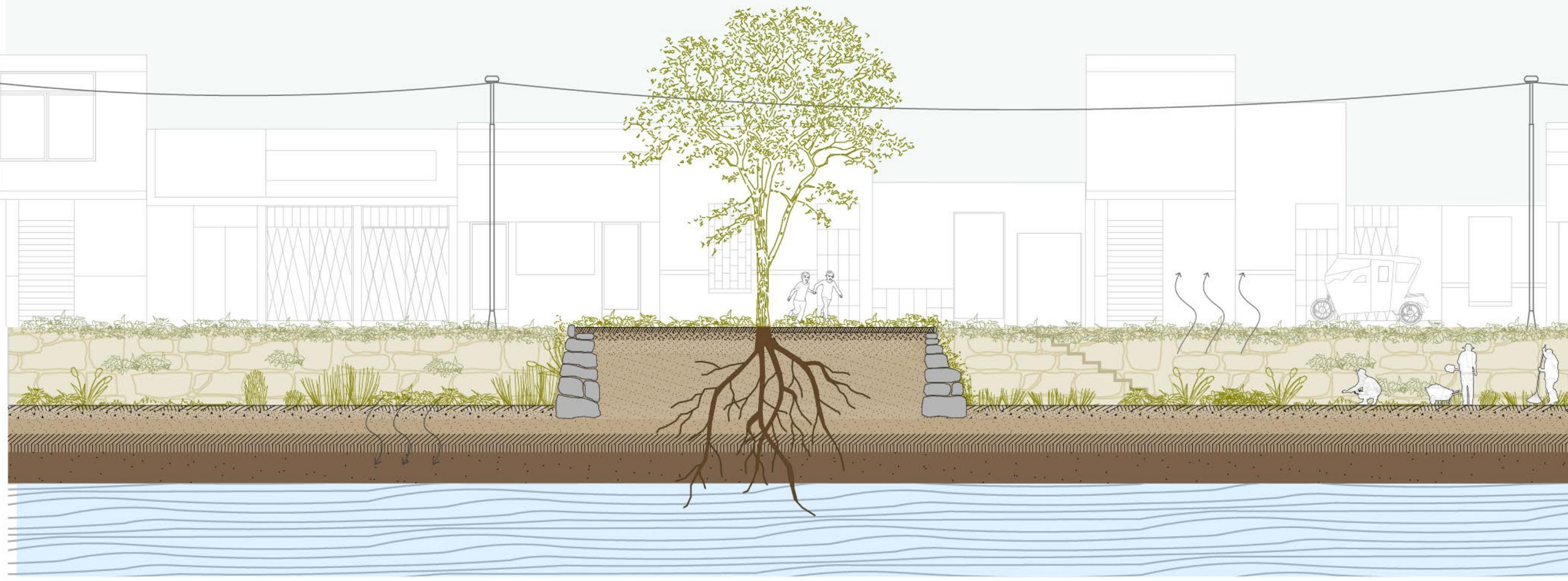
Proposal_Street scale_After El Niño floods

0 .75 1.5 km N

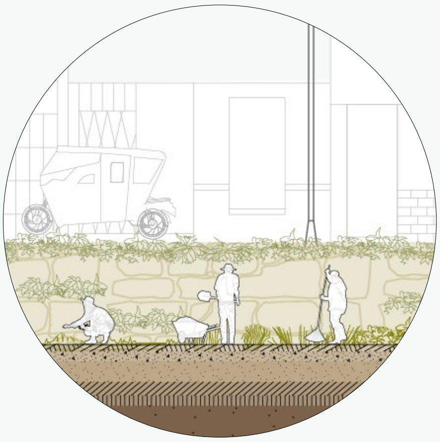

1.5m
2.6m
1.2m
18m
1.2m
2.6
1.5


Recharge acquifer

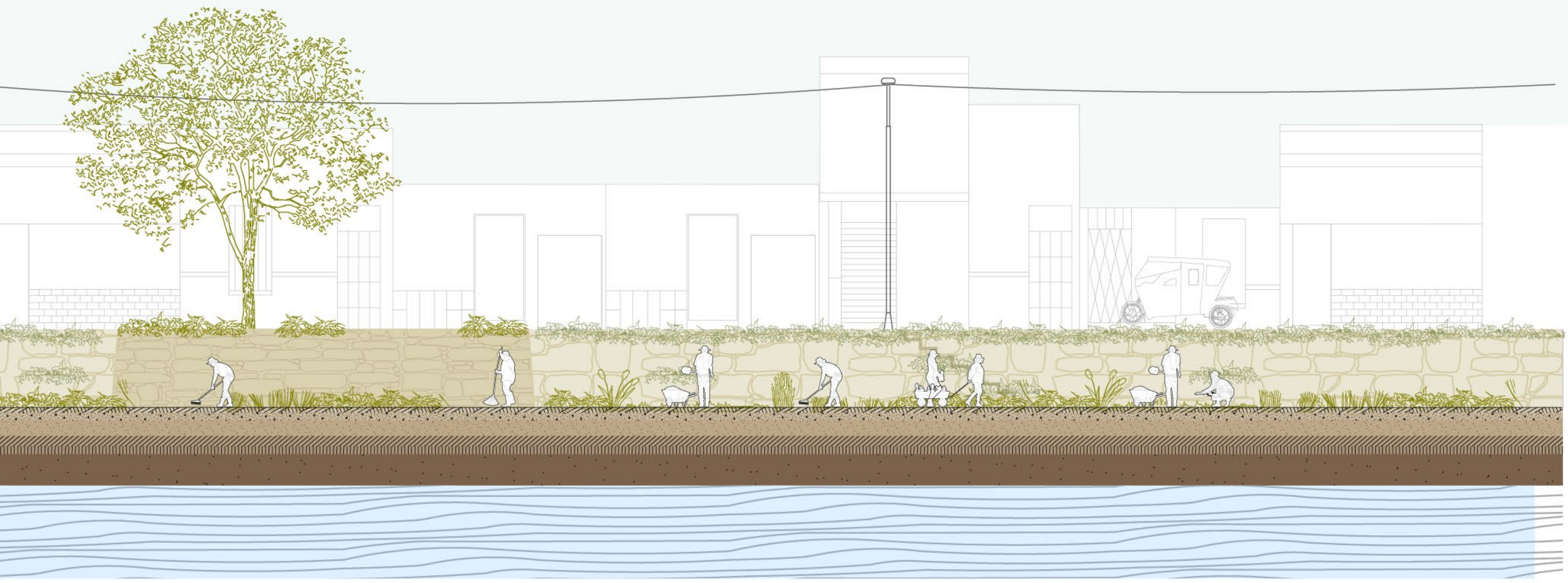

Temporal space for activities



Vegetation reduces evatranspiration



Comunity and public sector helps to clean and open blockage by flood's sediments The sediments are re-used for construction material in recovering corridors.



2.3 Droughts

The primary vulnerabilities that transcend the three scales include a lack of water accessibility, the urban heat island effect, high water demand from crops, and associated health risks. To address these issues, several key proposals have been developed. These include comprehensive water management strategies, improving water accessibility, and creating cooling spaces.

The city faces several significant vulnerabilities due to drought conditions. There is a lack of water for human consumption and agricultural practices, exacerbated by high water demand from crops such as rice fields. The urban heat island effect causes temperature rises, particularly near the airport and industrial areas, leading to increased health risks from heat waves.

To address these vulnerabilities, the city should implement wind corridors by using wind direction to decrease temperature sensation and mitigate the urban heat island effect. Water recycling should be promoted by utilizing water from retention areas for citizen use. Additionally, agricultural practices should shift to crops that require less water to reduce overall water demand.

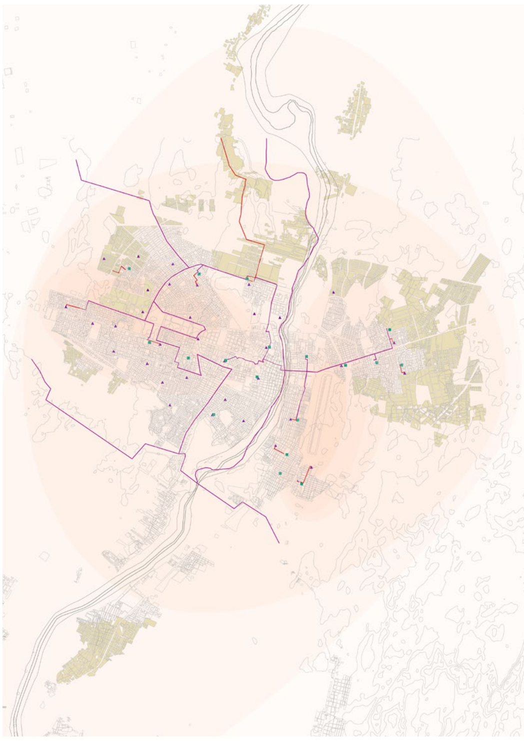
At the district level, the lack of vegetation exacerbates the heat island effect and reduces natural cooling. The area is prone to erosion due to drought conditions, which degrades land quality and damages infrastructure. Wind storms during dry conditions carry sediments and waste, causing blockages.

Strategies to combat these vulnerabilities include increasing shaded spaces by planting tall trees such as Molle or Algarrobos to reduce surface temperature. Designating transitional spaces for public use and recovery during droughts will provide necessary relief. Community engagement should be fostered through recreational and educational elements to promote awareness and aid in water management.

Street-level vulnerabilities include inadequate shaded spaces, leading to higher surface temperatures. High evapotranspiration rates result from a lack of permeable areas and high temperatures, further exacerbating drought conditions.

To mitigate these issues, increasing shaded spaces by planting tall trees like Molle or Algarrobos will help reduce surface temperatures. Incorporating green infrastructure, such as rain gardens and additional vegetation, will improve infiltration and provide natural cooling, addressing both heat and water management challenges.

Summary of vulnerabilities



A. Lack of accessability for water: not enough water for human consupmtion and agricultural practices. potable water infrastructure doesn't reach the peripheries.

B. Urban heat island effect: temperature rises, specifically data shows that temperature increases most nnear the airport and the industrial area.

C. Water demand from crops: many agricultural fields demand a lot of water, for example, rice fields.

D. Health risk: rise of temperature because of heat waves

Strategies

A. Water recycling: Use water from the retention areas for citizens use.

A. Water management: Change crops that demand less water for agricutlrual activities.

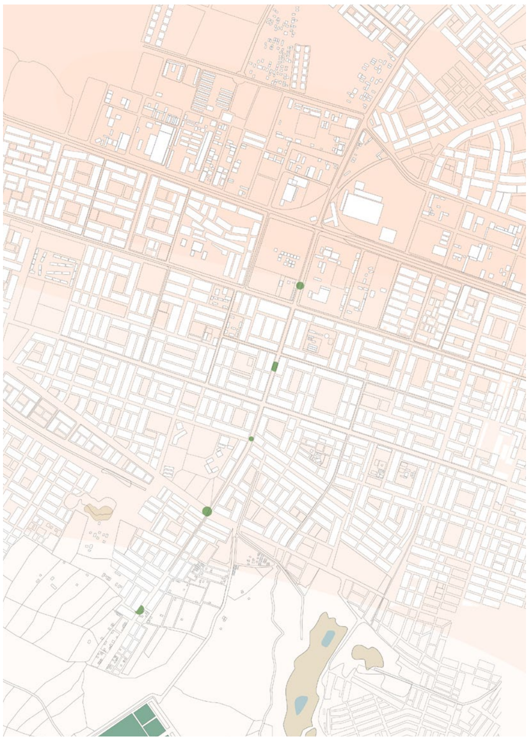
B.D Accesability to water: add infrastructure for equal distribution of potable water in each neighborhood

C. Wind corredors: Use wind direction to identify wind corredors and decrease temperature sensation

Proposal_City scale_Drought scenario

0 .75 1.5 km N

Summary of vulnerabilities



A. C.D Water shortage:
Regulation and restriction of water use in households during drought periods, causing limited water availability.

B. High sensation temperature in the streets:
Insufficient shade and vegetation, leading to elevated surface temperatures and discomfort

B. Lack of wind circulation:
Poor air flow in urban areas, exacerbating heat buildup and reducing natural cooling effects.

B. Prone to erosion:
Drought conditions degrading land quality and damaging infrastructure

Strategies

A. Use stored water: Use water stored in wells and tanks in parks and other public spaces for neighborhood use, ensuring reliable access during droughts
.
A.B. Water Pumps: Implement water pumps to drive water from the south to the north, using gravity for efficient water distribution from the north to the south.

C. Exposed water: Retain water in public spaces to naturally cool the surrounding temperature.

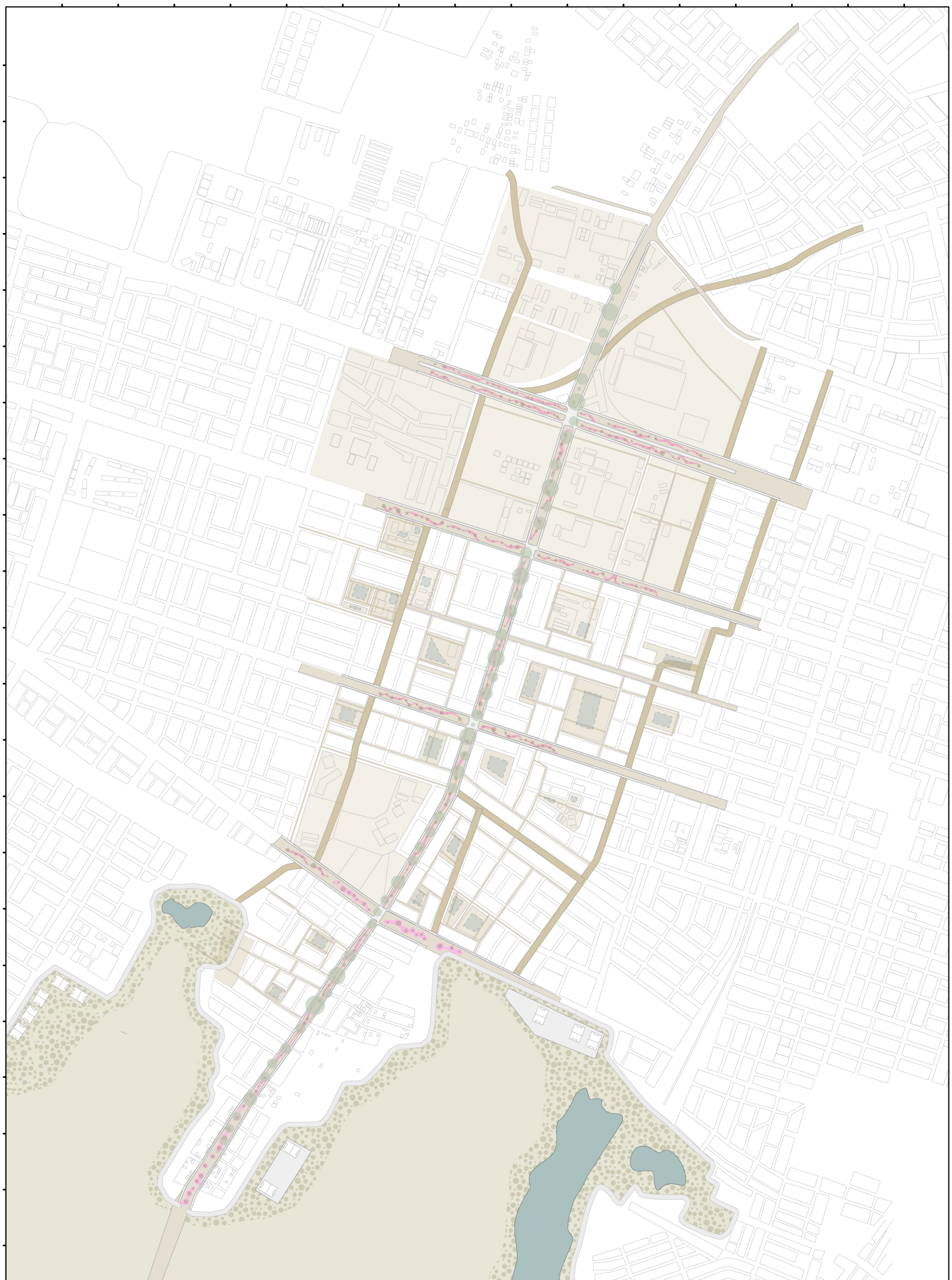
C. Wind flow: Design main corridors with open spaces to facilitate natural south-to-north wind flow, enhancing cooling in urban areas.

C. Shadowed spaces: Plant tall, drought-resistant trees like Molle or Algarrobos to create shaded areas and significantly reduce surface temperatures.

A. C. Use of vegetation: vegetation that doesnt requiere much water and roots are deep, to prevent erosion.

Proposal_District scale_Drought scenario

0 .75 1.5 km N



Summary of vulnerabilities

A.C. D. Water shortage:
Regulation and restriction of water use in households during drought periods, causing limited water availability.

B. Lack of wind circulation:
Poor air flow in urban areas, exacerbating heat buildup and reducing natural cooling effects.

B. Materiality:
Use of materials like asphalt and metal in pavement and public furniture, which absorb and retain heat, increasing the overall temperature and discomfort in public spaces.

B.D. High sensation temperature in the streets:
Insufficient shade and vegetation, leading to elevated surface temperatures and discomfort

Strategies

A.C. Use Stored Water:
Use water stored during El Niño events for household use from individual units and community use from public reservoirs, ensuring a reliable water supply during droughts.

B.D Shadowed spaces:
Increase shade by planting tall trees such as Molle or Algarrobos to reduce surface temperature and provide natural cooling.

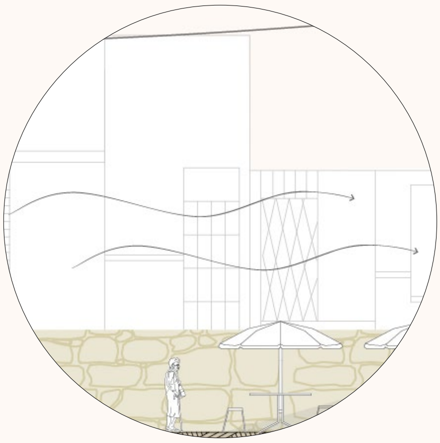
B.D. Wind Flow:
Design main corridors with open spaces to enhance natural south-to-north wind flow, cooling urban areas and improving air circulation during droughts.

B. Materiality:
Implement materials that reflect heat during the day and stay cool at night, reducing temperature stress and enhancing comfort in public spaces during droughts.

Proposal_street scale_Drought scenario

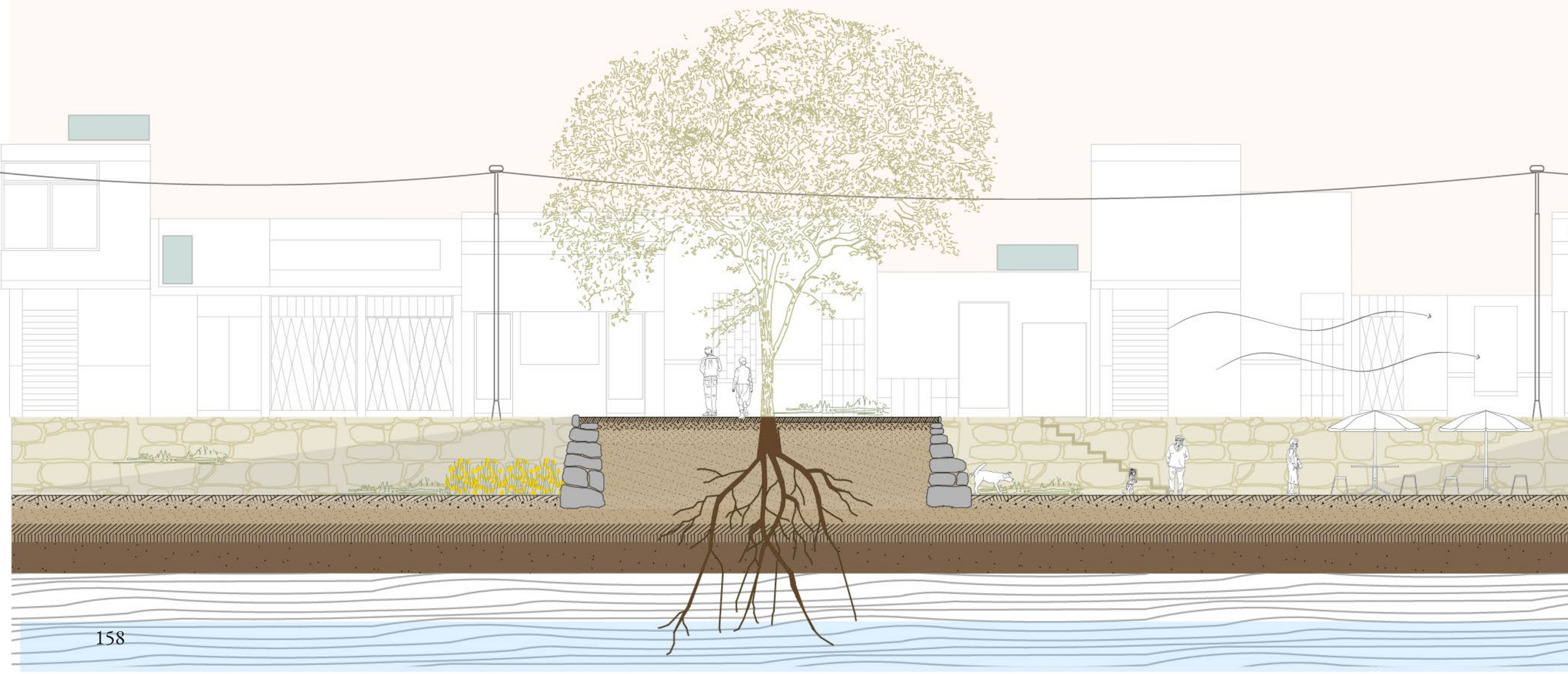
0 .75 1.5 km N

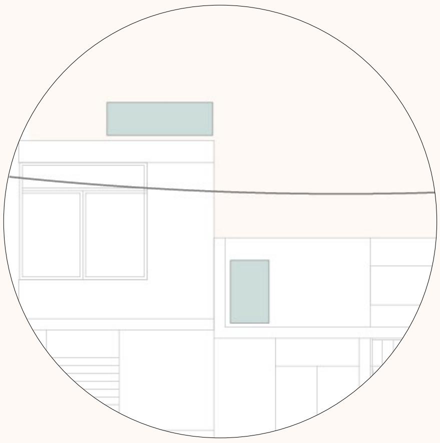
1.5m
2.6m
1.2m
18m
1.2m
2.6
1.5



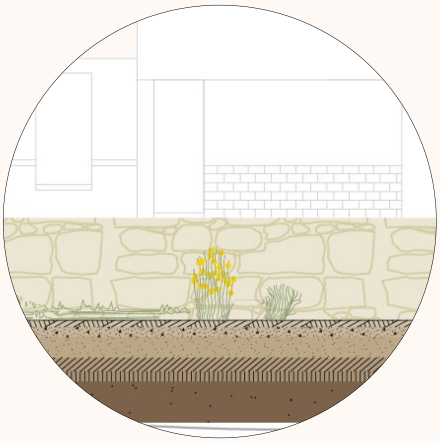
Wind corridor

Algarrobo and Molle have a large tree crown that provides shade, and deep roots that survive droughts

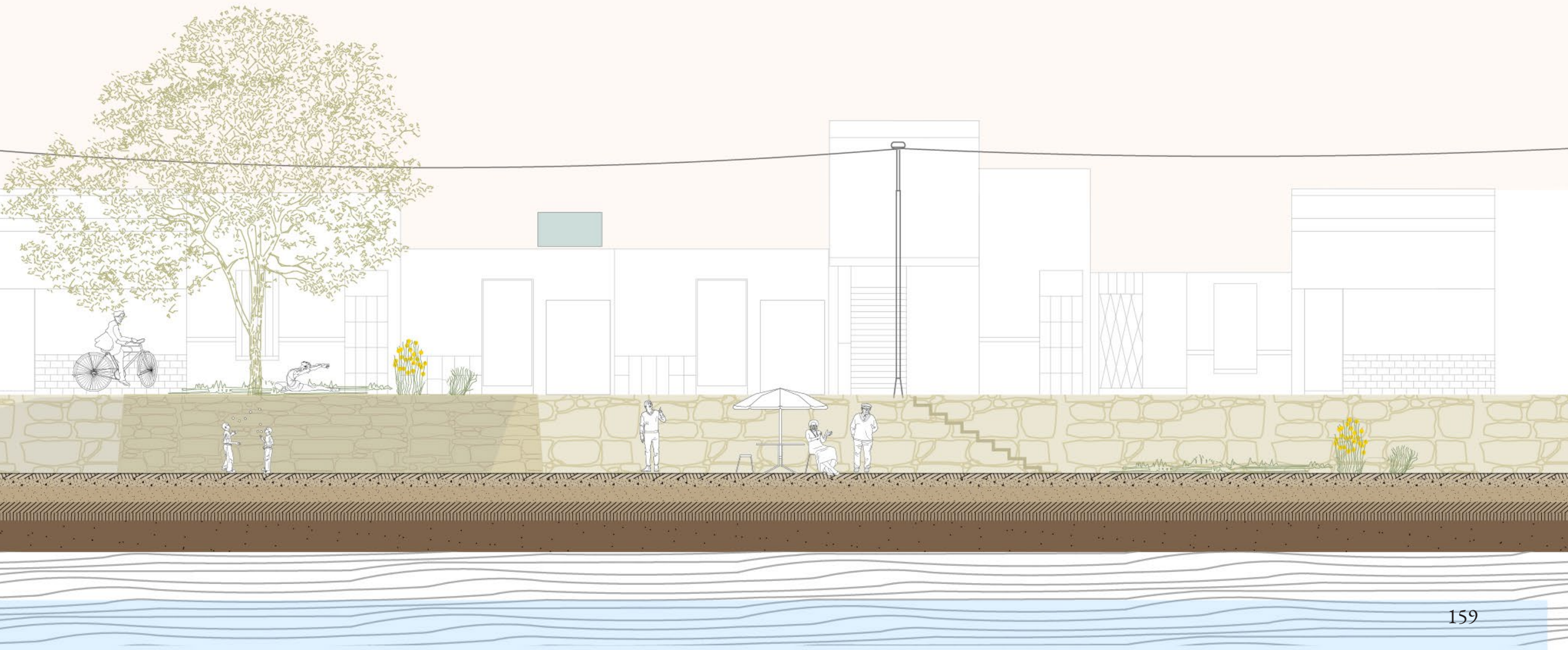




Use water captured during El Niño rains



local vegetation for hot temperatures and requier low amount of water



2.4 Summary

	Day to day	During El Niño
	Current main vulnerabilities: A. Expansions B. Informal activities and lack of urban facilities C. Lack of green spaces Main proposals: A. Limit urban expansions B. More recreational and green open areas C. Adress socio-economic disparities	Current main vulnerabilities: A. Lack of connectivity and capacity from drainage systems B. Disruption and impact in transportation, economic network and built environment C. 'Loss' of valuable water resources D. Lack of integrated emergency response Main proposal: A. Blue and green corridors B. Controlled floods C. Build more capacity for water (capture) D. Flood preparedness
City as a system network	A. Informal expansions B. Economic disparities relying on informal activities B. Castilla's heavy reliance on Piura's economic activities and urban facilities C. Absence of metropolitan parks in both districts A. Limit urban expansions A. Restoration, protection, and conservation measures B. Address socioeconomic disparities. C. Develop large-scale metropolitan parks	A. Failure in drainage network A. Mix run-off water with sewage network A. Lack of metropolitan green open space B. Disruption in transportation and economic network B. Occupation in flood-prone areas C. Loss of Valuable Water Resources D. Lack of integrated emergency response A. Blue and green corridors A. Separate rainwater from sewage B. Controlled floods B. Enhance groundwater recharge C. Build more capacity for water E. Flood preparedness
District of Piura system in specific location	A. Informal expansions towards wetlands B. Industrial pollution and spatial segregation B. Scattered semi-formal and informal activities C. Lack of green and recreational areas A. Limit informal settlements towards wetlands B. Increase social permeability B.Relocate industrial activities B. Designated spaces for semi-formal and informal activities C. Develop recreational areas	A. Failure in local drainage systems A. Failure in local sewage systems B. Damage to community facilities and infrastructure B. Local transoportation disruptions B. Residential zones in flood-prone areas C. Loss of Valuable Water Resources D. No evacuation routes and safe zones A. Blue and green corridors A. Implement systems to separate rainwater from sewage B. Controlled floods B. Enhance groundwater recharge C. Water-retention parks D. Safety Areas
Street design	B. Inadequate accessibility in street design B. Safety concerns from mixed transportation modes C. Poorly designed public spaces B. Improve street-level accessibility B. Foster community participation C. Delimitate flows of transport C. Improve public spaces	A. Poorly Designed Street Drainage B. Flooded streetsB. Deterioiration in housing infrastructure B. Accessibility issues C. Impermeability of pavement C. Evapotranspiration D. Safety areas and evacuation routes A. Blue and green corridors A. Green infrastructure B. Enhance soil permeability B. Erosion B. Reduce surface runoff C. Balance evotranspiration C. Build more capacity for water D. Safety areas

Aftermaths

Current main vulnerabilities:
A. Stagnet water
B. Health risks (Dengue)
C. Damage in infrastructure
D. No plans of recovery

Main proposal:
A. Water management (retention and storage)
B. Flow of water and vegetation
C.D Maitenance and recovery
D. Temporal spaces

A. Stagnet water
B. Health risks
C. Transportation and economic activities disruptions
C. Damage in infrastructure
D. No plans for response or recovery plans
A. Water management (retention and storage)
B. Water quality
B. Minimize the mix of sewage and run-off water
C. Quick recovery
C.D. Ensure needed services
D. Temporal spaces in blue and green corridors

A. Stagnet water
B. Health risks
C. Soil erosion
C. Transportation and economic disruptions
C. Damage in infrastructure
C. Blockage
D. No plans for response or recovery plans
A. Transitional spaces on a district scale
A. Stagnet water
A. Water management (retention and storage)
B. Water quality
B. Minimize the mix of sewage and run-off water
C.D. Ensure needed services
C.D Relieve blockage in the corridors
D. Temporal spaces in blue and green corridors
D. Meeting and collection points

A. Evapotranspiration
C. Blockage of streets
C. Accessibility issues
D. No plans for response or recovery plans
A. Green infrastructure
A. Retain and store
B. Enhance soil permeability
B. Balance evotranspiration
C.D. Temporal spaces in blue and green corridors
C.D Relieve blockage in the corridors

Droughts

Current main vulnerabilities:
A. Lack of water accessibility
B. Urban heat island effect
C. Water demand from crops
D. Health risk

Main proposal:
A.C Water management
A. Water accesability
B. D. Cooling spaces

A. Lack of accessability for water
B. Urban heat island effect
C. Water demand from crops
D. Health risk
A. Water recycling
A. Water management
B.D Accesability to water
C. Wind corredors

A. C.D Water shortage
B. High sensation temperature in the streets
B. Lack of wind circulation
B. Prone to erosion
A. Use stored water
A.B. Water Pumps
C. Exposed water
C. Wind flow
C. Shadowed spaces
A. C. Use of vegetation

A.C. D. Water shortage
B. Lack of wind circulation
B. Materiality
B.D. High sensation temperature in the streets
A.C. Use Stored Water
B.D Shadowed spaces
B.D. Wind Flow
B. Materiality

3. Process and implementation

3.1 Gaps and hinders in current plans

Its important to situate the project within the reality of the implementation projects in the north of Peru. How does the proposal comes along with the current program of Disaster Risk Management (DRM) establishes the State's obligation to build a national security and defense system to protect the population against disasters, provide appropriate and timely assistance, as well as ensure reconstruction after disasters and conflicts. The DRM plans goes from the national, regional, province and local scale. This section examines current plans and identifies gaps where the current proposed project can come along. The selected documents include the 'PLANEGERD 2023-2025', the 'Piura Region Disaster Risk Prevention and Reduction Plan 2023-2025', and the 'Piura Province Disaster Risk Prevention and Reduction Plan 2023-2025'. These documents were selected for their validity and importance in reducing Piura's vulnerability to El Niño events, as well as for providing a policy framework for actions, strategies, and future projects. In addition, previous documents were included to understand the progress in the implementation of their objectives and strategies.

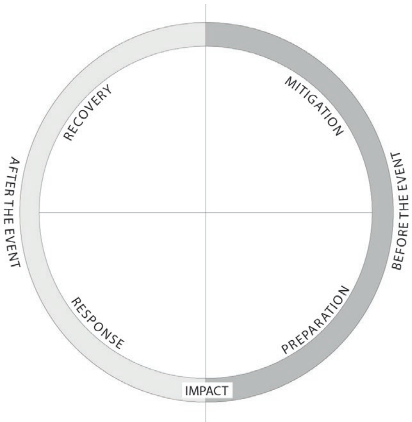


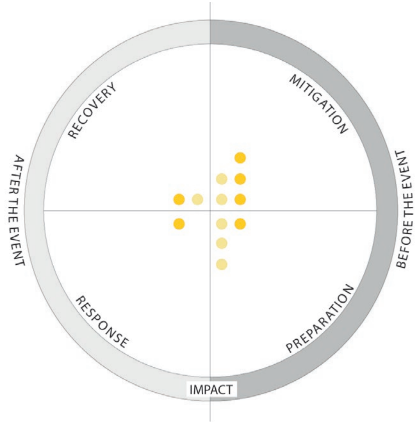
Figure: Disaster cycle
Adapted from Alexander, D. 2002

In order to better understand the scope of the plans, the analysis is accompanied by five key questions: who, when, where, why and what. In the 'who' category, the actors involved in the plans are examined, including the entity in charge of implementing the plans and projects, financing sources, and plan authors. In the 'when' category, the starting year and final goal of the plan, implementation status, monitoring indicators, and project phases are analyzed. In the 'where' category, the scale of the project, whether it is national, regional, or local, and the area of impact are considered. In the 'why' category, the general and specific objectives of the plan are identified. Finally, the 'what' category addresses the DRM cycle, divided between mitigative, preparedness, response and recovery.

Diving into the 'what' category: Firstly, it seeks to determine the focus of the proposed plans within the DRM cycle—whether they are predominantly oriented towards pre-disaster or post-disaster approaches. Secondly, it evaluates the actual implementation of the proposed plans; specifically, whether the projects have been executed or have merely remained on paper. The latter aspect is corroborated by cross-referencing previous documents, along with data provided by the National Institute of Civil Defense (INDECI), news sources, and reports, to ascertain whether the plans were implemented and to identify any instances of failure in their execution

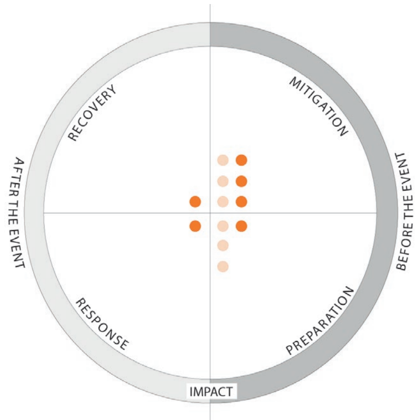
It is important to acknowledge certain limitations in this analysis.. Firstly, the availability and comprehensiveness of data in the selected policy documents may vary, which could affect the depth of analysis. Additionally, relying on secondary data sources may introduce inherent limitations in data accuracy and completeness. However, despite these limitations, this brief analysis aim to understand how the current project can fit into current policy plans.

There are seven phases that encompass the implementation cycle and the responsible entities involved in DRM. These phases include pre-disaster preparedness, post-disaster response, rehabilitation, reconstruction, assessment, prevention, and reduction (JICA, 2014). However, for the purpose of this analysis, the theoretical framework of the Principles of Emergency Planning and Management developed by David Alexander (2002) is used, due to its approach and pertinence from the El Niño contexts in Piura. According to this approach, disasters are considered repetitive events that follow a cycle, and DRM is divided into two parts: the pre-disaster phase and post-disaster phase. These consist of four phases: mitigation, preparedness, response, and recovery (Alexander, 2002).



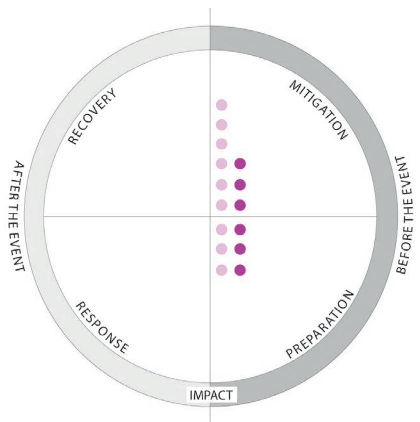
National Plan Objectives 2014-2021
National Plan Objectives 2022-2030

Figure 2. National Objectives of the plans within the disaster cycle



Piura's Regional Plan Objectives 2020-2022
Piura's Regional Plan Objectives 2023-2025

Figure 3: Regional objectives of the plans within the disaster cycle



Piura's Local Plan Objectives 2017-2021
Piura's Local Plan Objectives 2023-2025

Figure 4: Local objectives of the plans within the disaster cycle

Regarding the theoretical aim of the three level plans, most of the efforts are focused on the pre-disaster phase, with the objectives responding to mitigation and preparation efforts (see figure 5). The previous and current national plan has three times more proposals in the pre-disaster phase than in the post-disaster. Similarly, the regional plan has ten proposals in the pre-disaster phase versus only two in the post-disaster. Lastly, the local plan has fifteen proposals for the pre-disaster phase and none in the post-disaster. The sum-up of the previous and the current objectives are thirty-four in the pre-disaster phase and five in the post-disaster phase. The reason of this radical contrast is still to be determined despite Sendai Framework regarding all four phases (mitigation, preparation, recovery and response) as highly important.

As can also be seen in the analysis chapter, there is a significant gap between theoretical proposals and their implementation (see figure 6). Approximately, less than 25% of the objectives have been implemented. The reasons for the hindering of the project's implementation varies widely. Firstly, one of the reasons could be due to the short-term political benefits in the local government. For example, elected authorities often prioritize short-term investments for high-visibility outcomes, which can lead to neglecting DRM regulations in order to gain political support. In other words, regional and local authorities ignore taking measures to protect and restore illegal occupied areas, due to unorganized urban growth, and instead grant property certificated in order to seek political and electoral benefits. (French et al., 2020, & Defensoría del Pueblo, 2018). Similarly, many short-term projects are undertaken to address flood problems when the political term is coming to an end, merely to showcase projects that in reality do not mitigate the real problem.

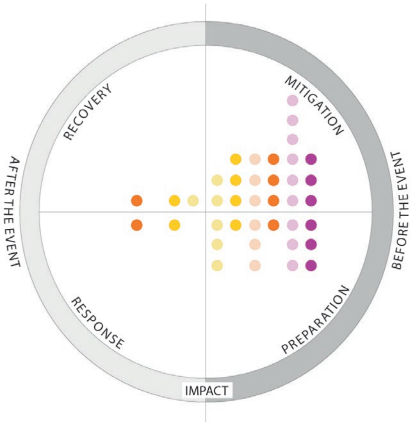
Secondly, another reason for the gap between the proposed plans and their implementation can be the lack of cooperation and intersectoral coordination between governments levels and sectors (French et al., 2020). In the Peruvian government, there are several ministries with independent bureaucratic structures that often have overlapping policies and responsibilities, without clear processes for integration or prioritization, resulting in institutional inefficiencies. This lack of coordination hinders collaboration between sectors, which is crucial for carrying out DRM activities. For example, while the National Water Authority is responsible for delimiting protection zones around water bodies, which are high-risk areas, the responsibility for landscape-level planning and zoning is divided between the Ministry of Environment and the Ministry of Housing. However, the Ministry of Environment is in charge of ecological and economic zoning, in collaboration with regional governments, while the Ministry of Housing focuses on urban development. Furthermore, these zoning processes are disjointed and only partially implemented at the national level (Venkateswaran, MacClune, & Enriquez, 2017, & Defensoría del Pueblo, 2018). Another example is that implementation is done to a certain extent, such as monitoring in the prevention phase. In other words, these measures must be supported by other sectors, such as communication mechanisms, education, and prevention plan to function effectively as a whole. The effective execution of these plans remains a long-term challenge, as the government has struggled to even meet the most basic needs of displaced individuals.

Thirdly, the gap may be because of the high levels of centralization (French et al., 2020). In Peru, administrative authority and fiscal resources are heavily concentrated at the national level, making decentralization and effective implementation of DRM policies challenging at local levels. There is a disconnect between the existing legislative and institutional structure and the lack of autonomy and capacities at the subnational levels. Additionally, there is a lack of financial and technical support, as well as limited power and shared resources at the regional and local levels. Therefore, it is necessary to work on building strong and effective institutions at the subnational level to enhance DRM in the country (Venkateswaran, MacClune, & Enriquez, 2017, & Defensoría del Pueblo, 2018). Lastly, it should be noted that at the national and regional levels, plans have a more structured approach with specific actions and indicators. However, at the provincial level, there are fewer monitoring of the implementation cycle and specific activities due to the lack of technical capacity and lack of empowerment at the local level.

The lack of implementation and the limitation in the response and rehabilitation phase is evident in the ongoing impact of El Niño 2023. Therefore, it is important to shift our thinking about DRM. Instead of treating it as a short-term response to individual emergencies, we should consider it as a long-term effort with lasting social benefits. To achieve this change, it is necessary to more fully integrate DRM activities into the national development agenda and to take these considerations into account in the daily decisions of policymakers and residents.

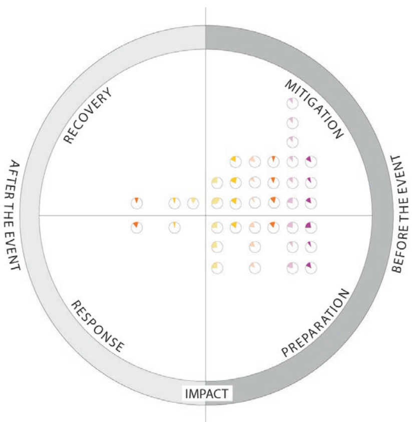
It is necessary to understand the country's reality and the constant obstacles faced during the pre-disaster phase implementation, and equal importance should be given to the strategies in the post-disaster cycle. In that regard, the response and rehabilitation phase should be planned despite reflecting shorter-term interventions. Sufficient time is needed to gather and analyze information, and having adequate information is essential for making efficient decisions during an emergency and learning from past experiences. Over time, short-term emergency planning has become more systematic and technological, and unlike "developed" countries that have access to advanced technology and communication to help in disaster prevention, in "underdeveloped" countries the challenge is ongoing, despite the investments made (Alexander, 2002).

After a disaster, there is an opportunity to increase public awareness of risks, demand for safety measures, and long-term planning. It is during this time that response and rehabilitation strategies are crucial and therefore, seize this window of opportunity for planning because over time, political interest and support decline. Particularly, it should be considered that proposals encompassing the rehabilitation phase towards mitigation, which are characterized by being long-term projects, require constant effort and continuous improvements to maintain vigilance and reduce risks in the future (Alexander, 2002). When a disaster occurs and normal institutions cannot adequately cope, a shift in how society responds is needed. It is important to strengthen existing organizations and utilize resources efficiently. Additionally, long-term planning is necessary, considering both the stages of response and rehabilitation, as well as preparedness and mitigation. In the case of Peru, more comprehensive measures need to be taken to reduce long-term risks and vulnerabilities.



- National Plan Objectives 2014-2021
- National Plan Objectives 2022-2030
- Piura's Regional Plan Objectives 2020-2022
- Piura's Regional Plan Objectives 2023-2025
- Piura's Local Plan Objectives 2017-2021
- Piura's Local Plan Objectives 2023-2025

Figure 5: Objectives of the plans within the disaster cycle



- 0% implemented
- 100% implemented
- National Plan Objectives 2014-2021
- National Plan Objectives 2022-2030
- Piura's Regional Plan Objectives 2020-2022
- Piura's Regional Plan Objectives 2023-2025
- Piura's Local Plan Objectives 2017-2021
- Piura's Local Plan Objectives 2023-2025

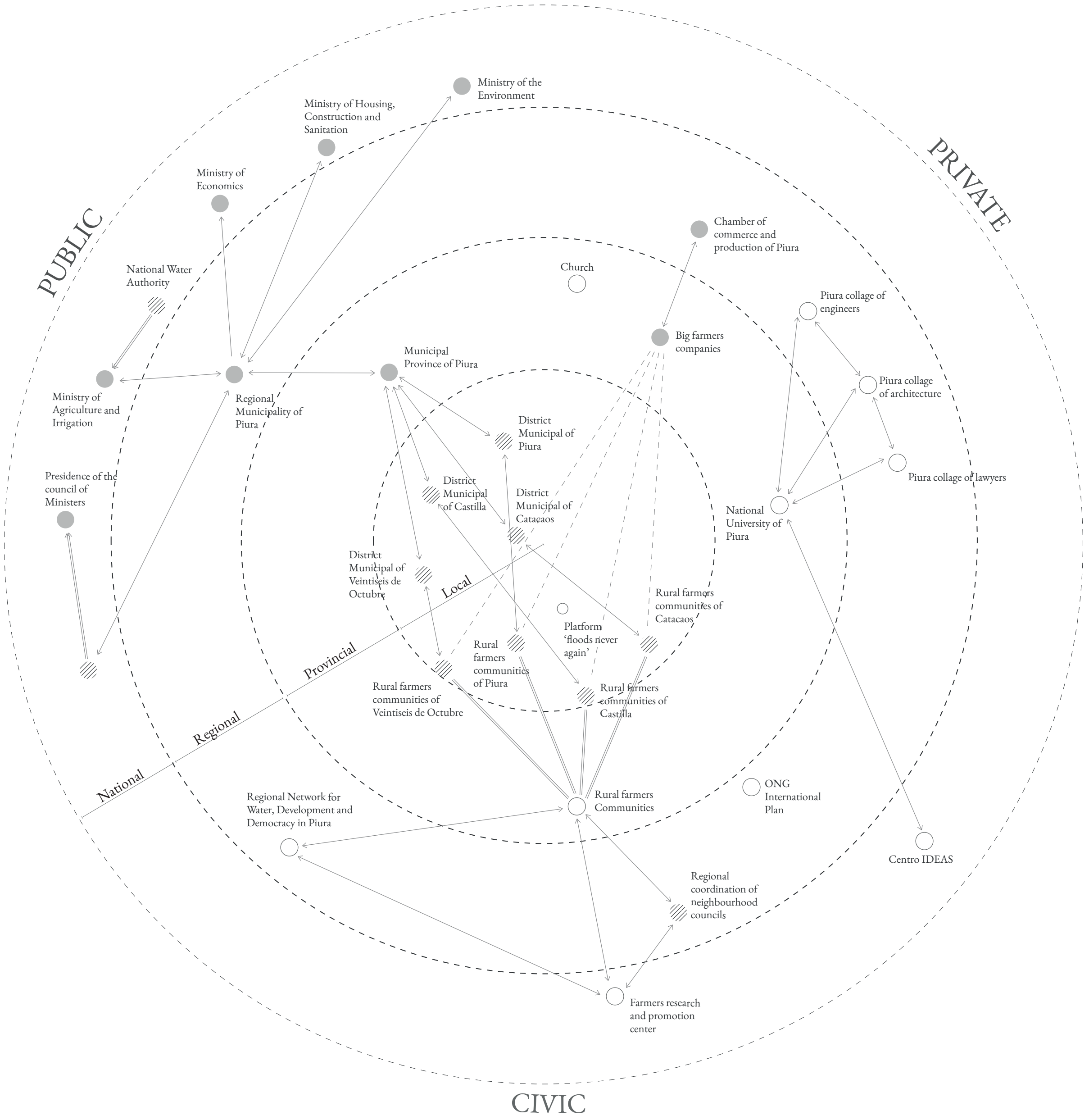
Figure 6: Implementation of the objectives from the plans

3.1 Mapping actors

The analysis of mapping actors within the project spans across public, private, and civic spheres, and extends from national to local scales. At the public and national level, key actors include the Ministry of Agriculture and Irrigation, National Water Authority, Ministry of Economics, Ministry of Housing, Construction and Sanitation, Ministry of the Environment, and the Presidency of the Council of Ministers. Regionally, the Regional Municipality of Piura is involved, while at the provincial level, it is the Municipal Province of Piura. Locally, the District Municipalities of Veintiséis de Octubre, Castilla, Piura, and Catacaos are significant.

In the civic sphere at the national level, the Farmers Research and Promotion Center plays a role. Regionally, the Regional Network for Water, Development, and Democracy in Piura, the Regional Coordination of Neighborhood Councils, and ONG International Plan are important. Provincially, the Rural Farmers Communities are key actors, while locally, the Rural Farmers Communities of Piura, Castilla, and Catacaos, along with the Platform 'Floods Never Again', are significant.
In the private sector at the regional level, the Chamber of Commerce and Production of Piura, Piura College of Engineers, Piura College of Architects, Piura College of Lawyers, and Centro Ideas are involved. At the provincial level, important actors include the National University of Piura and large farming companies.

The graphic analysis illustrates the relationships, collaboration, conflicts, and coexistence among the different actors, as well as their influence on decisions. Another graphic highlights the power and interest dynamics within these actors.



Stakeholders analysis

Relations:

Collaboration

Conflict

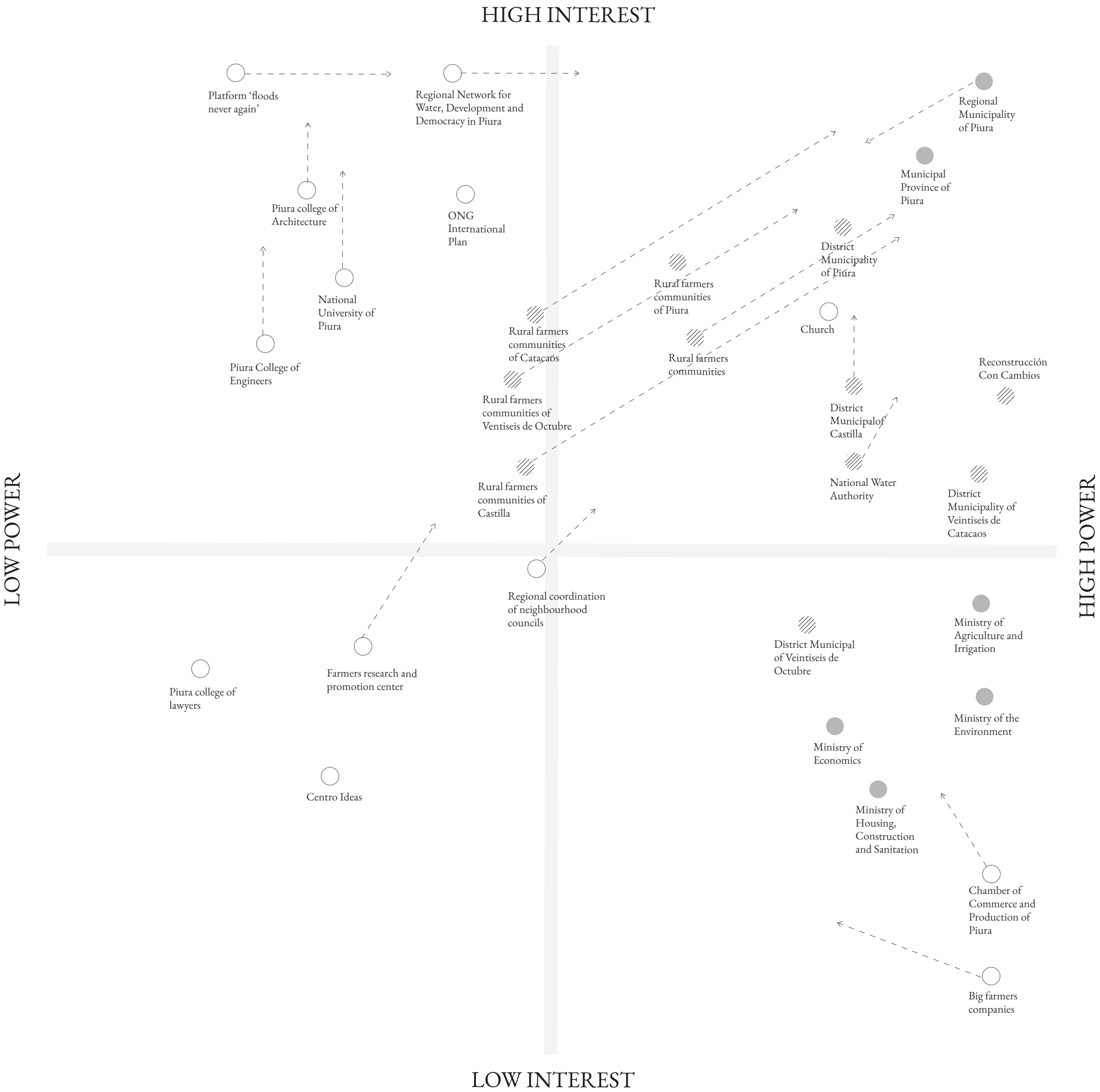
Co-exist

Influence on decision:

High

Medium

Low

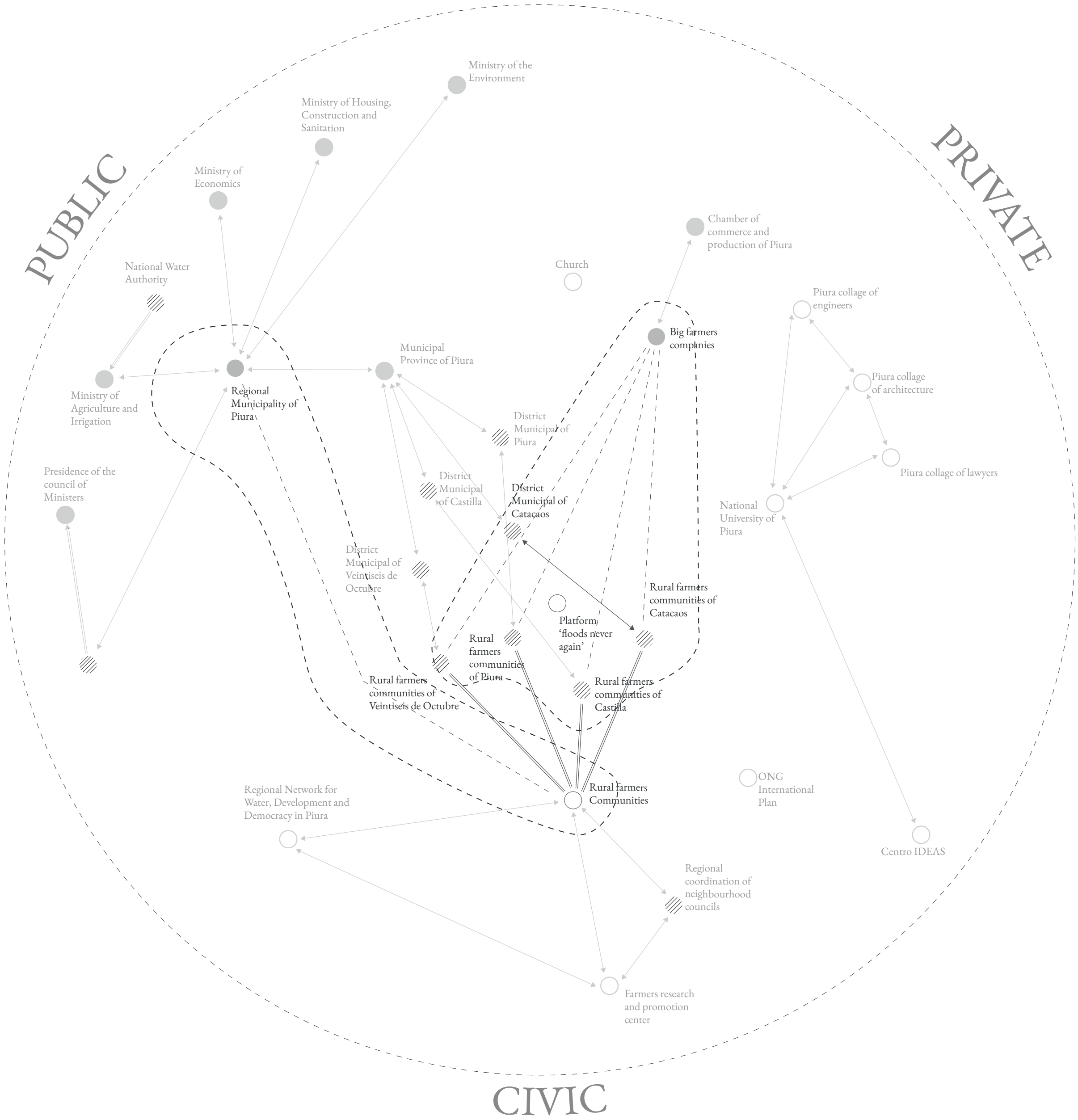


Power and interest

- – – – Tendency

Influence on decision

- High
- Medium
- Low



Conflict between stakeholders

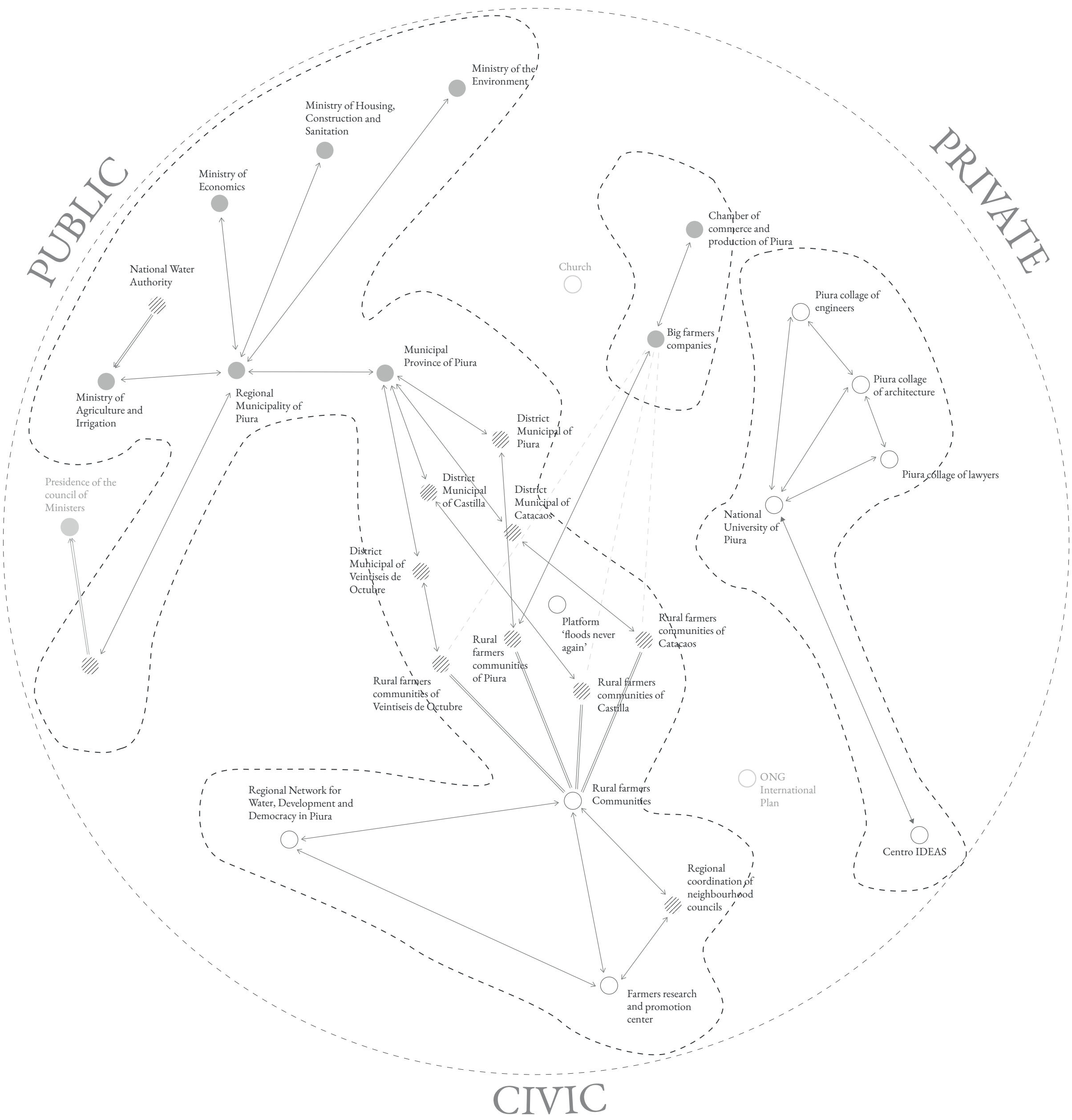
Conflict

Influence on decision

High

Medium

Low



Collaboration between stakeholders

Collaboration

Influence on decision

High

Medium

Low

3.2 Project timeline

The proposal is structured into multiple phases across different scales, with each phase featuring progressive design development, reinforced policies, and involvement from various actors.

City Scale Implementation:

The design for Phase 1 involves significant earthmoving to create a contrast between high and low topography by exaggerating depressions. Key streets will be transformed based on their location and current use, including Av. 2, Av. Raul Mata la Cruz, Av. Marcavelica, Av. Cesar Vallejo, Av. Guillermo G, Av. Sullana, Av. Luis Montero, Av. Curumuy, Av. Andres Avelino Caceres, and Av. San Jose María Escrivá Balaguer. Additionally, a new street or corridor will be constructed in the Castilla district. Policies during this phase will enforce the protection of the dry forest, implement zoning regulations for flood-prone areas, and delimit housing occupation zones. Regional and municipal authorities, specifically designated departments responsible for heavy machinery, will oversee this phase. A detailed schedule will be provided, along with community consultations and public feedback sessions to ensure community involvement.

In Phase 2, the design will focus on covering soil in water retention areas with clay from the river margin to create semi-permeable surfaces, stabilizing slopes using local vegetation and rocks, and integrating urban equipment in the peripheries of parks for adjacent districts. Key streets to be transformed include Av. Juan Velasco Alvarado, Av. Grau, Av. Las Americas, Av. Algarrobo, Av. Integradora, Av. Los Diamantes, Av. Circumvalación, Av. Independencia, Av. Ramon Castilla, Av. Jorge Chavez, and Av. Sanches Carrion. Policies will delimit zoning areas within the park for temporary uses and safety during El Niño events and their aftermath, adapt crop usage to match water availability, and implement community education programs on water conservation. This phase will involve regional and municipal authorities and organized civil society groups. Responsibilities will be clearly defined for each group, with specific milestones and deadlines set for each task. Workshops and surveys will be conducted to gather input from local communities.

The design in Phase 3 will focus on capturing water through designated blue corridors and storing it in low-depression areas. Policies will aim to protect local flora and fauna in affected areas and develop emergency response plans, safety areas, and evacuation routes. Regional and municipal authorities will oversee this phase, with roles assigned to relevant departments and agencies. Clear timelines for water capture and storage activities will be established, and regular meetings with stakeholders will be held to review progress and adjust plans as needed. Risk management strategies will be put in place to mitigate potential risks associated with water capture and storage.

In the final phase, the design will involve maintaining soil and vegetation post-El Niño events and clearing blockages from runoff water. Policies will establish regular maintenance schedules and systems for monitoring and evaluating the effectiveness of measures and policies. Regional and municipal authorities, particularly those responsible for heavy machinery, will handle this phase. Specific maintenance and monitoring duties will be assigned to appropriate departments, with routine maintenance and monitoring schedules put in place. Continuous input from the community and stakeholders will be sought for ongoing improvements. Contingency plans will be developed to address potential maintenance challenges, and a comprehensive framework for assessing the impact and success of each phase will be implemented.

Street scale implementation:

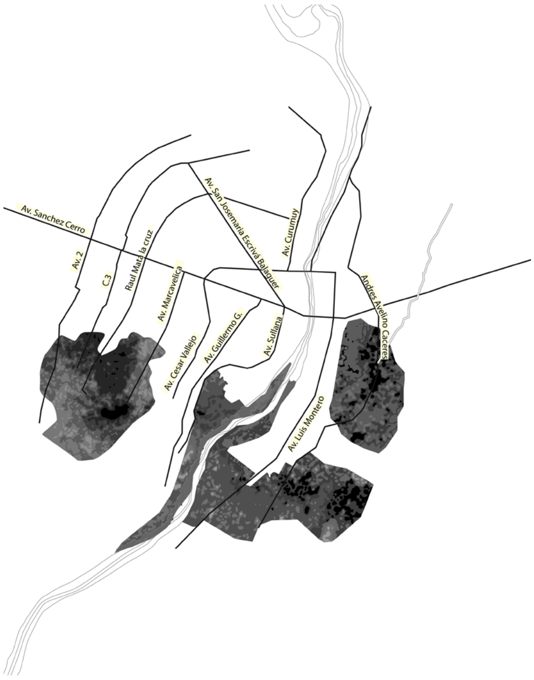
The design for Phase 1 involves delimiting new transit areas such as pedestrian sidewalks, cycle lanes, and vehicle roads, while removing earth from the center based on the groundwater table, with corridor depths varying from 1m to 2.5m. Existing trees and their roots will be preserved. Policies will focus on establishing transit delimitation to ensure the proper use of designated areas, along with community engagement through educational campaigns and workshops. Municipal authorities will be responsible for this phase.

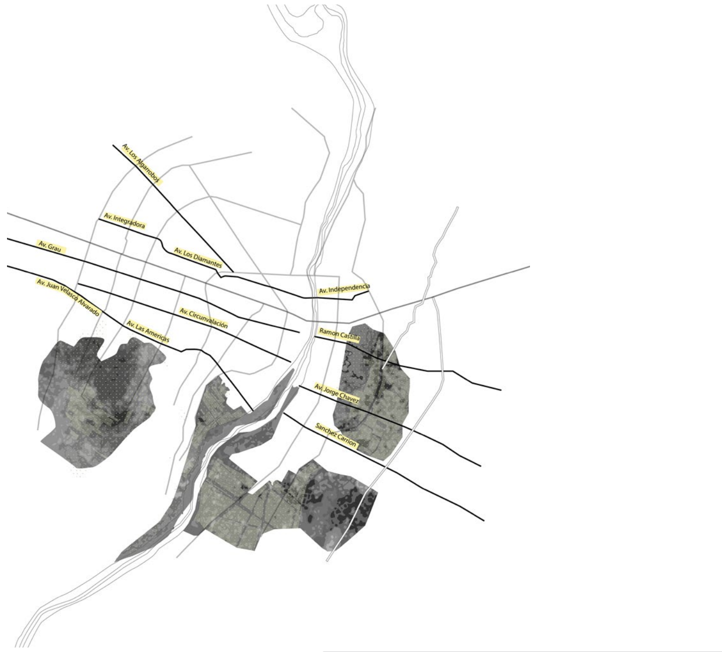
In Phase 2, excavation will be carried out according to the groundwater table, forming corridors and maintaining trees and their roots to create 'little islands' with different level recreational areas. Margins will be consolidated with local vegetation, rocks, and stones from the upper basin. Policies will promote the use of local vegetation compatible with water availability and implement erosion control measures to protect excavated areas and margins. This phase will involve organized civil society groups and municipal authorities.

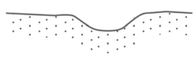
Phase 3 will facilitate community appropriation of the corridor space to suit local needs, allowing for flexible use and adaptation. Bridges will be built between the islands and pedestrian streets to enhance connectivity. Policies will implement participatory planning with communities to integrate their needs and preferences into the design, and ensure that bridges and pedestrian areas are accessible to everyone. Actors involved will include organized civil society groups, municipal authorities, and colleges of architects and engineers.

The design in Phase 4 will channel runoff water through corridors towards retention areas while promoting soil infiltration, and clear corridors of sediments and debris after floods. Policies will launch a water conservation and harvesting program, establish water storage solutions for each household or a central storage facility for the community, and implement a regular schedule for removing blockages from the corridors. Additionally, monitoring systems will be put in place. This phase will involve organized civil society groups, municipal authorities, and NGOs.

City scale implemention

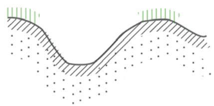






0. Current topography, soil predomenently sandy

1. Exagerate deppresions to make contrast between high and low topography.



2. Cover the soil with clay from the river margin to make it semi-permeable. Vegetation and rocks from upper basin for stabilization of slope

PHASE 1

Design:
- Earthmoving to exaggerate depressions and create contrast between high and low topography.
- Transformation of key streets based on location and current use: Av. 2, Av. Raul Mata la Cruz, Av. Marcavelica, Av. Cesar Vallejo, Av. Guillermo G, Av. Sullana, Av. Luis Montero, Av. Curumuy, Av. Andres Avelino Caceres, Av. San Jose María Escrivá Balaguer.
- Construction of a new street/corridor in the Castilla district.

Policies:
- Enforce protection of the dry forest.
- Implement zoning regulations for flood-prone areas.
- Delimit housing occupation zones.

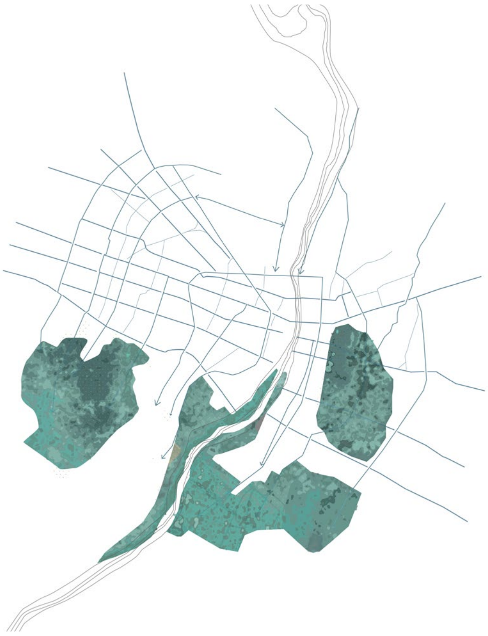
Actors involved:
- Regional and municipal authorities (due to the need for heavy machinery).

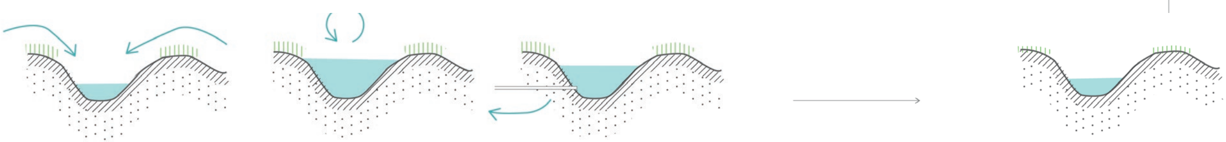
PHASE 2

Design:
- Cover soil in water retention areas with clay from the river margin to create semi-permeable surfaces.
- Stabilize slopes using local vegetation and rocks.
- Integrate urban equipment in the peripheries of parks for adjacent districts.
- Transformation of key streets: Av. Juan Velasco Alvarado, Av. Grau, Av. Las Americas, Av. Algarrobo, Av. Integradora, Av. Los Diamantes, Av. Circumvalación, Av. Independencia, Av. Ramon Castilla, Av. Jorge Chavez, Av. Sanches Carrion.

Policies:
- Delimit zoning areas within the park for temporary uses and safety during El Niño events and their aftermath.
- Adapt crop usage to match water availability.
- Implement community education programs on water conservation.

Actors involved:
- Regional and municipal authorities.
- Organized civil society groups.
- Rural farm communities





3. Capture water through the blue corridors

4. Store water (semi) permenently for further use

5. If necessary, use water.

6. Maintenance of soil and vegetation after each event

PHASE 3

Design:
- Capture water through designated blue corridors.
- Store water in low-depression areas.

Policies:
- Protect local flora and fauna in affected areas.
- Develop emergency response plans, safety areas, and evacuation routes.

Actors involved:
- Regional and municipal level

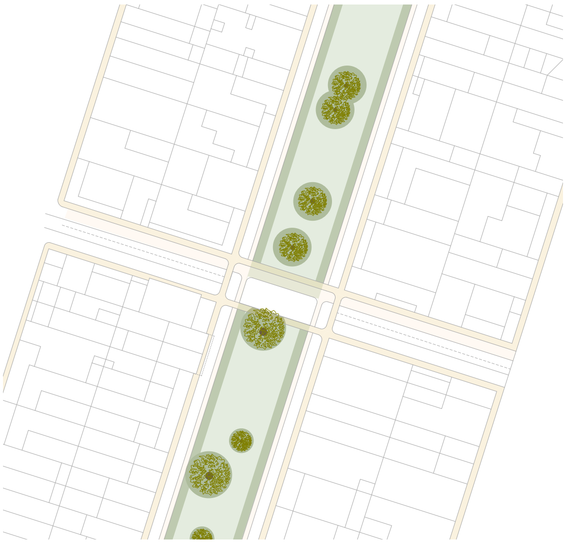
PHASE 4

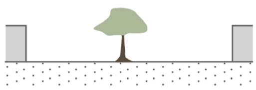
Design:
- Maintain soil and vegetation post-El Niño events.
- Clear blockages from runoff water.

Policies:
- Establish regular maintenance schedules.
- Implement systems for monitoring and evaluating the effectiveness of measures and policies.

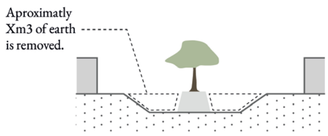
Actors involved:
- Regional and municipal level
- Organized civil society groups.

Street scale implemention

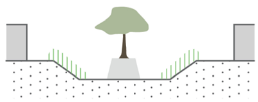




0. Current average street section, oversized space, soil predomenently sandy



1. Excavate depending on the water-ground table, forming corridors. Mantain the three and its roots (form like 'islands')



2. Consolidate margins with local vegetation, rock and stones from the upper basin

PHASE 1

Design:
- Delimit new transit areas such as pedestrian sidewalks, cycle lanes, and vehicle roads.
- Remove earth from the center. The depth is related to the groundwater table of the area, with the corridor depth varying from 1m to 2.5m.
- Preserve existing trees and their roots.

Policies:
- Establish transit delimitation to ensure the proper use of designated pedestrian, cycle, and vehicle areas.
- Community engagement through educational campaigns and workshops

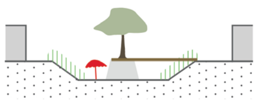
Actors involved:
- Municipal Authorities

PHASE 2

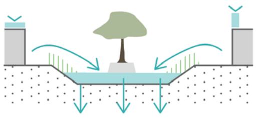
Design:
- Excavate according to the groundwater table, forming the corridors while maintaining trees and their roots, creating 'little islands' that provide different level recreational areas.
- Consolidate margins with local vegetation, rocks, and stones from the upper basin.

Policies:
- Use local vegetation compatible with the water availability in the area
- Implement erosion control measures to protect excavated areas and margins.

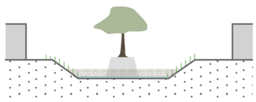
Actors involved:
- Organized civil society groups.
- Municipality Authorities



3. Appropriation of space by the community. Activities and connections (following regulations)



4. Channalize runoff water though corridors towards retention areas while infiltrating water into the soil. Capture water in buildings.



5. Clear corridor from the sediments and other things brought by the flood.

PHASE 3

Design:
- Facilitate community appropriation of the corridor space to suit local needs, allowing for flexible use and adaptation.
- Build bridges between the islands and the pedestrian streets to enhance connectivity

Policies:
- Implement participatory planning with communities to ensure their needs and preferences are integrated into the design.
- Ensure that bridges and pedestrian areas are accessible to everyone.

Actors involved:
- Organized civil society groups.
- Municipal authorities.
- Colleges of architects and engineers.

PHASE 4

Design:
- Channel runoff water through the corridors towards retention areas while promoting soil infiltration.
- Clear corridors of sediments and debris brought by floods after such events.

Policies:
- Launch a water conservation and harvesting program.
- Establish water storage solutions for each household or a central storage facility for the community.
- Implement a regular schedule for removing blockages from the corridors.
- Implement monitoring systems

Actors involved:
- Organized civil society groups.
- Municipal authorities.
- Non-Governmental Organizations (NGOs).

FOURHT PART

1. Reflection

The approach of this research aims to understand the intrinsic vulnerabilities of Piura through an evolutionary resilience framework, addressing water extremes and local realities. The design is tested across three scenarios: El Niño floods, droughts, and day-to-day life.

The propositional sub-questions focused on how to harmonize urban morphologies and geomorphologies to reduce Piura's social and ecological vulnerabilities, and to what extent the urban form can adapt through design re-management and space redistribution to enhance urban system flexibility. The third chapter of the second part of the report addresses these questions. It strategically identifies spaces that are flexible by design, examining which spaces within consolidated urban structures and local routines can be transformed to enhance Piura's overall resilience. By understanding the open space network and the city's flexibility, the chapter defines mediation spaces—areas that reconcile dissonance between climate patterns, substratums, occupations, and networks. Grounded in on-site conversations with residents and technical analysis, the chapter identifies what can be changed, what is permanent, persistent, removable, and necessary to add. These mediation spaces address how to manage floods caused by El Niño, droughts, the urban heat island effect, and everyday informal settings.

Another key propositional sub-question was how Piura can design just and equitable spaces that are evolutionarily resilient to extreme water events. The fourth chapter of the third part responds to this by presenting a design proposal that addresses different scenarios and scales. It considers day-to-day socio-ecological vulnerabilities, El Niño flood impacts, and drought challenges. The proposal spans multiple scales: at the basin scale, it recognizes the connection between the upper and lower basin during El Niño events; at the city scale, it highlights the city's function as a system and network; at the district scale, it provides an example of the spatial network; and at the street scale, it details design implementation. For each scenario and scale, exposures, vulnerabilities, and risks are identified based on previous mapping and analysis, corresponding to the proposed strategies.
The research also sought to understand how policy, governance structures, and socio-cultural factors in Piura influence community responses and adaptability to El Niño-induced water extremes. The fifth chapter of the third part addresses this question by exploring the implementation process, where different actors, including the public sector and communities, respond, build, and adapt to various scenarios.

The analytical part of the research aimed to answer why social, environmental, and economic vulnerabilities from El Niño water extremes are prevalent in Piura, what variables contribute to the cycle of disaster-flooding, and what historical urban development patterns influence these vulnerabilities. The second chapter of the first part addresses these questions by identifying the main problems of Piura: the risk of natural phenomena such as El Niño, underlying socio-political vulnerabilities, and the disconnection between inhabitants and their local environmental dynamics. This chapter deconstructs the socio-ecological patterns, contextualizes them within specific temporal and spatial frames, and analyzes their interrelations. It systematically identifies spatial variables interacting with natural and urban systems, categorized into four groups: substratum (soil, topography, hydrology, vegetation, and ecosystems), climate patterns (wind, precipitation, and temperature), network (transport, local economies, water infrastructure), and occupation (urban developments, state of consolidation, built form, land use, locations prone to flooding and heat).

Reflecting on the overall approach, it was effective in addressing Piura's vulnerabilities through a comprehensive understanding of socio-ecological dynamics and strategic design interventions. The integration of local knowledge with technical analysis provided nuanced, contextually appropriate solutions. The focus on adaptability and flexibility within urban design was crucial in addressing the identified vulnerabilities.

Feedback from mentors emphasized the importance of integrating local insights and technical rigor. This led to a more robust design framework, ensuring that proposed solutions were grounded in real-world contexts and scientific analysis. The feedback was incorporated by enhancing on-site research, increasing community engagement, and refining technical analyses. This iterative process improved the overall quality and relevance of the research and design proposals.
Through this process, I learned the value of a multi-scalar approach and the importance of flexible, responsive design. The integration of socio-ecological insights with urban design principles proved essential in developing effective resilience strategies for Piura. The experience highlighted the need for continuous learning and adaptation, both in methodology and practical application, to address complex urban challenges.

My graduation project examines the vulnerabilities faced by the city of Piura. The first vulnerability is external, stemming from natural processes, particularly the El Niño phenomenon. This recurring event causes extreme water conditions, alternating between floods and droughts. The second vulnerability is internal and deeply rooted in Piura's society, characterized by limited accessibility, government neglect, informal economies, and social inequality.

This project explores the interplay between these vulnerabilities through the lens of urban and natural morphologies. Currently, there is a dissonance between these two factors, perpetuating a cycle of disasters in Piura. The concept of 'Altered Nature', which forms the core of this study, investigates how urban and natural processes mutually transform the landscape.

Each El Niño event brings significant destruction to the city of Piura, leaving it struggling to recover. As the second-largest region in the country, Piura is home to over 2 million people who are directly affected by these events. Despite this, the city lacks a comprehensive plan that addresses its unique challenges within it's realities. This thesis project, with an internship at Blue Deal Peru under the Groningen Waterschap, provides a combination of academic research and practical on-site experience. This dual approach offers a deeper understanding of Piura's vulnerabilities and potential strategies for an evolutionary resilience process.

2. Project and scope limitation

The major challenge in this thesis is the limitation of information, as there is a significant lack of readily available data pertinent to the region of Piura. This poses a substantial challenge in accurately situating the project within the real-life context of Piura, particularly in understanding how to enhance the city's resilience to the effects of El Niño, while considering the on-ground realities such as informality. The existing gap in obtaining updated and comprehensive information online, especially regarding specific aspects of Piura's urban and environmental dynamics, necessitates a more hands-on approach. Consequently, an on-site visit becomes essential to gather detailed observations and insights. Through photography, videography, and detailed drawings, it's possible to document the current state of the region, thereby enriching the research and providing a solid foundation for the thesis project.

Regarding the project's capacity to manage flooding, it can handle pluvial (rainfall) floods effectively. However, for fluvial (river) floods, the project requires additional capacity. Therefore, it is important to note that the proposed project must be complemented by upstream interventions to manage river overflow before it reaches the city. (See in annex the calculations)

3. Conclusions

The project strategies extend beyond just bouncing back from El Niño events. They proactively seek to enhance accessibility to social and economic activities, fostering new opportunities. They aim to provide equal access to water infrastructure for Piura's residents, reinforce self-organization capacities and restrict urban expansion into flood-prone areas to minimize exposure. These strategies manifest in spatial actions, such as creating collective public spaces for gatherings, temporarily designating public use in hazard areas and adding value to the dry desert through access routes to limit urban expansions, connecting and expanding drainage and sewage networks in areas in need and proposing new uses in areas lacking accessibility to social and economic activities.

Simultaneously, the project strategies address water extremes by enhancing flood resilience during El Niño and minimizing desertification impacts during droughts. This actions spatially involves implementing water retention spaces in low-lying areas for El Niño rainfalls, applying delayed water systems in critical areas to slow down the water flow, using vegetation systems for water recycling and reuse, draining water through re-vegetation, increasing permeability through de-paving or land-use changes, facilitating rapid water discharge during heavy rainfall with integrated grey, blue, and green infrastructure, preventing soil erosion by identifying erosion hotspots de re-vegetating and using local vegetation species resistant to droughts to boost biodiversity.

All these strategies are supported by the strategy of increasing urban system flexibility. This spatially involves transforming the use of identified 'persistent' areas, proposing new uses for 'subtraction' qualified spaces, and implementing the previous spatial strategies within identified urban system flexible spaces.

4. Ethical paragraph

In conducting this thesis, it is imperative to approach the research with a high level of ethical consideration. Central to this is the respect for the community of Piura, particularly when documenting informal urban areas and environmental challenges. Any data collected, especially through photographs, videos, and drawings, will be gathered with the utmost sensitivity to the privacy and dignity of the local inhabitants. Prior consent will be sought wherever necessary, and all information will be used solely for academic purposes, ensuring confidentiality and anonymity where required.

Moreover, this research recognizes the ethical responsibility to portray the situation in Piura accurately and without bias. It aims to reflect the realities of urban expansion, environmental degradation, and local resilience strategies without amplifying vulnerabilities or stigmatizing the community. The analysis and conclusions drawn will aim to contribute constructively to the discourse on urban resilience and environmental management, especially in the context of El Niño. By adhering to these ethical principles, this thesis not only respects the rights and dignity of the subjects involved but also contributes to a body of knowledge that is grounded in ethical research practices.

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6. Annex

Calculations for the capacity of the project regarding the pluvial floods:
Area and Inflow Volume Calculations:

Total Area of Main Catchment Basins:
- Combined area: 1,345,580 square meters

Total Area of Additional Catchment Areas:
- Combined area: 25,730,000 square meters

Total Area of All Catchment Areas:
- Combined area: 27,075,580 square meters

Inflow Volume for All Catchment Areas:

- inflow Volume: Inflow Volume=Total Area×Rainfall Depth×Runoff Coefficient\Inflow Volume = 27,075,580m2×3.288m×0.45≈40,061,028cubic meters

Comparison with Storage Capacity:

Total Storage Capacity of All Catchment Areas: 79,881,160 cubic meters
- Total Inflow Volume from Rainfall: 40,061,028 cubic meters

Conclusion:
The combined storage capacity of all the catchment areas (approximately 79.88 million cubic meters) is sufficient to handle the inflow volume from the rainfall during an El Niño event similar to 2017 (approximately 40.06 million cubic meters). This indicates that the proposed catchment areas should be adequate for mitigating rainfall-related flooding in the city of Piura during such extreme weather events.

Calculations for the capacity of the project regarding the fluvial floods:

Calculation Results:

Total Inflow Volume from the River During Peak Flow Event:
Total Inflow Volume=500 m3/s×72 hours×3600 seconds/hour\Total Inflow Volume = 500m3/s×72hours×3600seconds/hour

Total Inflow Volume=129,600,000 cubic meters\Total Inflow Volume = 129,600,000cubic meters

Total Existing Storage Capacity:
79,881,160 cubic meters

Additional Capacity Needed:
- Additional Capacity Needed=Total Inflow Volume−Total Existing Storage Capacity\Additional Capacity Needed= 49,718,840cubic meters

Conclusion:
The project would need an additional capacity of approximately 49,718,840 cubic meters to handle the peak river inflow during a severe flood event like the hypothetical one described.