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Municipalidad Provincial de Piura
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CITY LAB PIURA, PERU

CLIMATE RISK AND RESILIENCE ASSESSMENT

FULL VERSION AND RESULTS

MORGENSTADT GLOBAL SMART CITIES INITIATIVE
GLOBAL APPROACH – LOCAL SOLUTIONS

Morgenstadt
City of the Future

On behalf of
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

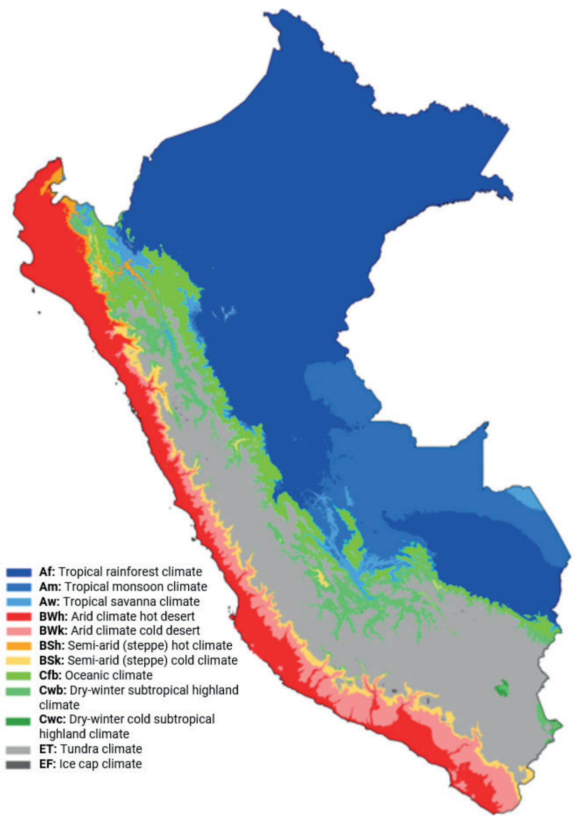
CONTENTS

1. INTRODUCTION

The climate crisis is already affecting most of the countries in the world, urging public entities, companies, civil organizations, indigenous peoples, and citizens to plan and implement locally attuned mitigation and adaptation actions. Together with urbanization, it represents two of the main challenges of global change in the 21st century. Both phenomena are characterized by a multitude of complex, interconnected, and sometimes mutually reinforcing processes. In a special report 2018, the Intergovernmental Panel on Climate Change (IPCC) predicts and outlines the effects of global warming of 1.5 degrees and beyond, which implies many risks both for humans and wildlife on Earth. Rising temperatures are exacerbating all types of climate catastrophes, such as storms, heat waves, floods, and droughts. Warming temperatures change weather patterns causing humid areas to become wetter and arid areas to become drier. For instance, water demand could increase by 55 percent by 2050, further increasing the already existing pressure on this resource. Cities will be particularly affected as they will lack two-thirds of the water that is still available today (Alley et al., 2018). Latin America and the Caribbean (LAC) has been identified as one of the regions most affected by extreme hydrometeorological phenomena because of its geographic conditions and features, such as the Andean Mountains.

Peru is considered one of the most vulnerable countries to the effects of climate change due to its exposure, sensitivity, and adaptive capacity to climate change impacts. The country is thereby especially prone to natural phenomena, floods, droughts, landslides, frosts, glacial melting, amongst others. These may be enhanced by inadequate sociocultural practices attributed to deforestation in the Amazon caused by land-use change, migratory agriculture, livestock, urban development, as well as mining and oil exploitation. Moreover, the particular configuration of the Peruvian topography, such as the presence of the Andes Mountains and the Pacific currents, generates a diversity of climates and microclimates, which are reflected along the desert coast, the Puna, or the tropical jungle of the Amazon basin (Figure 1), concurring in the territory a great variety of natural resources. To face these challenges the country seeks to reduce its vulnerability to the effects of climate change, take advantage of low-carbon development opportunities and comply with the international commitments assumed by the state before the United Nations Framework Convention on Climate Change (UNFCCC). This commitment is reflected in the National Climate Change Strategy (in Spanish Estrategia Nacional ante el Cambio Climático ENCC), in which national actions related to climate change are oriented and promoted, providing the necessary guidelines for the sectors, regions, and public institutions, in general, to implement it through their action plans. (PODER LEGISLATIVO PERU, 2018).

FIGURE 1: KÖPPEN–GEIGER CLIMATE CLASSIFICATION MAP FOR PERU; SOURCE: LUCIONI (2018)



The northern region of Peru, where the city of Piura is located, is strongly affected by global warming, causing severe storms, increased droughts, hotter temperatures, changes in agriculture, poverty and displacements, and health risk. However, the impacts of climate change are dominating this region are the ones related to the ENOS (El Niño–Southern Oscillation) cycle, an irregular, seasonal fluctuation of winds and sea surface temperatures over the eastern tropical Pacific Ocean, affecting climate in two opposing phases: El Niño Phenomenon (FEN) in the case of an increase in sea temperature, and La Niña Phenomenon in the case of a decrease in sea temperature.

The city of Piura is the capital of the province of Piura and the region of the same name and comprises four districts: Piura, Castilla, Veintiseís de Octubre, and Catacaos . Its territory is generally flat, with a mostly dry and warm climate, with temperatures between 17.1°C in winter and 34.1°C in the summer months. In normal conditions it rains with greater intensity in the month of March reaching 65.5 mm/month (Autoridad Autónoma de la Cuenca Hidrográfica Chira Piura (AACHCP), 2005) .In the Piura region, there are three hydrographic basins, the Huancabamba river basin, the Chira river basin, and the Piura river basin. The city of Piura is located in the Piura River basin, whose origin is where the Huarmaca River is born, in the district of Huarmaca and Province of Huancabamba. When this river joins the Bigote River, it changes its name to the Piura River (Ministerio de Medio Ambiente PERU, 2016) It has a total length of 280 km and flows through the city of Piura, separating the districts of Piura and 26 de Octubre from the district of Castilla. There are 3 different zones in the Piura river basin (Ministerio de Vivienda, 2020) :

> Upper basin, the territory upstream from the town of Serrán .
> Middle basin from Los Ejidos dam (city of Piura) to Serrán.

> Lower basin, the plains from the city of Piura to the sea.

Normally, the Piura River is characterized by the low rainfall regime, resulting in low flows between 350 m3/s and no-flow periods. However, this situation changes dramatically during the FEN, with flows over 4,000 m³/s (Callañaupa Tocto, 2021), as in the mega events from 1983, 1998, and 2017. During these events, runoff and flow are significantly increased due to intensive rainfall - a situation that puts the city at risk of flooding.

Located in this geographical setting, the city of Piura has to cope with the different impacts of climate change. It is one of the pilot cities in the Morgenstadt Smart Cities Initiative (MGI). The initiative is an international development cooperation project funded by the German Environmental Ministry through the International Climate Initiative (IKI). It aims at inducing transformational change towards sustainable urban development in the partner cities Kochi (India), Saltillo (Mexico), and Piura (Peru), especially with regards to the mitigation and adaptation to climate change. To achieve this, a thorough analysis of the urban system, as well as the identification, and development of sustainable cross-sectoral solutions together with key local stakeholders has been conducted in each of the cities following the Morgenstadt City Lab approach (Morgenstadt Global Smart Cities Initiative 2020).

As a part of the City Lab Piura, a risk and vulnerability assessment for climate change impacts was carried out, including a literature review and an expert evaluation conducted by both local and City Lab experts. It focused on five risk clusters which were perceived as most critical for the city - namely 1) El Niño Phenomenon (FEN), 2) river overflow, heavy rainfall, and stormwater, 3) La Niña, water scarcity and drought, 4) temperature rise and urban heat islands, and 5) change in the biological system. It also assessed the adaptation measures that the city of Piura has already implemented to deal with these risks, as well as citizen perceptions of microclimate and public space. This report presents the applied assessment framework, the methods used, as well as the full analysis results. It ends by summarizing overarching insights and recommendations and by linking the assessed climate risks and vulnerabilities to the project ideas that have been developed within the City Lab process. Moreover, a set of indicators is suggested that can be used to evaluate the contributions such projects can have in building up a resilience towards the discussed climate risks.

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2. METHODS, FRAMEWORK AND DEFINITIONS

In the following chapter, the results of a climate change risk and resilience assessment for Piura are presented. Climate change impacts are thereby understood as the effects of extreme weather and climate-related events on human or natural systems, whereas risks are defined as potential consequences of hazardous events. Figure 2 summarizes the applied assessment framework.

The following factors are considered, in close accordance with the IPCC framework for identifying key risks and vulnerabilities (Oppenheimer et al., 2014)

Magnitude and intensity: Measure of how strong the impact and consequences will be.

Probability y frecuency: Measure how likely and often a hazard will occur.

Irreversibility y persistence: Measure how permanent the effects will be and if they can be reversed/corrected.

Exposure (temporal & spatial): Measure of how exposed a community or socio-ecological system is to climatic stressors and hazards at hand.

Susceptibility: Measure related to the individual preconditions that make communities or socio-ecological systems highly susceptible to additional climatic hazards or that reduce their adaptive capacity.

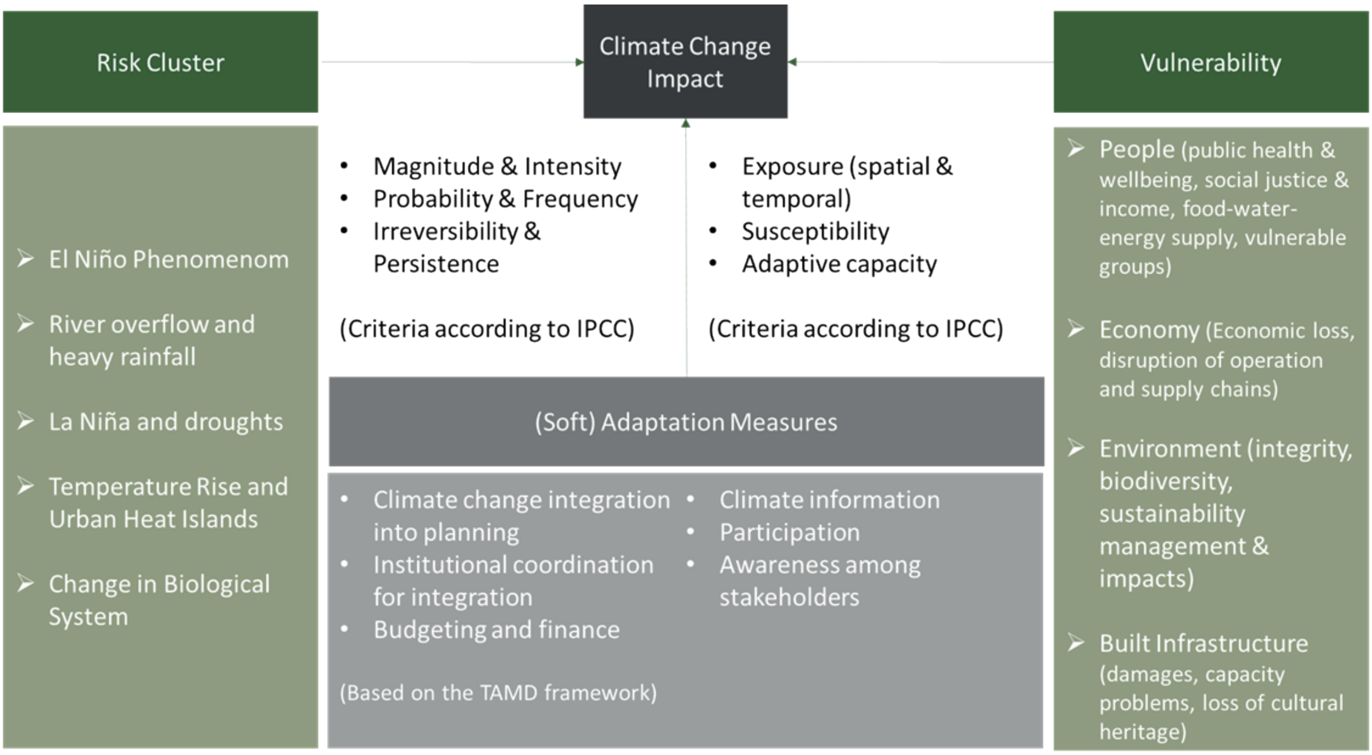
Adaptive capacity: Measure the ability of a system to adapt and respond to the risk at hand to avoid and moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Climate change adaptation (measures): Measure that "anticipates the adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise"(European Commission, 2020).

The first part of the assessment is organized according to five climate-related risk clusters and includes information from scientific evidence and forecasts, as well as results from an expert evaluation. The latter was conducted by fifteen local and city lab experts, to better incorporate local knowledge and on-site findings on risk clusters and vulnerabilities. A survey was used to capture and streamline the expert evaluation. For each risk cluster, the IPCC criteria for climate change impacts and the respective vulnerability of people, economy, environment, and built infrastructure were estimated and discussed. Chapter 3 summarizes the findings for each cluster.

In the second part, the Tracking Adaptation and Measuring Development (TAMD) framework, was used to summarize climate change adaptation measures taken by the city of Piura. The TAMD framework was developed by the International Institute for Environment and Development (IIED) to track adaptation and measure its impact on development and focusses on soft adaptation and governance measures (IIED, 2014). Relevant data for Piura was synthesized from the overall city lab assessment and related expert interviews, as well as initial document review and desktop research performed by the University of Piura. A list of survey participants, as well as a full table with all survey results, can be found in the Annex. Results on local climate change adaptation and integration in planning processes are presented in chapter 4. Lastly, an empirical study has been conducted to further assess citizens' perceptions of climate change impacts. Thereby informal urban gardens have been chosen as reference areas to assess perceptions on how differing urban space designs can influence local microclimate and

FIGURE 2: RISK AND RESILIENCE ASSESSMENT FRAMEWORK



environment. Five different neighborhoods have been chosen in the city of Piura, in which citizen initiatives have redesigned local public spaces by developing informal gardens. On-field visits, a questionnaire on the perception of the residents on the impacts of the garden in the neighborhood and their potential for climate change adaptation has been distributed and 25 answers could be collected. All respondents are homeowners and most of them have been living in the study area for more than 20 years. The results of the citizen survey are presented in chapter 5.

3. CLIMATE RISKS AND VULNERABILITIES

3.1 EL NIÑO PHENOMENON (FEN)

The impacts of climate change in the Piura Region are manifested in the atypical increase or decrease in the temperature of the equatorial waters of the central and eastern Pacific Ocean, which results in periods of intense rainfall and drought (Servicio Nacional de Meteorología e Hidrología, 2005a). These events are known as El Niño phenomenon (FEN) in the case of an increase in sea temperature, and La Niña phenomenon in the case of a decrease in sea temperature, where the most intense period of both events normally lasts one year.

FEN refers to a warm ocean current in the Tropical Pacific that happens normally during the summer months in the Southern Hemisphere. However, when the sea temperature experiments an atypical rise above the annual average, it is considered a phenomenon, and therefore an El Niño phenomenon event (CAF - Development Bank of Latin America, 2020). The alteration in the recurrence and intensity of the FEN is attributed to climate variability between 1976 and 1977 which was reflected in an abrupt increase in sea temperature in the equatorial Pacific (Servicio Nacional de Meteorología e Hidrología, 2005b). The explanation for this sudden change in temperature in 1976 is that the climate system may have reached its limit and is being affected by the increase in greenhouse gas (GHG) emissions into the atmosphere.

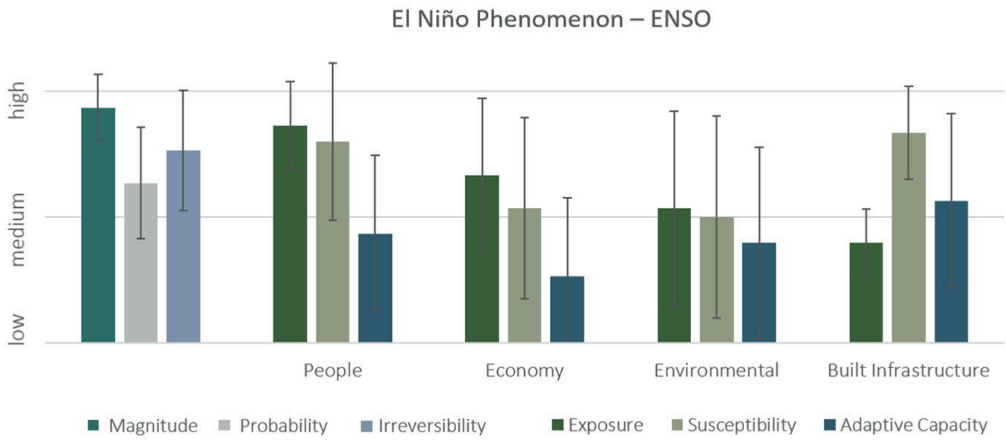
FEN events have been occurring for centuries. However, extraordinary events denominated 'Mega Niño events', refers to intense versions of these phenomena with even more devastating consequences and/or duration of more than 12 months, as occurred between 1982 and 1983, in 1992, between 1997 and 1998, and between 2016 and 2017. The last event that occurred between 2016 and 2017 was particular because the warming was only focused on the coasts of Perú and Ecuador, as happened earlier in 1925. For this reason, both events are known as Niño Costero.

The rainfall caused by the effect of the FEN and drought, due to the La Niña Phenomenon seriously affected the economic activities of the population with special incidence on agriculture and fishing. Likewise, heavy storms caused by the FEN and the Niño Costero affect urban areas, causing floods that damage the infrastructure, the transportation system, and energy, water, and sanitation systems. The damage caused by these events is evidence of the city's vulnerability since it does not have an efficient drainage system and also the occupation of risk areas such as old ravines, blind basins , etc.

According to the document *El fenómeno El Niño en el Perú* there is currently uncertainty in world climate research centers as to the evolution of the intensity and frequency of FEN in the future due to the recurrence of patterns associated with new modes of inter-annual variability, and to the context of climate change (SENAMHI, 2014). However, a scientific study by SENAMHI has concluded that there might be a greater probability that the intensity of future FEN events will increase. (Servicio Nacional de Meteorología e Hidrología, 2005a)

Figure 3 shows the expert evaluation for risk and vulnerability towards this phenomenon from the online survey conducted in 2021. The main impact of the FEN on Piura and most coastal cities is the great floods that affect people, the economy, the environment, and the built infrastructure. Likewise, most experts have considered the high magnitude of the FEN events with medium probability of occurrence and medium to high irreversibility. Whilst the FEN is not a yearly event, some of its impacts may be irreversible. For instance, the 2017 "Niño Costero", caused great damage in the urban area

FIGURE 3: EXPERT EVALUATION FOR THE RISK CLUSTER "EL NIÑO PHENOMENOM FEN" FOR THE CITY OF PIURA, INCLUDING GENERAL RISK FACTORS AND THE VULNERABILITY OF THE SOCIAL, ECONOMIC, ENVIRONMENTAL, AND BUILT SYSTEMS IN THE CITY. SURVEY RESULTS WITH 15 PARTICIPANTS FROM D DIFFERENT LOCAL INSTITUTIONS AND CITY LAB ON-SITE EXPERTS (1 = LOW RISK, 2 = MEDIUM RISK, AND 3 = HIGH RISK).



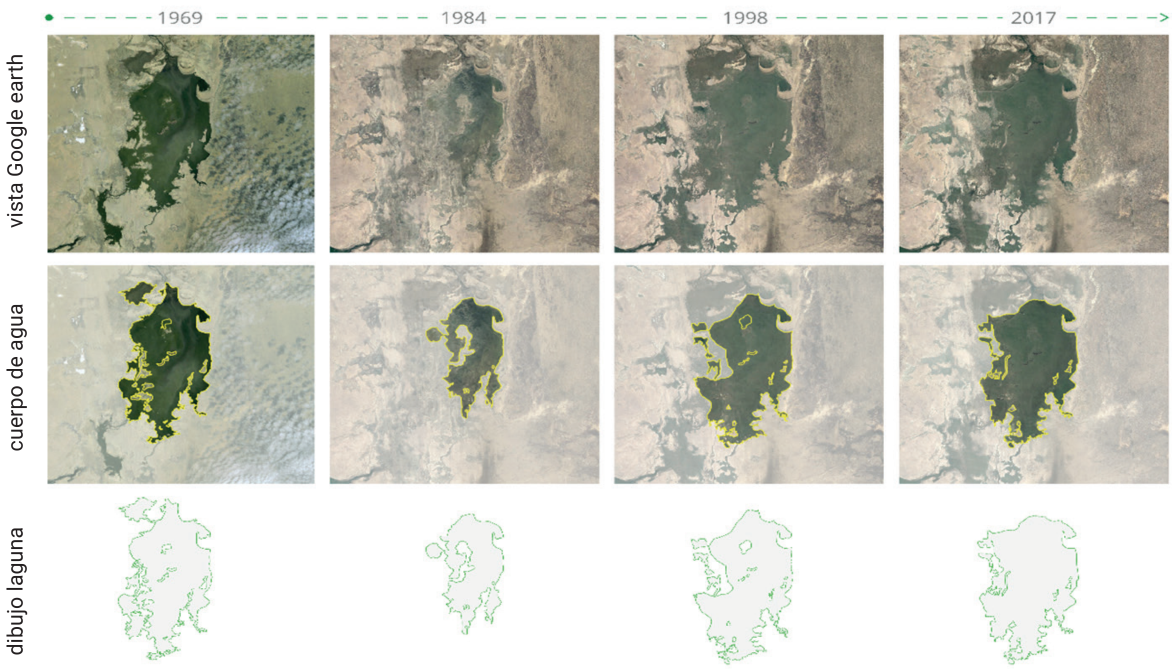
as well as the rural population of Piura which is being felt after four years. Despite being a recurrent and historic phenomenon, it was stated that the city is not well prepared since the applied measures are not sufficient to contain the impacts.

Regarding the vulnerability of the people, the experts stated that the poorest citizen groups are more endangered due to a lower adaptive capacity, and many of them are settled in informal areas within a high flood risk. Concerning economic vulnerability, it was mentioned that the economy of Piura city is closely attached and co-dependent on the rural areas, where agriculture is the main activity. It is precisely agriculture one of the most affected sectors during the FEN events, e.g. by landslides, spillovers, and floods. Furthermore, the fishery was named as a vulnerable economy branch, as the change in sea temperature reduces the amount of fish extracted and damages to the fishing infrastructure occur. Likewise, damage to buildings and road infrastructure were named, affecting for instance local shops and retailers in the city.

From an environmental perspective, the FEN is considered necessary for the dry forest ecosystem since they allow forests recovery and seeds germination. Additionally, the FEN can generate new temporary ecosystems that host different animal and plant species. For instance, after El Niño in 1998, a new lagoon was formed in the Sechura desert, called La Niña lagoon (Figure 4). Since then, after every FEN, it is formed again attracting a great number of bird and fish species. However, due to the heavy rain and the lack of adequate drainage systems, sewage and rainwater are mixed resulting in great pollution in the city.

Finally, most experts have indicated that the built infrastructure in Piura city has high exposure and susceptibility to the FEN. Likewise, damage to buildings and road infrastructure were named as effects within the urban area, affecting for instance local shops and retail. They mention the self-construction and lack of urban planning as the key factors for the vulnerability.

FIGURE 4: GROWTH OF THE "LA NIÑA" LAGOON FROM 1969 UNTIL AFTER FEN. THE DATES 1984 AND 1998 ARE ALSO LATER THAN THE PHENOMENA



Infrastructure is often built with no specialists that consider future FEN impacts.

3.2 RIVER OVERFLOW, HEAVY RAINFALL AND STORMWATER

The main reason for river overflow and heavy rainfall in Piura is due to the FEN. Hence, this risk cluster and the previous one are strongly connected in this document.

According to the study "Climate Change Risk Index in Piura"(CAF - Development Bank of Latin America, 2020), an increment of 5-20% of extreme precipitation values is expected in the River Piura basin by 2040, as well as an increment higher than 20% for the coastal zone of Piura.

Urban areas are mainly affected by the rainfall through floods that damage infrastructures like the different bridges that connect the city, the transport system, as well as the energy, water, and sanitation systems. Such vulnerabilities are stressed by the lack of an urban drainage system and the occupation of risk areas (low areas, blind basins). As most of the population is concentrated in the city of Piura, flooding also comes with losses of livelihoods and the risk of disease outbreaks (explained in detail in subchapter 3.5 change in the biological system).

The Plan for the Prevention and Reduction of Disaster Risks in the Province of Piura for 2021, identified 83 blind basins after the El Niño Costero Phenomenon 2017, 20 more than those existing before the last event. Many housing developments are located in these basins, so 1211 blocks were affected, 135 schools and 110,368 people.

FIGURE 5 SECTION OF PIURA - CHICLAYO HIGHWAY BLOCKED DUE TO OVERFLOWING OF LA LECHE RIVER. SOURCE: DIARIO EL TIEMPO, 2017

Figure 6 shows a vulnerability analysis to the Piura river overflow within the city, conducted by the CAF (Development Bank of Latin America). It shows that more than half of the metropolitan area presents moderate to very high vulnerability to overflow. Such vulnerability increases in the measure the area is more distant to the city center, especially to the south. According to this analysis, the vulnerability is lower in the city center because there is a higher concentration of hospitals, education centers, and high proximity to highways compared to the southern area. Then, the Catacaos district is considered the most vulnerable due to the low adaptive capacity since it has the highest level of illiteracy and vulnerable population, as well as lesser access to public services such as electricity, and sewage systems (CAF - Development Bank of Latin America, 2020).

Most experts considered a medium to high magnitude of heavy rainfall and stormwater (Figure 5). However, the probability and irreversibility of effects were rated as medium to low, since such events are uncommon in absence of the FEN. Nevertheless, when a heavy rainfall event occurs, people and built infrastructure are the most vulnerable. In addition, the increment of the Piura river has caused the collapse of bridges that connect the rural area where agriculture is performed, with the city, which is supplied with food. This has produced stockouts in Piura city and a great waste of food, affecting the whole region. In 2017, for example, the collapse of the bridge to the southern city of Chiclayo cut off the connection by land to other big cities (Diario El Tiempo, 2017).

As mentioned in the previous chapter, this situation also affects the environment and health, since the lack of a drainage system generates a mix of sewage with stormwater accumulated (Figure 7). When these waters dry, the polluting particles from the sewage contaminate the air. Additionally, the floods generated by stormwater are habitat of mosquitoes' larvae, and therefore infectious diseases, such as zika, dengue, and chikungunya. This risk will be further examined in section 3.5. "Change in Biological Systems".

3.3 LA NIÑA, WATER SCARCITY AND DROUGHTS

The opposite to the FEN is La Niña, which is characterized by a reduction of sea temperature, below the annual average (CAF - Development Bank of Latin America, 2020). Hence, La Niña event has the opposite effect, reducing rainfall and therefore producing water scarcity and droughts. Like an El Niño event, it will seriously affect economic activities, such as fishing and agriculture.

In general, droughts in the city and region have been much less studied, and therefore the idea of a less severe issue prevails. However, according to the meteorological records of the CORPAC station in the city, between 1932–1992 there were 24 years where rainfall was less than 25 mm/year and 11 years where rainfall was equal to or less than 50 mm/year. This means that the city has faced severe drought for 40% of this time

FIGURE 6: VULNERABILITY TO RIVER OVERFLOW IN METROPOLITAN PIURA. SOURCE: CAF - DEVELOPMENT BANK OF LATIN AMERICA, 2020)

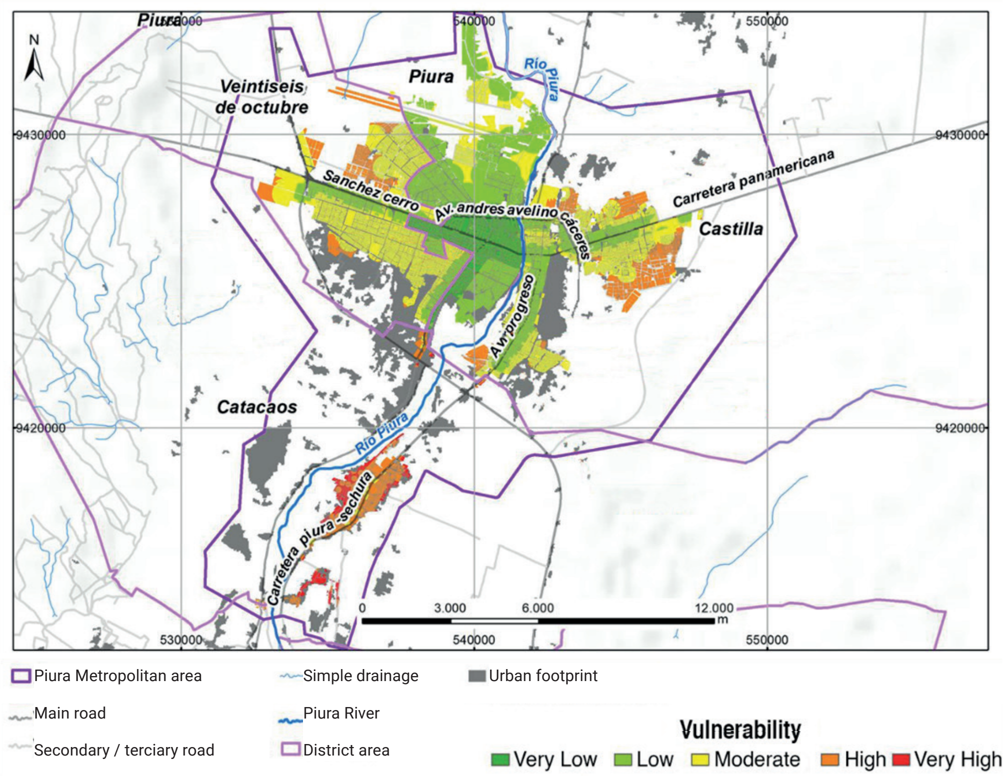
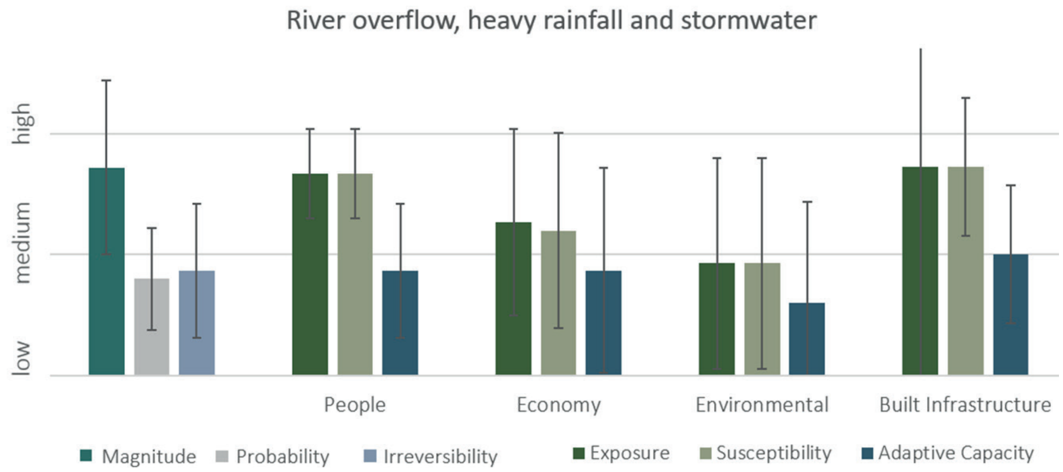


FIGURE 7: EXPERT EVALUATION FOR THE RISK CLUSTER "HEAVY RAINFALL AND STORMWATER" FOR THE CITY OF PIURA, INCLUDING GENERAL RISK FACTORS AND THE VULNERABILITY OF THE SOCIAL, ECONOMIC, ENVIRONMENTAL, AND BUILT SYSTEMS IN THE CITY. SURVEY RESULTS WITH 15 PARTICIPANTS.



(Palacios-Santa Cruz, 2010). There are no measures or initiatives to mitigate the impact of droughts when they occur since they are not perceived in time and mainly affect agriculture. Moreover, when this situation occurs, the metropolitan area is also severely affected due to demographic expansion and a lack of urban planning to guarantee water supply to all inhabitants (Fernández et al., 2021).

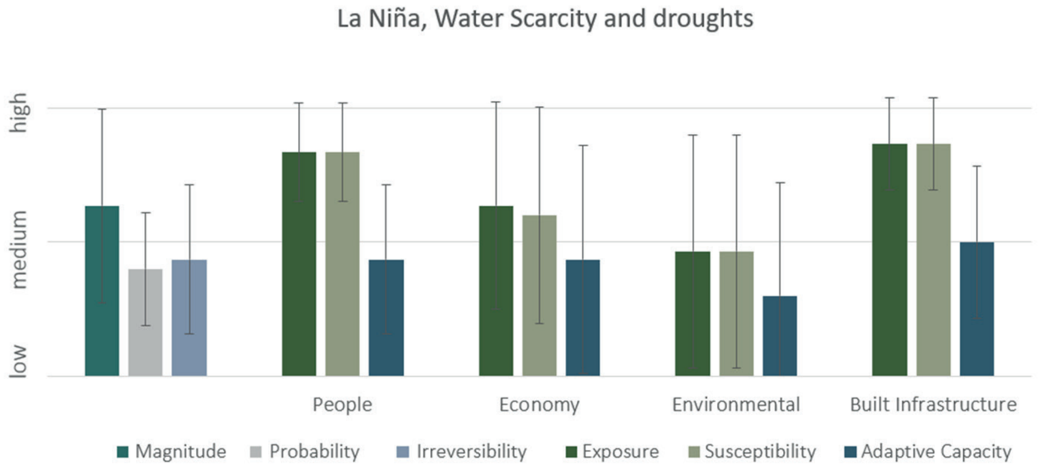
On the other side, according to the scenarios performed by the CAF - Banco de Desarrollo de América Latina (2020), water scarcity will not be a problem for Piura, since it is expected an increment of water availability. Some of the reasons for this situation is the increment of dry mountainous forests covered by 130%, in the period 1986-2017, which represents 47% of the total Piura River basin surface. Hence, it shows the need for a basin management approach to ensure cities' adaptation, and the important role of mountain forests conservation to regulate and ensure ecosystem services.

In accordance, experts who answered the survey mentioned that droughts are not as frequent as floods in the city of Piura (Figure 8). Nevertheless, when droughts happen there are not enough measures or initiatives to mitigate their impacts, and they mainly affect agriculture and farming. In addition, when this situation happens, the metropolitan area is severely affected due to the demographic expansion and lack of urban planning to ensure water supply for all the dwellers.

3.4 TEMPERATURE RISE AND URBAN HEAT ISLANDS

There is an increasing trend regarding temperature rise in Piura, which was acknowledged by the Government of Piura already 2008 (Gobierno Regional Piura et al., 2008). According to the study "Climate Change Risk Index in Piura", a significant increase in temperature is expected by 2040. The monthly average and the maximum daily temperature would increase between 1,0 and 1,5 °C respectively, during both the rainy and dry seasons. Likewise, temperature extremes are expected

FIGURE 8: EXPERT EVALUATION FOR THE RISK CLUSTER "LA NIÑA, WATER SCARCITY & DROUGHTS" FOR THE CITY OF PIURA, INCLUDING GENERAL RISK FACTORS AND THE VULNERABILITY OF THE SOCIAL, ECONOMIC, ENVIRONMENTAL, AND BUILT SYSTEMS IN THE CITY. SURVEY RESULTS WITH 15 PARTICIPANTS FROM DIFFERENT LOCAL INSTITUTIONS AND CITY LAB ON-SITE EXPERTS (1 = LOW RISK, 2 = MEDIUM RISK, AND 3 = HIGH RISK).



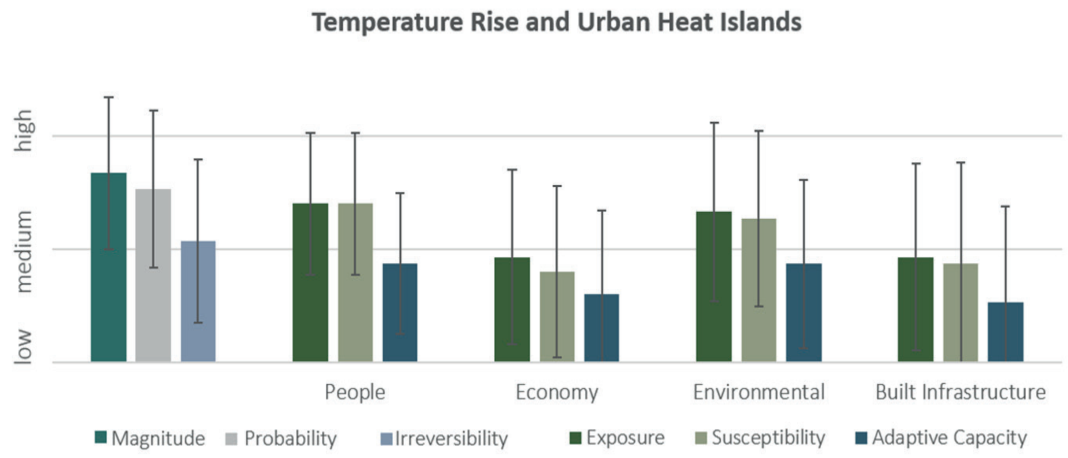
to increase between 1,0 and 1,5 °C (CAF - Banco de Desarrollo de América Latina 2020).

According to (Caldas et al., 2019) the temperature rise in Piura city is also a consequence of urbanization processes, mainly due to lack of vegetated cover. Hence, both rapid urbanization and accelerated demographic growth are considered two important factors that generate urban heat islands (UHI) in the city of Piura. This is due to the land use and land cover change from forests and agricultural areas, towards impermeable urban areas. Additionally, the accelerated demographic growth and migration (rural to urban and also between cities and nations) have produced unplanned expansion of the city, mainly informal settlements located in the most desertic areas of Piura.

Figure 9 summarizes the assessment made by the survey experts, showing a medium to high risk in magnitude and probability to urban heat islands in Piura. Most of them have mentioned the lack of initiatives to reduce the UHI effect in the city and on the opposite, it was mentioned that the government tolerates the cutting of the few remaining trees. Moreover and in accordance to the research of (Caldas et al., 2019), experts mentioned the reason of this effect might be due to deforestation to increase urban areas, logging of urban trees, lack of green areas, predominant grey infrastructure, and lack of permeable surfaces.

With respect to people´s vulnerability, the lack of urban trees and shadows was mentioned by most respondents, which makes the city uncomfortable to walk, a fact that is worsened during the summer periods. It also affects human health by producing heat shocks, which children are the most vulnerable (EL TIEMPO, 2020). Additionally, UHI restricts the use of public spaces for recreation activities and commercial activities and reduces employees’ and workers’ performance due to the lack of thermal comfort. Generally, a lower vulnerability was indicated for the local economy and infrastructure. These aspects and related citizen perceptions are further summarized in chapter 5.

FIGURE 9: EXPERT EVALUATION FOR THE RISK CLUSTER “URBAN HEAT ISLAND” FOR THE CITY OF PIURA, INCLUDING GENERAL RISK FACTORS AND THE VULNERABILITY OF THE SOCIAL, ECONOMIC, ENVIRONMENTAL, AND BUILT SYSTEMS IN THE CITY. SURVEY RESULTS WITH 15 PARTICIPANTS FROM DIFFERENT LOCAL INSTITUTIONS AND CITY LAB ON-SITE EXPERTS (1 = LOW RISK, 2 = MEDIUM RISK, AND 3 = HIGH RISK).



3.5 CHANGE IN BIOLOGICAL SYSTEM

El Climate change has a direct impact on the biological system in Piura. The Peruvian carob tree (Prosopis pallida or algarrobo in Spanish) for instance is the flagship species in the north of Peru where Piura is located. According to the National Service of Forests and Wildlife (SERFOR) and the Ministry of Environment (MINAM), 40% of carob trees' population is affected by plagues that are persistent due to the temperature increment. Additionally, new viruses and fungi affect the species (Diario El Regional de Piura, 2020).

Concerning risk to human health, the presence of epidemics and zoonotic diseases is promoted by the changing climate. Dengue, malaria, and zika are becoming more frequent and lethal (UDEP, 2016). According to the University of Piura, dengue covers already 70% of the surface of Piura and occurs throughout the year (formerly only during the rainy season). In accordance, further studies (Cabezas & Donaires, 2017) have identified that climate change has made it more difficult to control the Aedes aegypti, the mosquito which is a vector of the abovementioned diseases. For instance, after the El Niño Costero occurred in 2017, the vector's population suffered an explosive growth and dengue cases increased: the city of Piura became one of the most affected cities since it concentrated 64% of the total national cases of dengue in Peru(Díaz-Vélez et al., 2020). Figure 10 shows the interconnection and the peak of dengue cases in Peru after the Coastal El Niño of 2017.

Looking at the survey results, this risk cluster has been rated as the lowest of all (Figure 11). However, it has to be mentioned that many experts stated a lack of knowledge in this regard, adding uncertainty to the evaluation. Generally, the experts have also mentioned a moderate vulnerability of people, mainly due to the impacts on human health caused by the increment of vectors and infectious diseases. From an economic perspective, sectors such as forestry, agriculture, and fishing, might be affected due to changes in plagues and variation in temperature and precipitation patterns that affect biodiversity and yields. However, more research and data would be needed to uncover the full extent.

FIGURE 10: NUMBER OF DENGUE CASES IN PERU AFTER THE COASTAL EL NIÑO. SOURCE: DÍAZ-VÉLEZ ET AL. (2020)

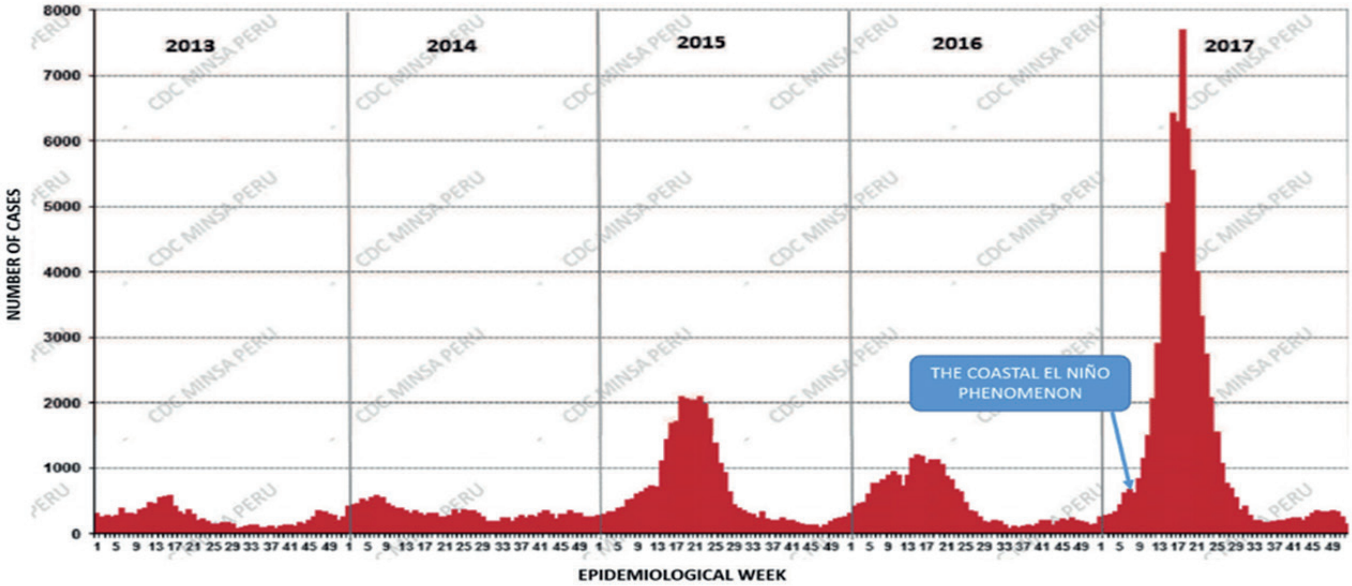
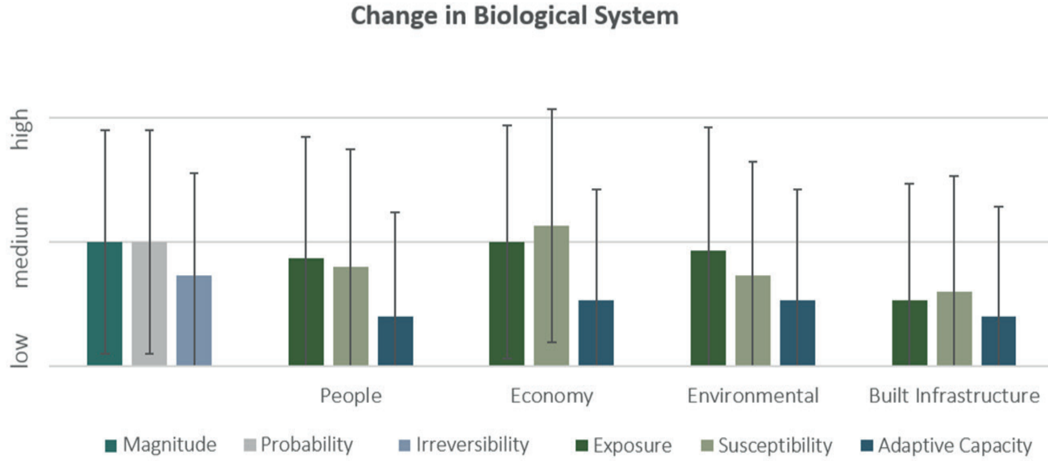


FIGURE 11: EXPERT EVALUATION FOR THE RISK CLUSTER "CHANGES IN THE BIOLOGICAL SYSTEM" FOR THE CITY OF PIURA, INCLUDING GENERAL RISK FACTORS AND THE VULNERABILITY OF THE SOCIAL, ECONOMIC, ENVIRONMENTAL, AND BUILT SYSTEMS IN THE CITY. SURVEY RESULTS WITH 15 PARTICIPANTS FROM DIFFERENT LOCAL INSTITUTIONS AND CITY LAB ON-SITE EXPERTS (1 = LOW RISK, 2 = MEDIUM RISK, AND 3 = HIGH RISK).



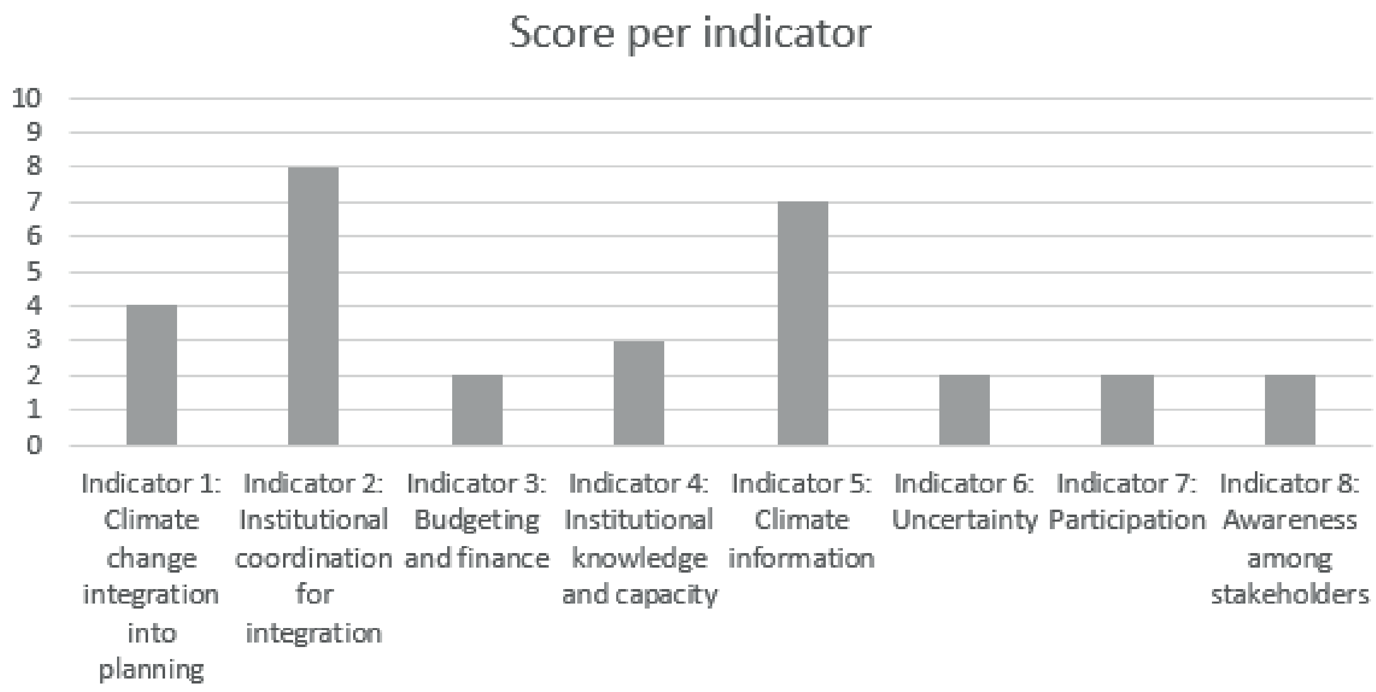
4. CLIMATE CHANGE ADAPTATION MEASURES

In face of the aforementioned risks, climate change adaptation needs to play a more important role in the future of urban planning and development. Next to the more technical, nature-based, and infrastructural adaptation measures, which have been hinted at throughout the previous sections, softer measures as governance approaches will be needed to support strategic and lasting change. Figure 12 summarizes the current state in Piura with regards to eight distinct indicator areas based on the TAMD framework which have been filled using the city lab data collection and interviews. Each indicator area consists of 3 to 5 questions to find out how many adaptation measures a city has already implemented. The result suggests many opportunities to further deepen and improve existing climate governance and adaptation measures and the key findings on each indicator are outlined in the following sections. Furthermore, the city lab Piura has developed a roadmap with specifically adapted measures and project ideas that can be implemented and benefit the city in the future (see also chapter 7). (Fernández et al., 2021)

4.1 INDICATOR 1: CLIMATE CHANGE INTEGRATION INTO PLANNING

High-level management instruments on climate change, in general, exist at the national level, such as National Strategy for climate change 2050 (approved in 2021), Peru's National Climate Change Adaptation Plan: An input for updating the National Climate Change Strategy, Policy of Disasters Risks Management, and the Framework Law of Climate Change and its Regulation. The National Policy of Disasters Risks Management by 2050, issued in 2021, has as its main objective to

FIGURE 12: CLIMATE CHANGE ADAPTATION ASSESSMENT FOR THE CITY OF PIURA ACCORDING TO THE TAMP FRAMEWORK (IIED 2014). EACH INDICATOR CONSISTS OF 3 TO 5 QUESTIONS ON POTENTIAL ADAPTATION MEASURES IN A CITY, WHICH AMOUNT TO A MAXIMUM SCORE OF 10. SCORES ARE GIVEN ACCORDING TO HOW MANY MEASURES IN EACH INDICATOR CATEGORY HAVE ALREADY BEEN IMPLEMENTED BY THE CITY.



incorporate and implement the Management of Disasters Risks, through the development planning and the prioritization of human, material, and financial resources. Likewise, the National Plan of Disasters Risks Management for the period 2014-2021 (Presidencia del Consejo de Ministros - PCM, 2014), in its Strategic Goal 5, aims to strengthen the institution's capacities to develop disasters risks management, To achieve this, it aims to institutionalize the Disasters Risks Management in the three levels of Government,
The Framework Law of Climate Change and its Regulation, approved in 2019, is the most important policy document and aims to establish the principles, approaches, and general provisions for coordinating, monitoring, assessing, and disseminating public policies for the management of climate change adaptation and mitigation measures, and thus reducing the country's vulnerability to disasters and harnessing of low-carbon growth opportunities (PODER LEGISLATIVO PERU, 2018). One of the main characteristics of the Framework Law is to establish the MINAM as the national authority on climate policy, which establishes and promotes compliance with climate change. In addition, the State, at its three levels of government, will implement programs aimed at reducing greenhouse gas emissions, capturing carbon and increasing sinks, prioritizing the protection and sustainable management of forests, forestation, and deforestation, control of the use and change of land use: sustainable transport, solid waste management and energy efficiency in the various productive sectors (PODER LEGISLATIVO PERU, 2018).

The advantages and opportunities promoted by this Framework Law (Ministry of Environment of Peru, 2021):

For every 1 PEN[1] invested in preparing for climate change, we will save 10 PEN in potential reparation costs due to the impact of disasters.

The State will integrate climate change into its development planning, guaranteeing efficient management of public resources.

Private enterprises will be able to access new capacities to develop new green technologies.

Citizens will have greater possibilities of accessing measures to adapt to extreme climate events.

At the sub-national level, the Regional Government developed in 2011 the Regional Strategy on Climate Change for 2021 as a result of the raising concerns of the government after the FEN of 1998. This strategy includes five strategic goals by 2021:

SG1: Regional actors identify Piura's vulnerabilities to climate change and propose measures to be implemented for its adaptation.

SG2: Representatives of the regional government and municipalities with strengthened capacities improve decision-making processes on development policies, plans, and programs by incorporating the challenges and opportunities posed by climate change.

SG3: Regional actors with strengthened capacities promote energy, clean processes, and energy efficiency in the department of Piura, aimed at effectively reducing GHG emissions and increasing carbon capture capacity.

SG4: The Regional Council of Water Resources of the Chira-Piura Basin promotes the integrated management of this resource under an ecosystem approach and in the context of climate change.

1 PEN se refiere a soles peruanos, la, moneda nacional de Perú. 1PEN = 0,25EUR

SG5: Relevant regional actors consolidate the processes of generating information and knowledge on climate change with a scientific and technical focus, based on research and oriented towards the implementation of adaptation and mitigation measures.

At the local level, the Municipal Province of Piura developed in 2017 a plan for disasters risks reduction and prevention for 2021 (Municipalidad Provincial de Piura, 2017). In this, priority action 4 aims to update and boost strategic management and operational management tools by incorporating the prospective and corrective components of disaster risk, including:

Update the Agreed Local Development Plan by incorporating the prospective and corrective components of risk.

UIpdate the Spatial Development Plan, Metropolitan Development Plan and Urban Development Plan by incorporating the prospective and corrective risk components including unmitigated risk zones and seismic micro-zoning

To promote and support the formulation of Disaster Prevention and Risk Reduction Plans of the District Municipalities

A functioning system to routinely screen for climate risks, as well as a safeguard system that
integrates climate risk screening, assessment, and risk reduction measures in urban planning could help the city to further institutionalize and strengthen adaptive capacity in this area. Lastly, the identification and implementation of concrete measures have to be promoted.

4.2 INDICATOR 2: INSTITUTIONAL COORDINATION FOR INTEGRATION

The MINAM of Peru is the national authority in climate change topics, as well as technical and normative authority; hence it monitors and assesses the implementation of the climate change integral management in the three levels of governments (local, regional and national) (PODER LEGISLATIVO PERU, 2018).

In September 2020, a national High-Level Commission on Climate Change (CACC) was installed, through D.S. N°006-2020-MINAM. The Commission aims to propose mitigation and adaptation measures, issue the technical report on the National Determined Contribution (NDC) every 5 years, among others. Since these require great coordination efforts, the CACC comprises 14 Ministries, the National Centre of Strategic Planning (CEPLAN), and representatives of local and regional governors (Ministerio del Ambiente del Perú, 2020). Additionally, it can call a representative of public, private, civil society, indigenous peoples, and international cooperation organizations.

Regarding the funding for sustaining the institutional coordination, the Ministry of Economics and Finance (MINEM) coordinates with the MINAM to incorporate the vulnerability and climate risks analysis and to identify adaptation and mitigation measures to be incorporated in the different public investment projects, to ensure the sustainability of the state actions (PODER LEGISLATIVO PERU, 2018).

According to the Framework Law of Climate Change, the regional and local governments are competent authorities who are entitled to promote, coordinate, articulate, implement, monitor, and assess the whole management of climate change, as well as to issue the correspondent normative within their competences and functions.

The Regional Management of Natural Resources and Environmental Management from the Regional Government of Piura is responsible for leading the process of coordination and inter-sectoral agreement at the regional level, through the Regional Environmental Commission and the local Environmental Commissions (Gobierno Regional Piura, 2019). The Regional Environmental Commission – CAR Piura is entitled to coordinate and concert the regional environmental policy (Gobierno Regional Piura, 2019). For this, it is comprised of representatives of several organizations, such as the regional government of Piura, the Regional Directions of Health, Agriculture, Production, Energy, and Mining, among others. Likewise, the Local Environmental Commission works at local level.

However, despite the several policy instruments, there is still disarticulation between the regional and the local governments. It is necessary they continuously coordinate and articulate the progress they achieve in climate change and environmental work.

4.3 INDICATOR 3:BUDGETING AND FINANCE

Budgeting and finance for climate risks and resilience action are not very clear in Piura. The Plan for Disasters Risks Prevention and Reduction (PPRRD) 2021 for Piura assigns a budget of 1.205.228.500,00 Peruvian Soles (approx. 300 million USD) for action until 2021. The Multiannual Institutional Operative Plan (POIM) 2020-2023 considers a budget for vulnerabilities reduction and response to emergencies, but it does not include the budget for pilot projects or to integrate climate change in the local policies or actions (Municipalidad Provincial de Piura, 2020).

The actions regarding climate change in Piura, are supervised by the Regional Government of Piura and must be aligned to the Regional Strategy of Climate Change. Hence, the Regional Management of Natural resources and Environment is responsible to assess the level of insertion of the Regional Strategy of Climate change at the local level, in the different local budgets. Therefore, the Regional Management of Natural Resources and Environment, together with the Planning and Budget Management will design funding mechanisms to promote the incorporation and financial viability of ERCC implementation in the plans and budgets of public entities (Gobierno Regional Piura, 2013).

So far, no mechanisms or capacities exist on the local level to assess the costs associated with climate change adaptation measures. Developing such a system and linking it to available funding schemes (also on the municipal level) could help to increase autonomy and resource availability for disaster prevention and climate change adaptation.

4.4 INDICATOR 4: INSTITUTIONAL KNOWLEDGE AND CAPACITY

At the national level, the education, training, and awareness-raising activities on climate change have made some progress, mainly by MINAM, the Ministry of Education (MINEDU), universities, and civil society organizations. The MINAM provides technical assistance for climate change management which includes capacity building for public officials and regional technical groups. The MINEDU and MINAM have promoted the National Environmental Education Policy (PNEA). The implementation of the PNEA is carried out by the MINAM and MINEDU for which they developed the National Environmental Education Plan 2017 - 2022 (PLANEA) which contains strategies to incorporate environmental education in educational institutions, public and private institutions, and civil society. For example, the MINAM has promoted the creation of awareness on climate change through communication campaigns including publications, guides, dissemination materials, web portals, virtual courses, training workshops, and the creation of a table of communicators, especially at the regional level in several regions, including Piura. MINEDU has sought to increase adaptive capacity to face climate change, as evidenced by the development of the cross-cutting theme “Education Risk Management and Environmental Awareness” designed for school students. Likewise, universities in Peru have been generating and disseminating information on climate change. Likewise, civil society organizations (such as the Movimiento Ciudadano Frente al Cambio Climático - MOCICC) and international cooperation has led initiatives to disseminate and raise awareness of climate change issues in the country. (Ministerio de Medioambiente, 2010)However, there have been no formal education programs on climate change that address the low level of knowledge on the subject among the population so far.

At the regional level, strategic goal 2 of the Regional Strategy of Climate Change (ERCC) of Piura for 2021 states that: “representatives of the regional government and the municipalities have strengthened capacities and improve decision-making processes about development policies, plans, and programs through the cross-cutting inclusion of opportunities and challenges that climate change brings” (Gobierno Regional Piura, 2013). However, no concrete information was available on formal requirements or training of staff with regards to climate change issues. The Regional Management of Natural Resources and Environmental Management, and at local level the Management of the Environment, Population, and Health are the departments that have more experience and knowledge in this area, whilst other units do not focus on these topics. As a result, the holistic and systematic integration of climate mitigation and adaptation into planning processes has been difficult and should be strengthened in the future.

Since 2010 the Regional Government and the Regional Educational Directorate have been organizing the annual Regional Environmental Education Congress to promote a culture of environmental education in educational institutions in the Piura Region.

The municipalities have the authority to promote environmental education and research, for which the Municipal Program for Environmental Education, Culture and Citizenship (EDUCCA) has been implemented as an instrument of PLANEA at the local level.

In Piura the EDUCCA program has been implemented since 2017, working mainly with public and private educational institutions. In addition, youth environmental organizations such as Solidaries Teens and Generación Estudiantil Ambientalista (GEA) contribute to environmental management in the city through MINAM’s Environmental Youth program.

4.5 INDICATOR 5: USE OF CLIMATE INFORMATION

El SENAMHI is a public executing agency attached to the MINAM, which mission is to generate and provide meteorological, hydrological, and climatic information and knowledge to Peruvian society in a timely and reliable manner, thus contributing to the reduction of the negative impacts produced by natural phenomena of hydrometeorological origin (Servicio Nacional de Meteorología e Hidrología del Perú, 2020). All the information generated by the SENAMHI and the forecast is available on the website. More detailed information can be freely ordered, as well. Additional to the information generated and provided by the SENAMHI, all information provided by foreign and international organizations can be accessed through their portals, such as IPCC, universities, etc.

National policies, such as the Framework Law on Climate Change and the Action Plan of Gender and Climate Change include traditional knowledge and indigenous people's perspectives. According to the Climate Change Framework Law, in its art.3, approaches to integrated climate change management, includes mitigation and adaptation based on traditional knowledge: The law recovers, values and uses the traditional knowledge of indigenous or native peoples and their vision of harmonious development with nature in the design of climate change mitigation and adaptation measures, guaranteeing the fair and equitable distribution of the benefits derived from the use of this knowledge (PODER LEGISLATIVO PERU, 2018). Furthermore, at the national level, there is the Action Plan of Gender and Climate Change – PAGCC Peru -, which highlights the differentiated impact of climate change on women, especially those indigenous women who live in rural communities. Finally, the PAGCC Peru acknowledges the important role of women of indigenous peoples, who use to be the intergenerational guardians and transmitters of their peoples' traditional knowledge, and therefore play a key role in the climate change adaptation processes (Ministerio de Medio Ambiente PERU, 2019).Despite the consideration in formal documents, the inclusion of indigenous people's visions and their traditional knowledge could be better put into practice and seen as a complementing resource to scientific knowledge. There have been incidences in the past where indigenous guardians of nature have been assassinated or threatened by mobs who want to illegally extract minerals, timber, coca, or other natural resources: only in 2020 five environmental guardians were murdered and several threatened to death. In these cases, stronger support and protection by the government and public bodies would be needed (Vera, 2021). Moreover, the Congress of Peru has rejected to sign the Escazu Agreement, a Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean (Economic Commission for Latin America and the Caribbean - ECLAN 2021). Such examples show that there are still some drawbacks when it comes to including indigenous knowledge and perspectives in planning and decision-making.

4.6 INDICATOR 6: UNCERTAINTY IN CLIMATE PLANNING

Planning for climate adaptation and resilience is a task that has to deal with future projections, assumptions, and related uncertainties. Thus, it might be necessary to work within different ranges of key climatic parameters, different timescales, or climate scenarios, rather than sticking to static one-time projections. In the Piura context, there has been no evidence so far of taking uncertainty into account in planning, design, and decision-making processes. For instance, whilst the Regional Strategy on Climate Change Piura includes some climate scenarios, this information is not articulated to the local planning policies, like the Metropolitan Development Plan (PDM) Piura 2040. Scenario-based and adaptive planning is thus an action field that can still be explored further to increase well-informed and up-to-date decision-making and improve local risk assessment and mitigation. To achieve this, respective frameworks and methods have to be developed which include uncertainty and enable flexible and adjustable actions. Additionally, the processes of updating plans and policies need to become more agile and updateable (e.g., if new climate information becomes available), since they currently require a long time and are rather slow due to bureaucratic processes.

4.7 INDICATOR 7: PARTICIPATION

Citizen participation in the public affairs of the country is a fundamental right recognized by the Political

Constitution of Peru of 1993 (Chapter III, Article 31) and it is materialized through various mechanisms of participation in public management at the three levels of government. National policies, such as the Gender and Climate Change Action Plan, the National Adaptation Plan, the Climate Change Framework Law, etc. have gone through a public consultation process. Likewise, the Piura Metropolitan Development Plan -PDM- includes actions focused on people living in vulnerable areas, who are usually the poorest and most marginalized members of society. However, despite the existence of citizen participation mechanisms such as the participatory budget process, prior consultation, public hearings, JUVECOS, etc., there is dissatisfaction with the way public policies are decided and formal participation is very low. Two answers can be sketched on this last point:

a) the lack of knowledge of the existing mechanisms and how to use them; and,

b) the opportunity and transaction costs of activating these mechanisms. (Shack & Arbulú, 2021)

In terms of climate resilience planning, it is recommended to further engage with and create tools of participation for local communities and adversely impacted social groups. To achieve this, closer work with local community champions and bottom-up initiatives can help to reach respective citizen groups..

4.8 INDICATOR 8: AWARENESS AMONG STAKEHOLDERS

At national level, the MINAM is the national authority in raising awareness matters. At the regional level, is the Regional Government of Piura through the Regional Strategy of Climate Change, in its strategic goal 3, which mentions the role of regional stakeholders, with built and strengthened capacities to promote clean processes and energies, in order to reduce GHG emissions and enhance carbon capture (Gobierno Regional Piura, 2013). At the local level, there is no official authority to raise awareness on climate-related issues. Nevertheless, the Multiannual Institutional Operative Plan 2021-2023 of the Provincial Municipality of Piura, includes a budget for “Training on disasters risks management and climate change adaptation” (Municipalidad Provincial de Piura, 2020), which could be used as a means to raise awareness. The general perception and information within the population differ, chapter 5 gives insights into some climate-related perspectives and initiatives within different population groups in the city of Piura..

5. CITIZEN INITIATIVES AS A CLIMATE CHANGE RESPONSE

Inhabitants of many urban communities have been intentionally appropriating and reclaiming public open spaces as an opportunity, transforming their functions into orchards or gardens in close proximity to their own homes. Next to recreational and aesthetic reasons, the adaptation to climate change impacts and the creation of cool and livable environments has been a driver and motivator to these initiatives.

The implementation of urban gardens helps to reduce pollution in the city, reduce the effect of high temperatures thanks to the shade they provide, generate spaces for social interaction, protect against natural disasters, generate ecological awareness, and improve biodiversity. In addition, they transform unused spaces into landscaped areas with recreational and ecological value, contributing to the implementation of green areas in the city and improving the quality of life.

In this study, five initiatives of informal urban gardens by inhabitants of different neighborhoods in Piura were selected: (1) AH Santa Rosa, Parque San Judas Tadeo Sector 5B, (2) Urb. Santa María del Pinar, Parque Las Fresas, (3) AH Túpac Amaru III, Calle Humedales Santa Julia, (4) José María Arguedas, and (5) La Primavera. The criteria for selecting these communities followed three principles: 1) the presence of a neighborhood-initiated informal gardening initiative, which was

FIGURE 13: MAP SHOWING THE LOCATION OF THE 5 STUDIED GARDENING INITIATIVES. SOURCE: MGI INITIATIVE, 2021

FIGURE 14 IMPRESSIONS OF THE INFORMAL URBAN GARDENS IN THE STUDY AREAS . SOURCE: MGI INIATIVE, 2021

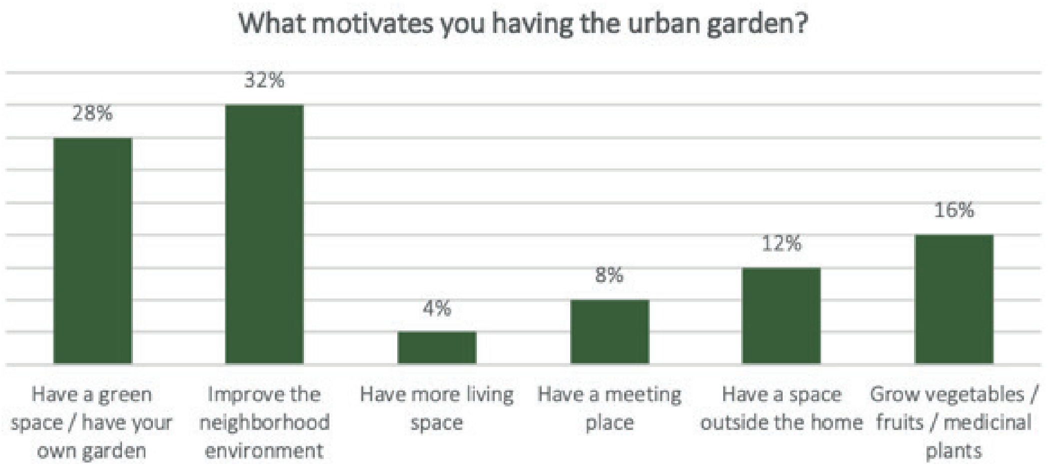
confirmed by fieldwork prior to the exploration; 2) a different composition of residents living in each of the neighborhoods, in relation to their socioeconomic status; 3) the location in a central part of the city, where urban gardens are less common, as opposed to the outer suburbs.

In addition, it is worth mentioning that the five neighborhoods of the initiatives show very different characteristics in terms of the years of construction of the buildings within the urbanization process of the city and include neighborhoods built in different decades of the last 60 years. Likewise, there are differences with respect to the origin of the neighborhood, such as the level of consolidation and occupation, taking into account whether the initiative is officially recognized or still part of informal land occupation by the neighborhood.

The five initiatives are characterized by their origin in the community and their desire to improve it at the urban, social, and environmental levels. Reasons include growing different fruits, medicinal or ornamental plants, reducing waste in the local environment, shading public spaces, draining and mitigating polluted street runoff, or creating cool resting spaces. All gardens are similar in terms of physical characteristics in that they use recycled elements such as bricks, fences, test tubes, bottles, etc., to fence their garden space creating a sense of ownership and with it the responsibility to take care of it. Impressions of the garden spaces are depicted in (Figures 13 and 14).

Figure 15 shows that a common and great desire of the communities is to improve the environment of their neighborhood, and thus have their own green space/ garden to revitalize their surroundings. This favors adaptation to climate change and the progressive mitigation of its effects in the future since green areas contribute to better air quality and reduce the sensation of heat. This is why the thermal comfort provided by the gardens allows for an area of rest and socialization, which many people want to achieve in their environment, which is why it would increase the percentage of green areas in the city. In addition, other desires are mentioned, such as continuing to grow vegetables, medicinal plants, among others, which are related to the promotion of

FIGURE 15 MOTIVATION BEHIND URBAN GARDENS



eco-friendly activities.

Figure 16 shows how neighbors have perceived the impact of the green spaces on their local environment and microclimate. Here it becomes evident, that cooling functions and thermal comfort, air quality improvement, and the increased presence of local fauna, are amongst the highest ranked positive impacts. But also issues such as flood mitigation or public life, in general, could be improved.

On the other hand, in Figure 17, the data show that the increase in water consumption for irrigation of the orchards is one of the negative factors for the neighbors

FIGURE 16 POSITIVE IMPACTS OF THE URBAN GARDEN (1= THE SAME, 2= A LITTLE, 3= A LOT).

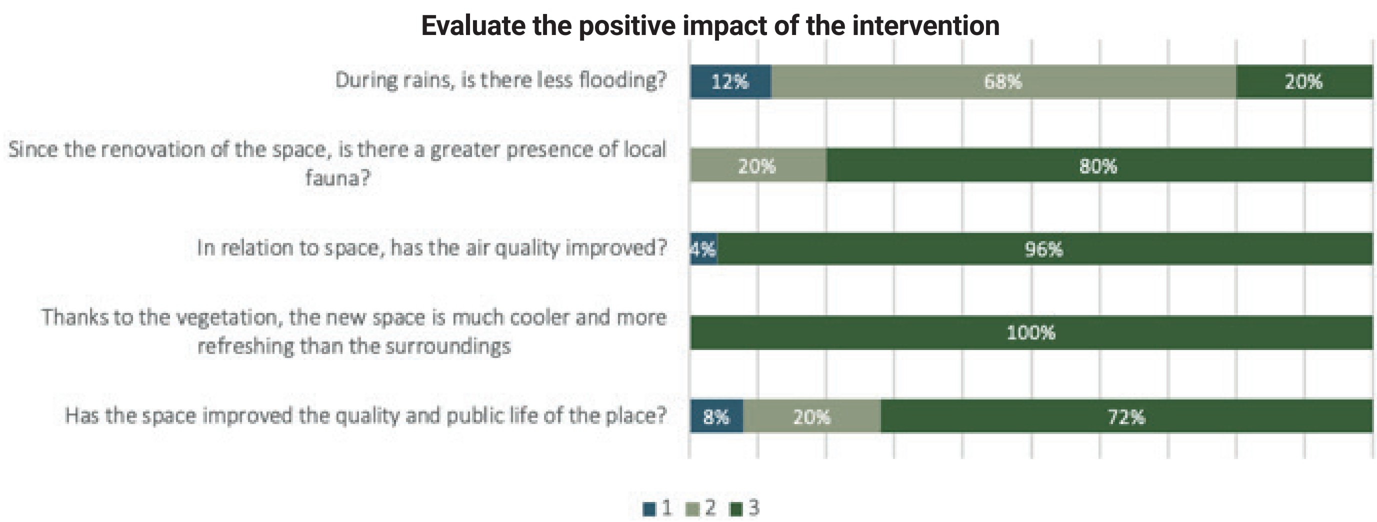
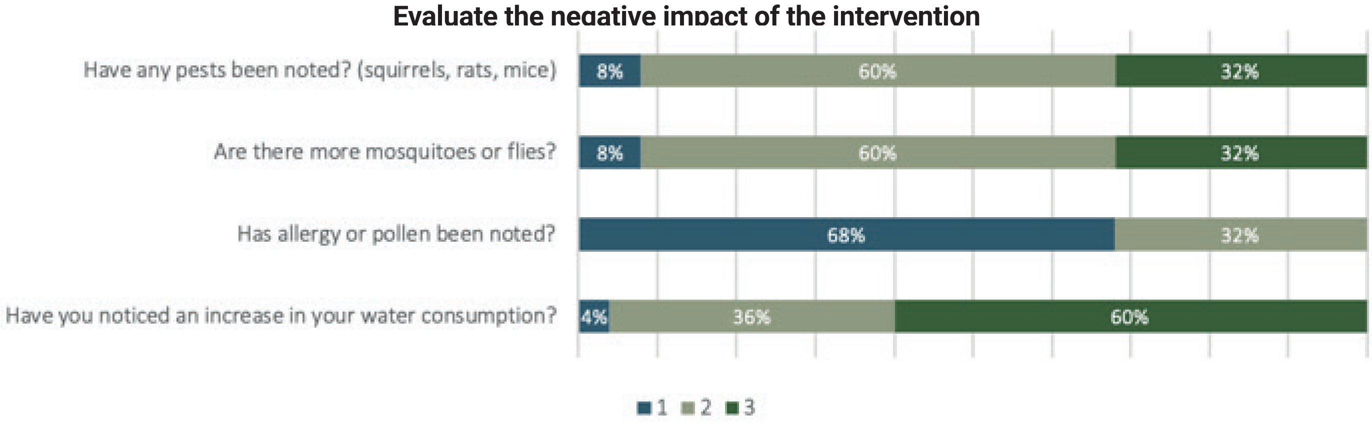


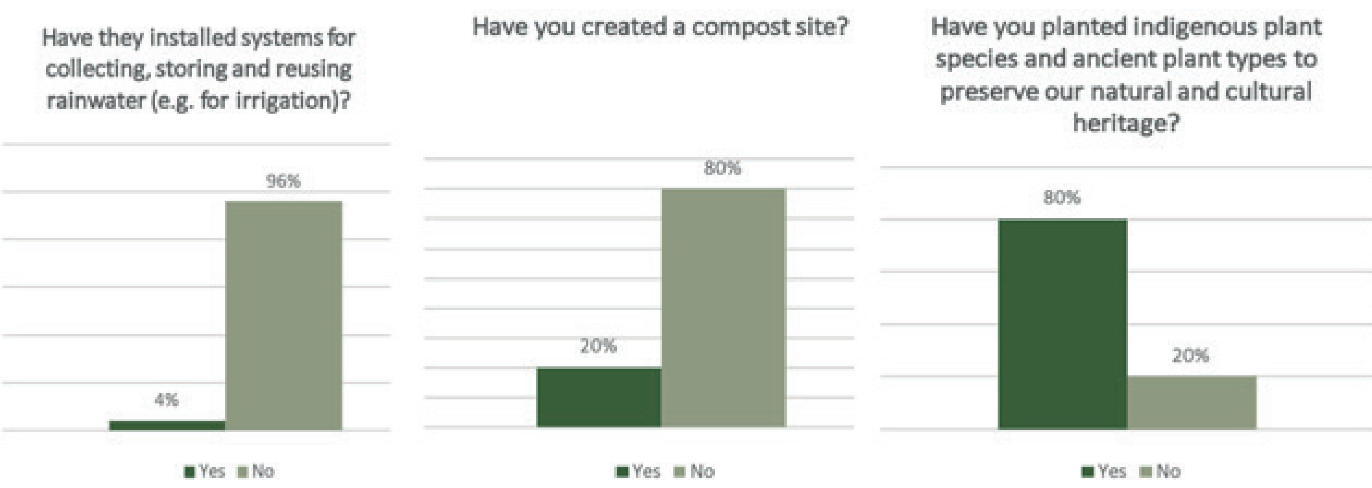
FIGURE 17 NEGATIVE IMPACTS OF THE URBAN GARDENS (1= THE SAME, 2= A LITTLE, 3= A LOT).



since it is economically detrimental to them. In addition, this has repercussions on the proper management of water resources, since Piura is a desert city with limited access to potable water, which is not accessible to the entire population. In addition, the increase in pests (squirrels, rats, mice), mosquitoes or flies, and allergies or pollen are negative trade-offs to a lesser extent.

In terms of maintaining the urban gardens, Figure 18 shows that most people have not installed systems that allow the collection, storage, and reuse of rainwater irrigation purposes. Especially in the face of a changing climate, it is essential to raise awareness in communities about water reuse as a technique for adapting to the bioclimatic consequences of climate change. The use

FIGURE 18: PERCENTAGE OF PEOPLE INSTALLING RAINWATER COLLECTION SYSTEMS, COMPOSTING SITES, OR USING NATIVE AND ADAPTED PLANT SPECIES.



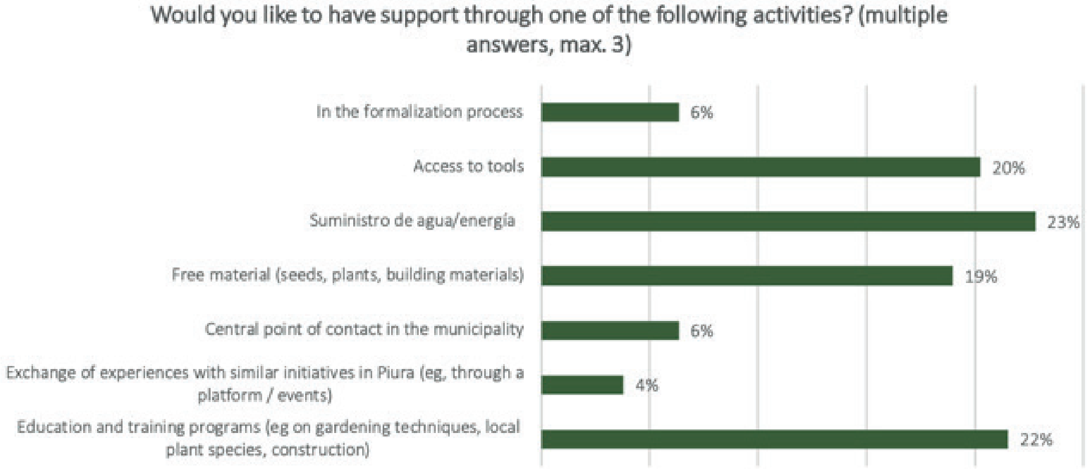
of domestic potable water raises maintenance costs and the stress of available freshwater resources. Another option to improve water availability could be the installation of systems and infrastructure to properly treat wastewater and make it available for irrigation of public green space.

Furthermore, barely 20 % of the respondents have created composting sites to support fertilization and soil health. Organic waste can be used in this type of urban intervention to obtain organic fertilizer that increases the productive capacity of the soil, is low cost, and avoids the use of artificial fertilizers, thus reducing pollution.

In terms of species selection, it was indicated that most of the neighbors have planted native plant species of the city and ancient vegetables to maintain their natural and cultural heritage. Another percentage of those surveyed have cultivated species native to their place of origin (Piura's highlands); however, they also seek to preserve their heritage and provide green areas for the city. The importance of planting species native to the area helps them to grow properly, since they are adapted to local circumstances, use fewer resources for their development and preserve the balance of ecosystems. Still, with a changing environment, other crops and plants may become more feasible in the future. Continuous improvement and adaptation of such management practices are thus crucial to maintain sustainable and climate-resilient urban green spaces.

Finally, many states would like to receive support for their initiative. Figure 19 shows that they mainly need water/energy supply, education, and training programs (related to gardening techniques, local plant species, and construction), access to tools, and subsidies for materials such as seeds, plants, and construction materials. The interest shown by the population to progress with the initiative is necessary to encourage public and private institutions to cooperate in these actions. The more actors involved in climate change adaptation and mitigation processes, the greater the impact on society and, above all, on the environment.

FIGURE 19 ACTIVITIES IN WHICH THE INITIATIVES WOULD LIKE SUPPORT (MULTIPLE RESPONSES, MAX. 3)



The lack of knowledge regarding ecological issues, sustainability, and climate change influence on the conservation and maintenance of urban gardens was identified as a crucial factor that limits the capacity of local initiatives in future-proofing their local neighborhood. Currently, there is a lack of follow-up in environmental awareness programs for citizens by public institutions, as well as little interest in the calls of the neighborhood associations (in Spanish known as Junta Vecinal Comunal or JUVECOS) to attend these initiatives. Because of this, the community does not have the tools or adequate guidance to sustain their gardens over time and generate a cycle of learning and mitigation of climate change with future generations.

6. OVERARCHING INSIGHTS

For the city of Piura, it is essential to work on its urban resilience in the face of climate change to encompass mitigation actions and disaster risk reduction, recognizing the complexity of rapidly growing urban areas and the uncertainty associated with climate change. This approach places greater emphasis on the ability to evolve and adapt to survive and even thrive in the face of these adverse situations. Piura will need to work on three levels of resilience by ensuring that: 1) city-systems survive shocks and stresses; 2) people and organizations are able to accommodate these stresses in their day-to-day decisions; 3) institutional structures are in place to support the ability of people and organizations to meet their objectives.

There is no single action that will make a city resilient to climate change, as this is achieved through a series of actions, which are developed over time. These actions will improve and progress as people and institutions learn from past experiences and apply them to future decisions. In that sense, the city of Piura, despite having gone through several extreme periods of floods and droughts, is not yet considered a resilient city as it is not prepared to recover in the case of one of these events, so it is considered essential to work on it to ensure a prosperous future.

Undeniably, there is a need for urgent climate action in Piura to reduce the impacts of the ENOS events and other climate-related risks, given that research predicts more frequency and intensity by 2040. According to this research, the main impacts are the consequence of the intense and extreme rainfall events, which produce an overflow of the Piura River and therefore floods in the north of Peru, where Piura is located. Furthermore, temperature rise, and urban heat islands have been rated as a high climate-related risk.

In terms of urban planning, the relocation of dwellings located in highly vulnerable sites, and the consideration of blind basins which are activated after intense rainfall, are recommended. In addition, building infrastructure with appropriate materials and reducing self-construction should be encouraged to reduce exposure and increase adaptive capacity.

Due to the excess of stormwater during the rainy season or during ENOS events, it is recommended to implement more nature-based solutions to enhance water resilience, such as detention ponds, bioswales, water harvesting, rain gardens, or other water management techniques. It is important to also focus on the Piura River margin, since it is necessary to implement mitigation measures to prevent its overflows, such as revegetation, reforestation, and installation of gabions, living fascines, or revetment with cuttings. In addition, floods also affect human health due to the pollution generated by the contamination of tap water with sewage due to the lack of an urban drainage system. Therefore, this is perhaps the most urgent action to be addressed.

Whilst this project focuses only on the city of Piura, Piura is not disconnected but intrinsically connected to surrounding ecosystems. Deforestation of the dry mountainous forests in the upper zones of the Piura River Basin affects ecosystem services provided for the city of Piura since it is located downslope in a flat area. Regulation, provisioning, supporting, and cultural ecosystem services are threatened by this activity. Based on that, it is recommended an ecosystem approach or a basin approach management for Piura.
Lack of permeable surfaces and increase of grey infrastructure, as well as reduction of green areas for urban development, is producing heat islands in the city of Piura, which affects human health and economic activities due to lack of thermal comfort which generates performance reduction. This is especially relevant since

studies have concluded the increasing trend of temperature for Piura in 1.0-1,5°C by 2040. This situation shows the relevance of increasing the surface of green areas and the permeabilization of urban soil.

There is much research concerning the FEN, La Niña, and changes in precipitation patterns. However, there is still needed more research regarding changes in biological systems and outbreaks of new infectious diseases and plagues that affect both people and biodiversity, such as plants, animals, and economic activities like agriculture and farming. Likewise, more research is needed with respect to urban heat islands, both about the impacts and solutions for Piura, as the identification or UHI hotspots in Piura, which is essential to start specific actions.

The Regional Government and the Municipality of Piura have been implementing measures to adapt to climate change; however, it is necessary to strengthen their internal capacities and to offer specific training and development of climate-related skills to relevant actors across different departments and decision-making bodies. Furthermore, the promotion of greater citizen participation and the inclusion of indigenous people and knowledge is recommended.

It is necessary to raise climate awareness among stakeholders, mainly in both civil society and public servants. Knowledge regarding climate change concepts and necessary adaptation actions is still basic. It is recommended to promote and encourage good environmental practices as well as citizens' involvement and participation in policies processes and local actions. Stakeholders' climate capacities should be strengthened in order to make better and more informed decisions related to climate change in the future.

The regional and the local government of Piura are disconnected. They should work together to coordinate their progress on climatic and environmental issues, but also with the academic, private sector, and the citizens if the idea is to create a prosperous environment for innovation and sustainable urban development. Furthermore, international cooperation should be sought and fostered for the development of cooperative research and implementation of projects related to climate change.

Whilst there is funding for disasters prevention, there is no specific budget for climate change adaptation and resilience for Piura. Moreover, the POI (Institutional Operative Plan) 2020-2023 considers a budget for vulnerabilities reduction and response to emergencies, but it does not include pilot projects. Thus, investment in pilot projects aimed at reducing vulnerability and increasing the resilience of cities should be promoted. It is important to carry out vulnerability and risk estimation studies on climate change; however, this knowledge should be implemented in regional and local development plans.

It is a priority that all regional and local management instruments be coordinated and oriented towards sustainable development. Furthermore, climate change is not yet well included in planning as a key priority. It is mainly associated with disasters caused by El Niño and vector-transmitted infectious diseases, such as dengue, zika, and chikungunya.

Universities and professional associations should be encouraged to develop research topics related to environmental quality and risk management which could help refine local climate scenarios and include uncertainty aspects and new monitoring approaches to promote adaptive planning.

In terms of citizen initiatives and their perception of climate change and urban spaces, the analysis described in chapter 5 has uncovered that urban gardens have been a way for neighborhoods to improve local microclimate and environment. Thereby the same needs and ideas for improvement for the implementation of gardens were raised. Often, the gardens are currently not adequately maintained, due to a lack of resources, lack of interest and support from public institutions, as well as a lack of knowledge on the part of the neighbors. Thus, three important related factors could be identified for further improvement and support of such initiatives and consequently the regeneration towards a climate change resilient city. These factors are 1) Organic waste management and soil recovery (composting), 2) Rain- and wastewater management and utilization; and 3) Environmental and climate change education and awareness-raising within community groups.

7. CITY LAB PIURA - CONTRIBUTIONS TO CLIMATE RISK ADAPTATION

As part of the MGI Piura City Lab, a roadmap has been developed which includes concrete project ideas that could support the city in its climate-friendly future development. (Fernández et al., 2021) . Whilst most of these projects target specific challenges in the focus sectors of the city lab – namely urban planning, water, and energy – they also hold a great potential to help enhance climate resilience. Figure 20 shows the links between the developed project ideas and the risk clusters as described above.

Additionally, as part of the MGI initiative in Piura, a citizen's engagement festival is planned to increase sensibilization, participation around the thematic of urban gardening and climate change within the city. The event is a follow up of the study described in chapter 5 and focuses on water use and re-use, cultivation of native plants, compost, capacity building, amongst others.

To enhance the synergies between climate change mitigation and adaptation and the potential in combatting climate risks, the individual project planning needs to take resilience considerations into account from the very beginning on. The use of selected key performance indicators (KPIs) and their integration in a holistic project monitoring plan can for instance be a way to make sure that the achieved effects can be measured, tracked, and improved. Table 1 presents an overview and collection of different KPIs that can be used in assessing project performance in the area of climate resilience. Furthermore, the TAMD framework that was used in this initial assessment can be used to keep track of undertaken adaptation measures. The full list of framework criteria can be found on the IIED official website. These examples are intended as the first guiding support for future project planning, implementation, and monitoring in the city of Piura. The adequate choice of relevant indicators, availability of reliable baseline data, as well as well-chosen measurement boundaries (project to city level), can help to prove impact and provide evidence on achieved project objectives.

FIGURE 20: LINKING PROJECT DEVELOPMENT IDEAS TO THE ASSESSED CLIMATE RISK CLUSTERS

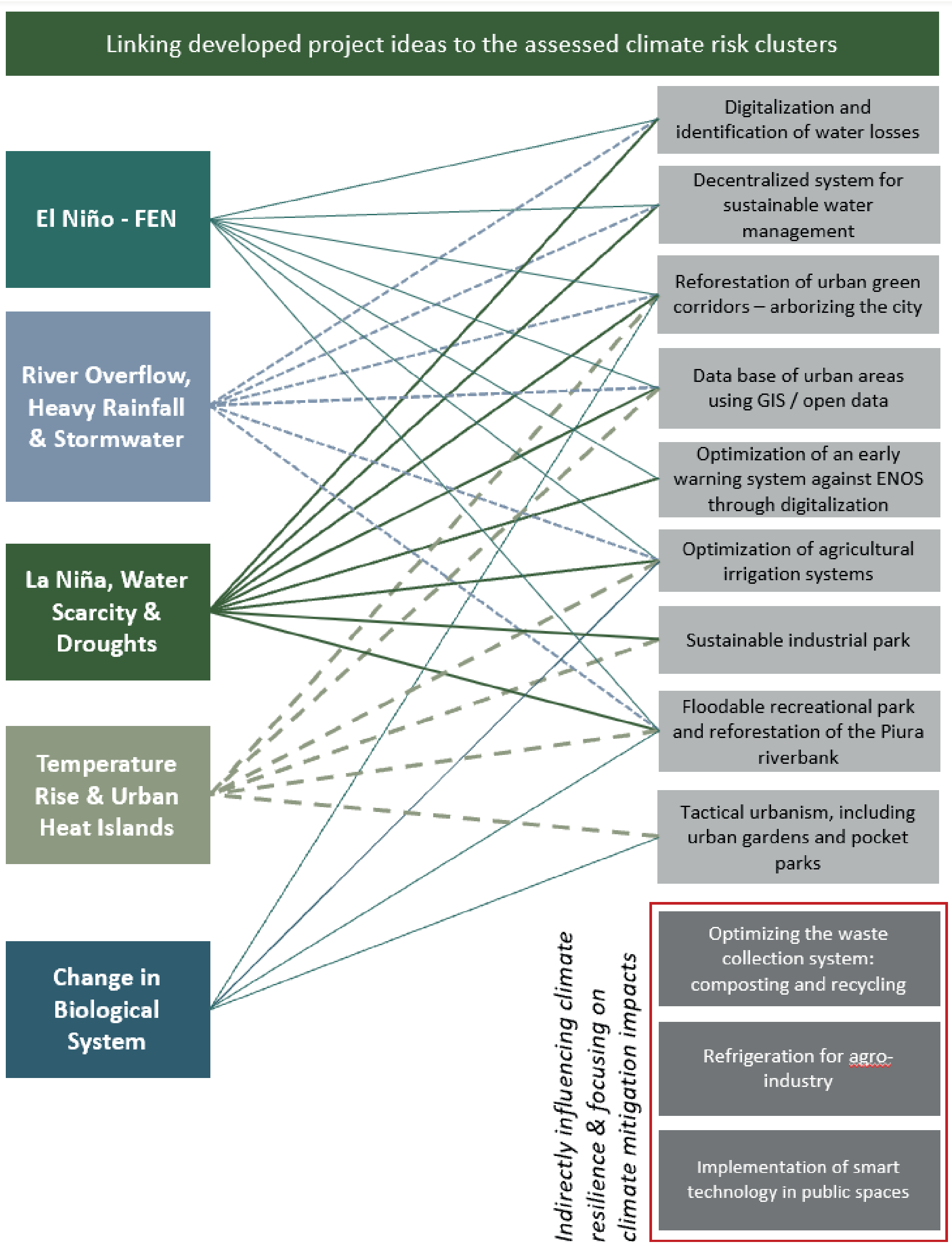


TABLE 1: OVERVIEW OF INDICATORS TO BE USED IN THE MONITORING AND PERFORMANCE EVALUATION OF CERTAIN CLIMATE CHANGE RISK CATEGORIES (EXEMPLARY COMPILATION).

Grupo de indicadores	Indicador	Unidad de medida	Descripción	Fuente
Heavy rainfalls & flooding	Flood peak height		Increase flow rate (peak flow) reduction due to a given rain event, thanks to the project intervention. The peak flow is the maximum value of the flow rate due to a given rain event. Peak flow variation is defined by the relative error in peak flow between the peak flow of the catchment where the project intervention is located and the peak flow of a catchment without the intervention. This indicator can be calculated as the average value of a sample of peak flows deduced from a rain/runoff time series (typically one year) and may be obtained with observed runoff or simulated runoff. This indicator will directly assess the impact of the project intervention in the reduction of the flow rate, which peak flow is a characteristic value.	Nature 4 Cities, SSWM (Nature4Cities 2017; McCaffrey n.y.)
	Stormwater run-off	mm/%	Run-off coefficient in relation to precipitation quantities	UNaLab (Wendling et al. 2019)
	WDT - Water Detention Time		Increased infiltration. The detention time corresponds to the theoretically calculated time required for a given amount of water to flow from a given area to another area at a given flow rate.	Naturaleza 4 Ciudades (Nature4Cities 2017)
	Areas exposed to flooding	ha	Updated flood maps and monitoring data	MAES (Comisión Europea 2016)
	Regulation of quantity of water		Measures for instance flood reduction due to increased soil permeability (Total permeable area) ÷ (Total terrestrial area of the city) × 100% This indicator aims to know if the project intervention increased soil permeability, which impacts on flood reduction)	Singapore Index (Chan et al. 2014)
Water scarcity	Rainwater or greywater use	% of houses	Percentage of houses equipped to reuse grey and rain water	CITY keys (Bosch 2017b)
	Increase in water re-used	in m3	Increase in percentage of rain and grey water re-used to replace potable water	CITY keys (Bosch 2017b)
	Water Exploitation Index	% of m3	Reduction in annual total water abstraction as a percentage of available long-term freshwater resources in the geographically relevant area (basin) from which the city gets its water	CITY keys (Bosch 2017a)
	Reduction of drought events	n°	Ratio between droughts since the project implementation / historic data (min. 50 years).	Green Surge (Hansen et al. 2017)
	Reduction in water consumption	% in m3	Reduced water consumption through more careful and/or efficient use	Claves de la ciudad (Bosch 2017b)
Rising Temperature & UHI	Temperature reduction	°C	Decrease in mean or peak daytime local temperatures. For specific project areas, (mobile) measurement of the microclimate on local level will be useful	UnaLab (Wendling et al. 2019)
	Urban Heat Island (UHI) Effect	°C	Reduction in Urban Heat Island (UHI) effect within the project zone	CITY keys (Bosch 2017a)
Change in biological system	Green Space Intensity	total area / %	The proportion of natural areas within a defined project zone	MGI Indicators
	Increase in green and blue space	% in m2	% increase of green and blue spaces due to the project	CITY keys (Bosch 2017b)
	Increased connectivity	TBD	Structural and functional connectivity of green spaces and habitats	UnaLab (Wendling et al. 2019)
		TBD	Ecological connectivity	UnaLab (Wendling et al. 2019)
	Conservation	Number per unit area	Number and abundance of species of conservation interest (#/ha)	UnaLab (Wendling et al. 2019)
	Species diversity	Number per unit area	Number and abundance of, e.g., species of birds (#/ha)	UnaLab (Wendling et al. 2019)
	Relative abundance of insect pollinators	n°/ha or m2		MAES (European Commission 2016)

8. ANNEXES

I. CLIMATE RISK AND RESILIENCE EXPERT SURVEY RESPONSE VALUES

TABLE 2: CLIMATE RISK AND RESILIENCE EXPERT SURVEY RESPONSE VALUES

El Niño Phenomenon - ENSO

Risk factors	Magnitude/intensity	Probability /Frecuency	Irreversibility/ Persistence
Expert rating*	2.87	2.27	2.53
Standard deviation	0.35	0.59	0.64
Response rate	1	1	1

Vulnerability		People	Economy	Environment	Built infrastructure
Expert rating*	Exposure	2.73	2.33	2.07	1.80
	Susceptibility	2.60	2.07	2.00	2.67
	Adaptive Capacity	1.87	1.53	1.80	2.13
Standard deviation	Exposure	0.46	0.82	1.03	0.35
	Susceptibility	0.83	0.96	1.07	0.49
	Adaptive Capacity	0.83	0.83	1.01	0.92
Response rate	Exposure	100%	93%	87%	100%
	Susceptibility	93%	87%	87%	100%
	Adaptive Capacity	100%	87%	87%	100%

*1= low, 2 = medium, 3 = high

River overflow, heavy rainfall and stormwater

Risk factors	Magnitude/intensity	Probability /Frecuency	Irreversibility/ Persistence
Expert rating*	2.27	1.80	1.87
Standard deviation	0.96	0.56	0.74
Response rate	93%	100%	93%

Vulnerability		People	Economy	Environment	Built infrastructure
Expert rating*	Exposure	2.67	2.27	1.93	2.73
	Susceptibility	2.67	2.20	1.93	2.73
	Adaptive Capacity	1.87	1.87	1.60	2.00
Standard deviation	Exposure	0.49	1.03	1.16	3.59
	Susceptibility	0.49	1.08	1.16	0.76
	Adaptive Capacity	0.74	1.13	1.12	0.76
Response rate	Exposure	100%	87%	80%	100%
	Susceptibility	100%	87%	80%	100%
	Adaptive Capacity	100%	87%	80%	100%

*1= low, 2 = medium, 3 = high

La Niña, water scarcity and droughts

Risk factors	Magnitude/intensity	Probability /Frecuency	Irreversibility/ Persistence
Expert rating*	2.27	1.80	1.87
Standard deviation	0.96	0.56	0.74
Response rate	93%	100%	93%

Vulnerability		People	Economy	Environment	Built infrastructure
Expert rating*	Exposure	2.67	2.27	1.93	2.73
	Susceptibility	2.67	2.20	1.93	2.73
	Adaptive Capacity	1.87	1.87	1.60	2.00
Standard deviation	Exposure	0.49	1.03	1.16	0.46
	Susceptibility	0.49	1.08	1.16	0.46
	Adaptive Capacity	0.74	1.13	1.12	0.76
Response rate	Exposure	100%	87%	80%	100%
	Susceptibility	100%	87%	80%	100%
	Adaptive Capacity	100%	87%	80%	100%

*1= low, 2 = medium, 3 = high

Temperature rise and urban heat islands

Risk factors	Magnitude/intensity	Probability /Frecuency	Irreversibility/ Persistence
Expert rating*	2.67	2.53	2.07
Standard deviation	0.90	0.92	0.96
Response rate	93%	93%	93%

Vulnerability		People	Economy	Environment	Built infrastructure
Expert rating*	Exposure	2.40	1.93	2.33	1.93
	Susceptibility	2.40	1.80	2.27	1.87
	Adaptive Capacity	1.87	1.60	1.87	1.53
Standard deviation	Exposure	0.83	1.03	1.05	1.10
	Susceptibility	0.83	1.01	1.03	1.19
	Adaptive Capacity	0.83	0.99	0.99	1.13
Response rate	Exposure	93%	87%	87%	80%
	Susceptibility	93%	87%	87%	80%
	Adaptive Capacity	93%	87%	87%	80%

*1= low, 2 = medium, 3 = high

Changes in biological system

Risk factors	Magnitude/intensity	Probability /Frecuency	Irreversibility/ Persistence
Expert rating*	2.00	2.00	1.73
Standard deviation	1.20	1.20	1.10
Response rate	80%	80%	80%

Vulnerability		People	Economy	Environment	Built infrastructure
Expert rating*	Exposure	1.87	2.00	1.93	1.53
	Susceptibility	1.80	2.13	1.73	1.60
	Adaptive Capacity	1.40	1.53	1.53	1.40
Standard deviation	Exposure	1.30	1.25	1.33	1.25
	Susceptibility	1.26	1.25	1.22	1.24
	Adaptive Capacity	1.12	1.19	1.19	1.18
Response rate	Exposure	73%	80%	73%	73%
	Susceptibility	73%	80%	73%	73%
	Adaptive Capacity	73%	80%	73%	73%

*1= low, 2 = medium, 3 = high

II. INVOLVED EXPERTS

In order to conduct this assessment, valuable contributions were made by experts in Peru who provided ideas, knowledge, and motivation during the interview and survey stages.

These experts belong to different institutions, organizations, companies, and government agencies, such as the University of Piura (UDEP), National University of Piura, Pontificia Universidad Católica del Peru, Centre for Water Research and Technology, Department of Innovative Piura (UDEP) and the Piura's College of Engineers.

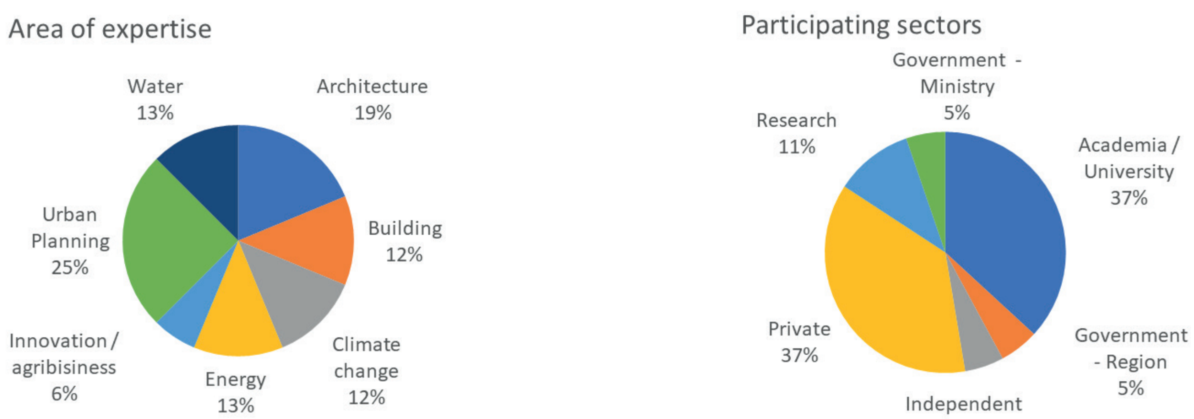
The active involvement of the Municipality of Piura was important for the success of this project, particularly from the following departments: Environment, Population, and Health; Ornament; Territorial; Solid Waste and the Formulation Unit. The Government of the District of Veintiséis de Octubre; National Ministry of Housing and the National Water Authority.

Contributions from the Strategic Planning Center of Piura Region, Authorities of "Reconstruction with Change" (ARCC), the Chira-Piura Special Project, and the Alto Piura Special Irrigation and Hydroenergy Project were also valuable for this endeavor.

Regarding the private sector, this project benefited from insights and recommendations from the Chamber of Commerce of Piura, EPS Grau S.A. (Piura, Paita and Curumuy Offices), TRESSAN SAC, Piura Futura, and ENOSA.

Experts interviewed for the completion of this project have a diverse professional and academic background. Figures below describe their fields of expertise and the percentage of each sector's participation.

FIGURE A.1: AREA OF EXPERTISE AND SECTOR OVERVIEW OF THE SURVEY EXPERTS



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CITY LAB PIURA, PERÚ

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