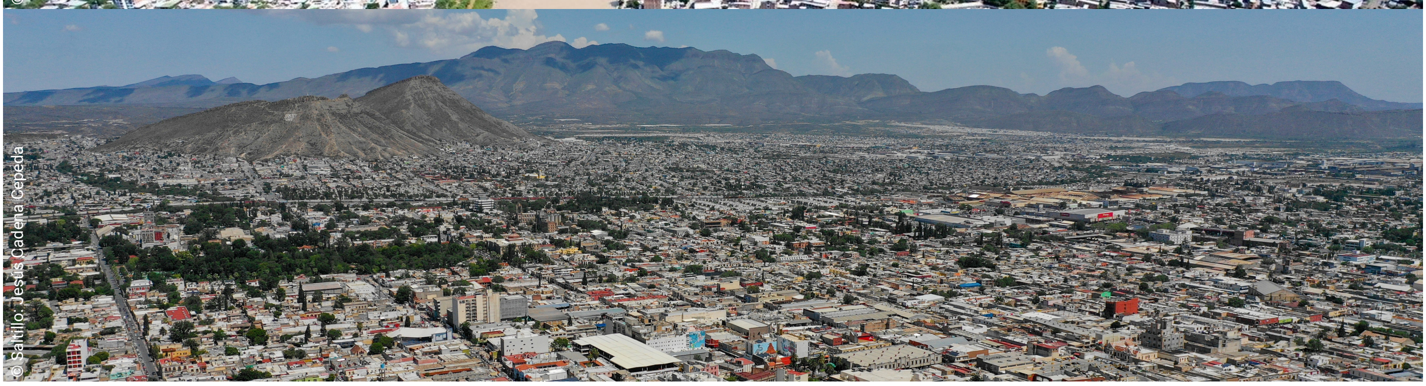
University of Stuttgart
Institute of Human Factors and
Technology Management IAT

Fraunhofer

CITY LABS KOCHI, PIURA, AND SALTILLO

CLIMATE RISK AND RESILIENCE IN THE GLOBAL CONTEXT

INSIGHTS FROM THE MORGENSTADT GLOBAL SMART CITIES INITIATIVE



mgi MORGENSTADT GLOBAL SMART CITIES INITIATIVE
GLOBAL APPROACH – LOCAL SOLUTIONS

MorgenStadt
City of the Future

Supported by:

Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag

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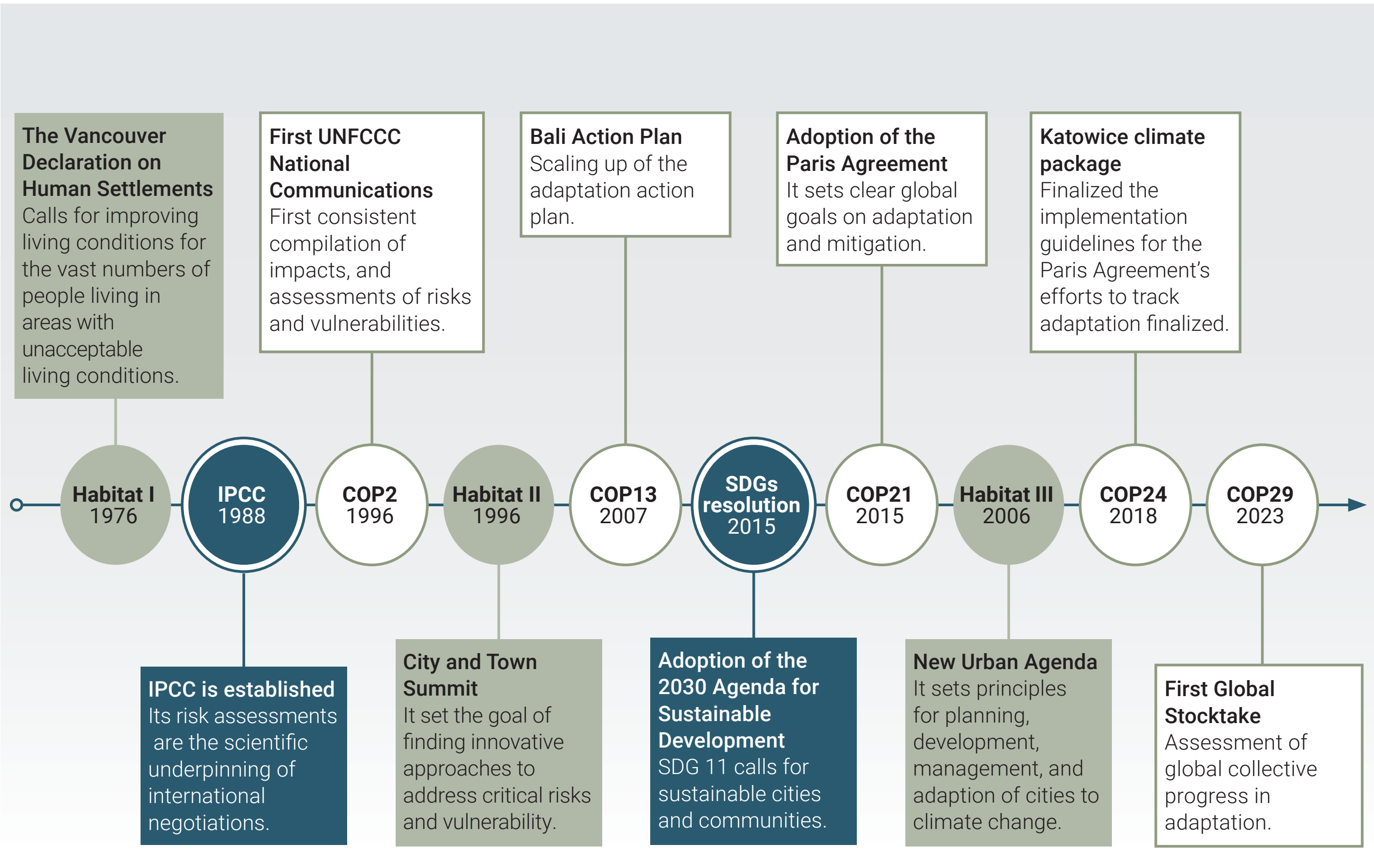
1 CLIMATE RISK AND RESILIENCE IN THE GLOBAL CONTEXT

The effects of rapidly rising mean temperatures due to climate change are materializing with both greater speed and higher severity than ever forecasted (Neu and Fünfgeld 2022; IPCC 2021). In particular, the impacts of climate change pose great threats for urban areas and the safety of urban residents. It is in cities where most of the world's inhabitants will live; and it is in cities where high population densities, dense building structures, and sealed surfaces increase climate-related risks and impacts. Many cities have therefore started implementing hard and soft adaptation measures to increase local climate resilience and protect citizens and vulnerable groups from emerging climate risks. Due to their action-oriented (local) focus and pragmatism, their role as economic activity hubs, as well as their significant impact on the quality of life for inhabitants, cities are especially well-suited for a leadership role in both climate change mitigation and adaptation (Rosenzweig et al. 2011). As most climate change impacts manifest at the local level, it is important to take adaptive action on comparatively local scales to ensure that social responses fit the climatic impact (Oberlack and Eisenack 2014).
Especially in middle- and low-income countries, a lower standard of service and infrastructure results in disasters that cause greater numbers of fatalities and affect greater numbers of people than in high-income countries. The Intergovernmental Panel on Climate Change's 4th National Climate Assessment Report (IPCC 2007) found that low-income individuals and communities are more exposed to environmental hazards and pollution and are less equipped to recover from the impacts of climate change. Hence, climate change threatens to reverse the development gains that these countries have made. High, middle- and low-income countries are thus highly unequal in terms of their historical responsibility for, risks of impacts from, and capacity to adapt to climate change (Oberlack and Eisenack 2014). Furthermore, their abilities and strategies to deal with climate change risks differ. Therefore, international cooperation and support are important for the promotion of climate justice, and to ensure that global challenges can be met through local action.

FIGURE 1: URBAN RESILIENCE AND ADAPTATION-RELATED MILESTONES IN INTERNATIONAL POLICY ARRANGEMENTS



Given this background, climate adaptation has also become a major agenda item in international climate policy (Oberlack and Eisenack 2014). The Paris Climate Agreement, ratified by 195 UNFCCC member states (UN 2016), for instance, reaffirms the obligations of high-income countries that have committed to support the efforts of middle- and low-income country governments to build clean, climate-resilient futures – a commitment that is yet to be fulfilled. Furthermore, the G20 countries should also reduce their emissions as they account for 80% of the world's total emissions (Climate Transparency 2019). Enhanced international cooperation and broad partnerships to address climate change are also major elements of the Global Goals and the 2030 Agenda for Sustainable Development (UN 2015).

According to the World Cities Report (UN-Habitat 2022), the pace and scale of global urbanization continues to outpace the ability of governments to plan and provide services for everyone, especially in middle- and low-income countries. Urbanization is currently stretching the boundaries of cities, blurring jurisdictional lines, and leading to a lack of clarity about who handles emerging challenges. The UN-Habitat report identified four major shocks facing cities across the globe: climate change, extreme poverty and inequality, the fourth industrial revolution, and COVID-19. The necessary urban governance responses to these shocks must also acknowledge the reality of unplanned growth and the blending of urban, peri-urban, and rural areas (UN-Habitat 2022). In this context, projects like the Morgenstadt Global Smart Cities Initiative (MGI), funded by the German Government through the International Climate Initiative (IKI), represent important international collaboration efforts to mitigate and adapt to climate change. The initiative focuses on three growing cities across the globe and builds on international expert knowledge and exchange to catalyze change at the local level. These efforts are crucial to help cities face the challenges that come in small and medium cities with high urbanization rates. The present publication summarizes the findings and lessons learned with a particular focus on climate risk and resilience.

FIGURE 2: IMPACTS OF CLIMATE CHANGE

LOSSES DUE TO WEATHER RELATED DISASTERS WORLDWIDE (1970-2019)[1]

11,072
REPORTED DISASTERS

577K
DEATHS FROM STORMS

650K
DEATHS FROM DROUGHTS

2.06
MILLION
DEATHS

58K
DEATHS FROM FLOODS

55K
DEATHS EXTREME TEMERATURES

3.6
TRILLION US$
ECONOMIC LOSSES

DEVELOPMENT OF RISKS

5×
THE NUMBER OF WEATHER DISASTERS HAS INCREASED BY A FACTOR OF FIVE OVER THE LAST 50 YEARS[2]

SINCE
1990
THE UN IPCC HAS PROVIDED EVIDENCE OF THE LINK BETWEEN INCREASED CLIMATE RISKS AND ANTHROPOGENIC CLIMATE CHANGE[3]

9 / 10
HOTTEST YEARS EVER RECORDED GLOBALLY AND IN EUROPE HAVE OCCURRED SINCE 2000[4]

EXPECTED IMPACTS

130+
MILLION
PEOPLE COULD BE PUSHED INTO POVERTY BY 2030 DUE TO CLIMATE CHANGE[5]

216
MILLION
PEOPLE COULD BE DRIVEN TO MIGRATE WITHIN THEIR OWN COUNTRIES BY 2050 DUE TO CLIMATE CHANGE[6]

UP TO **20%**
OF GDP COULD BE LOST DUE TO CLIMATE CHANGE IF NEITHER ADAPTATION NOR MITIGATION STRATEGIES ARE PURSUED. CLIMATE CHANGE CAN HAVE SIGNIFICANT IMPACTS ON THE ECONOMIES OF MOST MIDDLE- AND LOW-INCOME COUNTRIES [7,8]

CAUSES & CONTRIBUTORS

60% – 80%
OF ENERGY PRODUCTION WORLDWIDE
IS CURRENTLY CONSUMED BY URBAN ACTIVITIES AND ACCOUNT FOR ROUGHLY AN EQUAL SHARE OF GLOB-AL CO_2 EMISSIONS[9]

0.3
METRIC TONS
OF CO_2 PER CAPITA WERE EMITTED BY LOW-INCOME COUNTRIES IN 2019[10]

9.8
METRIC TONS
OF CO_2 PER CAPITA WERE EMITTED BY HIGH-INCOME COUNTRIES IN 2019[11]

[1,2,3,4,5,6,7,8,9,10,11] See references in section 7

2 MGI - MORGENSTADT GLOBAL SMART CITIES INITIATIVE

The MGI project is aiming to transform Kochi (India), Piura (Peru), and Saltillo (Mexico) through the analysis of their urban systems and the identification and development of sustainable cross-sectoral solutions to optimize urban infrastructure, processes, and services. It intends to help the cities to increase their resilience to the impact of weather events, as well as to support their GHG emission reduction efforts. As part of the IKI network, the MGI's primary objective is to mitigate the consequences of climate change in the pilot cities in order to increase their resilience to climate impacts and risks, and to preserve their natural resources better, whilst also promoting international cooperation and exchange.

Three so-called City Labs were conducted, to assess the status quo and develop an action roadmap. The focus of the City Labs was selected based on the main challenges each individual city faced with regards to climate and urban development. Part of the analysis was also the focus on climate risk and resilience, covered in this publication. The MGI project, developed out of the Fraunhofer Morgenstadt Initiative, is a network of research institutes, municipalities and companies that was launched in 2011 by the Fraunhofer Institute for Industrial Engineering (IAO) to conceptualize, develop and test innovations for the city of tomorrow (Mohr et al. 2020).

FIGURE 3: PROJECT PARTNERS

FUNDING

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

COORDINATION

University of Stuttgart Institute of Human Factors and Technology Management

Fraunhofer IAO

IMPLEMENTATON

Fraunhofer

Frankfurt School of Finance & Management

PIURA MUNICIPALIDAD PROVINCIAL

Tecnológico de Monterrey

Universidad de Piura

National Institute of Urban Affairs

IMPLAN Instituto Municipal de Planeación Saltillo

c-hed

FIGURE 4: OVERVIEW OF THE PARTNER CITIES

SALTILLO

POPULATION
Saltillo has a population of over one million inhabitants.

SOCIOECONOMIC PROFILE
It is located in Coahuila, among Mexico's wealthiest states, with a per capita income of 25% above the national average and a per capita Gross Domestic Product of 33% above the national average (Gobierno del Estado de Coahuila de Zaragoza 2021). The city is firmly based on industrial activities, in particular automobile, machinery and steel products manufacturing.

CLIMATE
Saltillo has semi-arid, dry weather with high solar radiation and low precipitation throughout the year. This represents vast solar potential above 1,900 kWh/kWp (~22% of the year) (Ordoñez et al. 2016).

PIURA

POPULATION
The Metropolitan area of Piura has a population of between 550 000 and 600 000 inhabitants, and has the eighth highest urban growth in Peru (Zucchetti, A., & Freundt, D. 2018).

GEOGRAPHY
The city has a surface area of approximately 589 km² and is located in the Sechura desert ecoregion in northwestern Peru, close to Ecuador.

SOCIOECONOMIC PROFILE
In the districts that constitute the metropolitan area of Piura, more than one-third of the population has at least one unmet basic need (NBI, to use the Spanish acronym), such as access to housing, sanitation, etc. (MPP, 2015).

CLIMATE
Piura's climate is hot, desert-like, and oceanic, with a climatic variability of extraordinary rainfall and droughts due to El Niño-Southern Oscillation (ENOS) events (Fernández et al. 2021).

KOCHI

POPULATION
The city is home to approximately 600,000 inhabitants, whereas the urban agglomeration accommodates 2.1 million inhabitants.

GEOGRAPHY
Kochi is located in Kerala, a state that outperforms most states on health, education and poverty eradication in India. Kochi has a coastline of 48 kilometers.

SOCIOECONOMIC PROFILE
It is the economic, touristic and commercial center of the state of Kerala. Second to Mumbai, Kochi is the most important port city on the western coast of India. However, the city has become increasingly exposed to the risks and concerns associated with climate change.

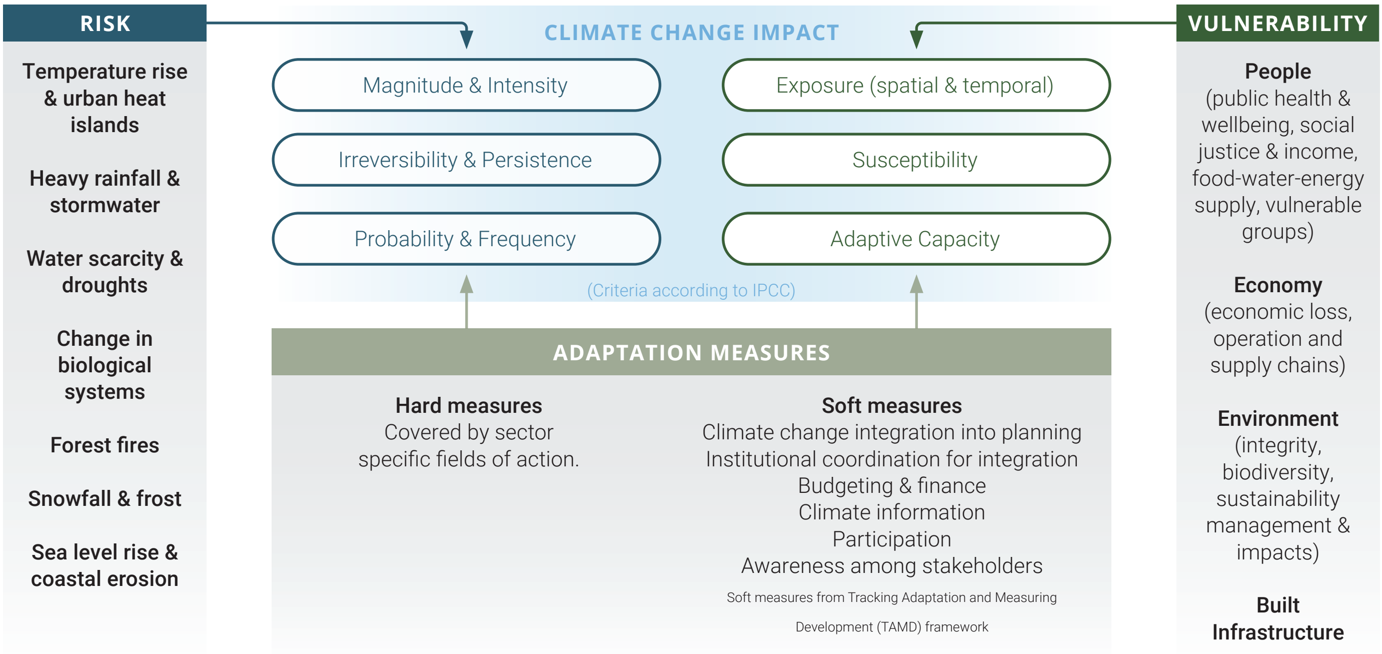
CLIMATE
The city is embedded in a complex network of rivers, tidal creeks and backwaters, due to which Kochi has been regularly subjected to natural disasters like floods, cyclones, droughts and landslides (Zucchetti, A., & Freundt, D. 2018).

3 ASSESSMENT FRAMEWORK AND DEFINITIONS

In the following chapters, the climate change risk and resilience assessment is presented, which has been conducted in the three MGI pilot cities to better understand climate risks and resilience across the world.

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 the potential consequences of hazardous events. Figure 5 summarizes the applied assessment framework.

FIGURE 5: MGI RISK AND RESILIENCE ASSESSMENT FRAMEWORK



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

Magnitude and intensity: How strong the impact and consequences will be.

Probability and frequency: How likely and often a hazard will occur.

Adaptive capacity: The ability of a system to adapt and respond to the risks in order to avoid and moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

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

Exposure (temporal & spatial): How exposed a community or socio-ecological system is to climatic stressors and hazards.

Susceptibility: Preconditions related to the individual that make communities or socioecological systems highly susceptible to additional climatic hazards or that reduce their adaptive capacity.

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

The vulnerability index:
A vulnerability index was developed with the data collected through questionnaires delivered to experts for each climate risk. Four sectors were considered: people, environment, infrastructure, and economy. Figure 6 shows an example.

The risk assessments:
In addition of the vulnerability index, triangle diagrams also show the risk assessment. The risks assessment graphs allow to observe the chances of the realization of impacts related to the climate risk in question. Figure 7 shows an example. The formula used to calculate the index is available in the annex.

FIGURE 6: EXAMPLE OF RISK ASSESSMENT DIAGRAM

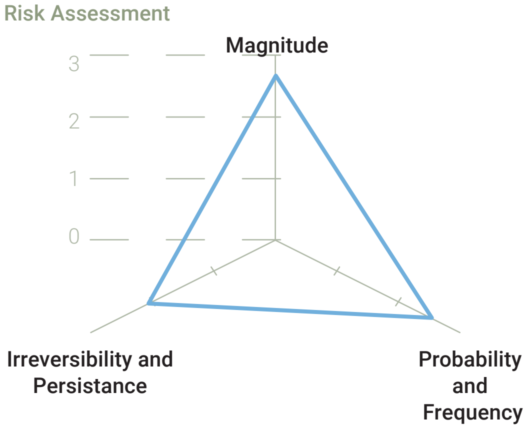
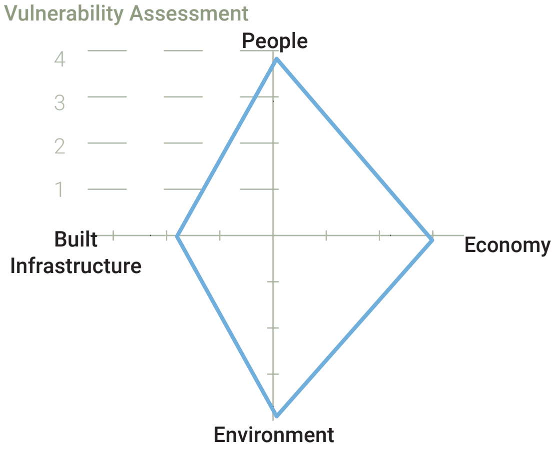


FIGURE 7: EXAMPLE OF VULNERABILITY ASSESSMENT DIAGRAM



The assessment framework combined two existing approaches to evaluate climate-related risk and resilience:

a) The IPCC assessment method on emergent risks and key vulnerabilities covering the aspects in Figures 5, 6 and 7. The IPCC is the United Nations body for assessing the science related to climate change. It provides regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation (UNEP 2022a). This framework was used to structure understanding around climate risks and vulnerabilities. It underscores that the development process of a society has significant implications for exposure, vulnerability, and risk. Climate change is not a risk per se, but its related hazards interact with the evolving vulnerability and exposure of systems and therewith determine the changing level of risk. Identifying key vulnerabilities facilitates estimating key risks. This approach provides the basis for the criteria developed in the following sections (Oppenheimer et al. 2014).

b) The Tracking Adaptation and Measuring Development (TAMD) framework by IIED covers the soft adaptation measures listed in Figure 5. The TAMD approach is a framework developed by the International Institute for Environment and Development (IIED) to track adaptation and measure its impact on development and focuses on soft adaptation and governance measures. It is used to evaluate adaptation success as a combination of how widely and how well countries or institutions manage climate risks. The original framework includes eight indicators which define sets of questions to assess the current status and track performance (IIED 2014). For the MGI analysis, the framework has been slightly adapted and summarized to six indicators.

Data Sources

Relevant data for the MGI risk and resilience assessment has been sourced through different means, including:

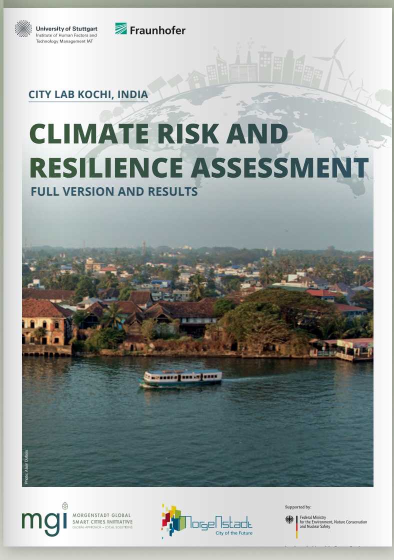
a) Information from scientific publications, official strategies, and municipal documents, as well as forecasts and models.

b) Expert surveys and interviews with local experts in the area of climate risk and resilience.

c) Results and data from an overarching city lab process, which assessed different climate-related sectors to develop a sustainability profile, as well as an action-oriented roadmap with innovative measures and pilot projects.

The information presented in this publication is largely taken and summarized from the individual risk and resilience assessment reports of the MGI cities available at the online library of MGI:

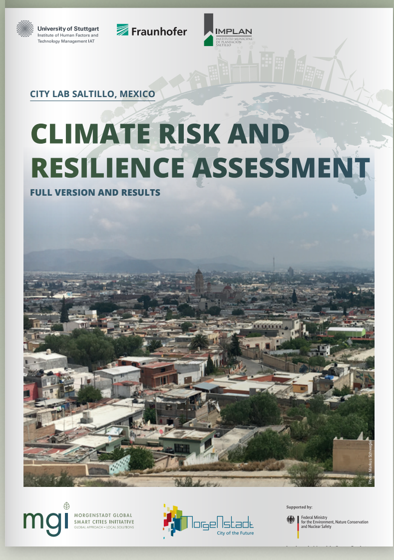
FIGURE 8: MAIN SOURCES OF THIS REPORT



KOCHI RISK AND RESILIENCE ASSESSMENT

FULL VERSION AND RESULTS

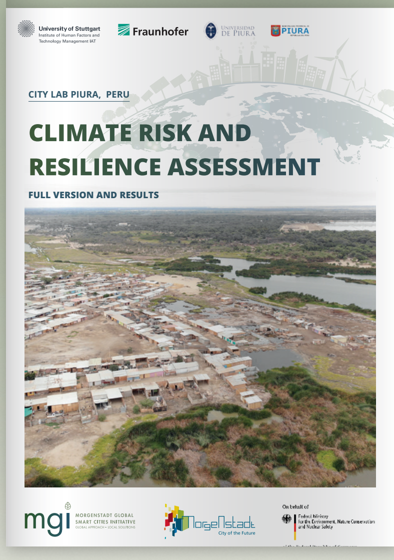
Click here to access the full report or scan the QR code



SALTILLO RISK AND RESILIENCE ASSESSMENT

FULL VERSION AND RESULTS

Click here to access the full report or scan the QR code



PIURA RISK AND RESILIENCE ASSESSMENT

FULL VERSION AND RESULTS

Click here to access the full report or scan the QR code

4 RISK CLUSTERS

4.1 TEMPERATURE RISE & URBAN HEAT ISLANDS

Increasing temperatures due to climate change pose a major challenge to cities, a trend that is intensified by the urban heat island effect (UHI).

UHI describes the heat accumulation phenomenon that leads to higher temperatures in cities compared to natural and rural areas. Main drivers of UHI include densely built-up environments that accumulate solar radiation, a lack of vegetation and surface moisture, waste heat generated by human activities, heat-trapping pollutants, and the canyon effect of buildings.

Heat waves and more frequent extreme temperatures especially impact vulnerable groups, such as elderly people or children. In an empirical study, Vicedo-Cabrera et al. (2021) used data gathered from 1991-2018 from 732 locations in 43 countries to estimate the mortality burdens associated with climate change. The study revealed that from a total of 29.9 million deaths during the warmest season, an average of 9,702 deaths across the 732 locations were specifically due to climate change.

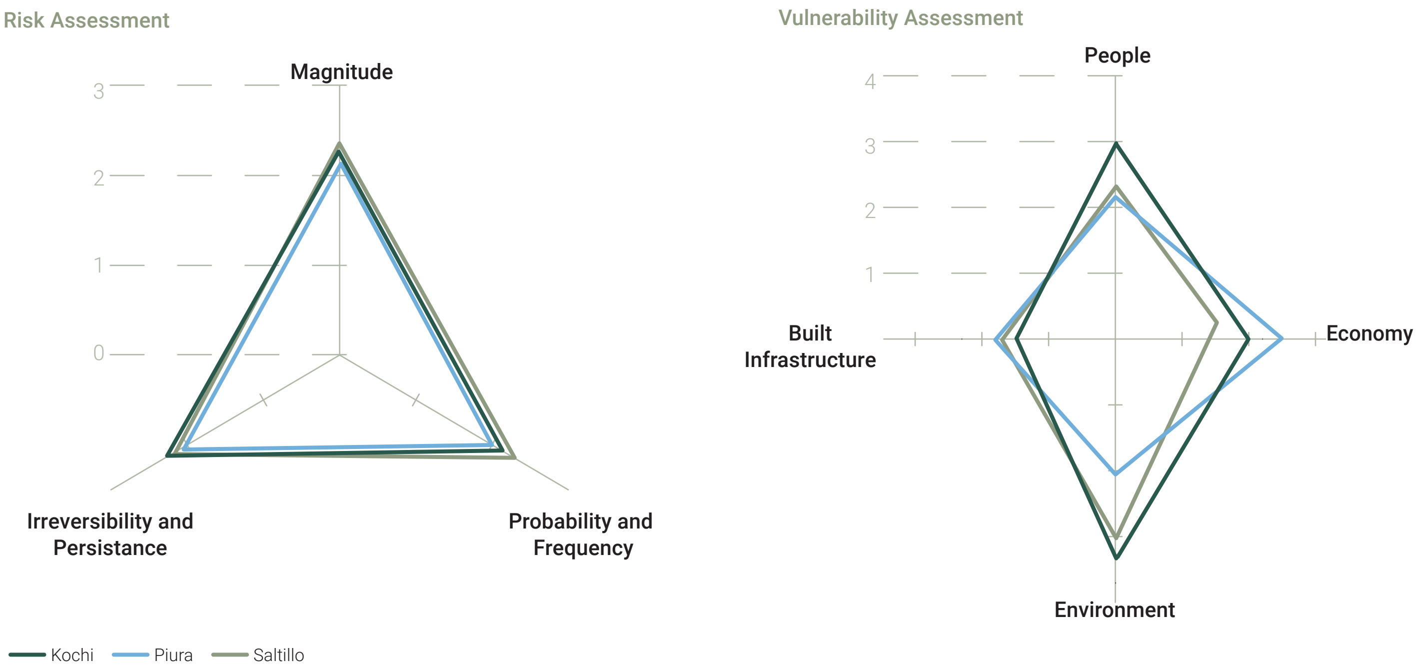
The same study reveals that country-specific estimates showed a clear north-south pattern within regions: deaths attributed to human-induced climate change are <1% of total deaths for countries in the northern subregions of America, Europe and Asia, while a larger effect was observed in southern Europe, southern and western Asia, parts of southeast Asia and South America. This study shows that some geographies, particularly those closer to the equator where the average annual solar radiation is higher, are worse affected by heat than others.

Next to climate-related health and well-being issues, a higher demand for water and electricity (e.g. for cooling and refrigeration devices) is expected in the impacted regions. Rising temperatures and UHI effects could be mitigated through urban landscape optimization, nature-based solutions (such as green spaces, trees, green roofs and facades), the use of high reflectivity and lighter materials, and the improvement of energy efficiency (Yang et al. 2016).

FIGURE 9: CITIZEN'S CLIMATE ADAPTATION MEASURES

The use of umbrellas is a common practice in the cities to provide protection from the sun while in the city.

FIGURE 10: RISK AND VULNERABILITY ASSESSMENT OF TEMPERATURE RISE AND URBAN HEAT ISLANDS



Context-specific risks

The risk of rising temperatures and UHI has been rated medium to high by local experts for each of the MGI cities. Several intensifying factors have been named, such as deforestation to increase urban areas, prevailing urbanization patterns, logging of urban trees, lack of green areas, predominant grey infrastructure, or blocking natural ventilation and cooling structures. Counter measures include municipal tree planting programs, improved green space conservation and adapted planting, and maintenance processes.

Context-specific vulnerability

In arid regions, such as in Saltillo and Piura, the agricultural sector is economically vital. Agriculture is particularly vulnerable to rising temperatures, as heat waves are generally accompanied by the loss of crops and livestock. Additionally, urban heat islands restrict the use of public spaces for recreation, social, and commercial activities. They also reduce workers' productivity due to the lack of thermal comfort. Built infrastructure is perceived as uncomfortably warm and is not designed to cool down.

FIGURE 11: EXPECTED AND CURRENT IMPACTS OF TEMPERATURE RISE AND URBAN HEAT ISLANDS

KOCHI	PIURA	SALTILLO
27.5 °C Mean annual temperature (Deutscher Wetterdienst 2022)	**24.5 °C** Mean annual temperature (Deutscher Wetterdienst 2018)	**17.1 °C** Mean annual temperature (IMPLAN 2021)
3.99 – 1.19 °C 2070–2099: projected rise in temperature (Jayasankar et al.)	**1.0 – 1.5 °C** Expected increase in temperature extremes (CAF – Banco de Desarrollo de América Latina 2020)	**4.4 °C** 2080: average annual temperature increase in Coahuila (Mendoza-Hernández et al. 2013, p. 529)
10.5 – 14 °C expected increase in UHI intensities in major Indian cities during summer periods (Sultana and Satyanarayana 2020)	**33 – 38 °C** is the projected maximum of daily max temperatures for the North of Peru during summer (WB, SSP2-4.5)	**36 – 40.2 °C** is the projected maximum of daily max temperatures for Mexico during summer (WB, SSP2-4.5)

4.2 HEAVY RAINFALL & STORMWATER

"Heavy precipitation" refers to instances during which the amount of rain or snow experienced in a location substantially exceeds what is normal. What constitutes a period of heavy precipitation varies according to location and season (USA EPA 2022). Furthermore, the thresholds for identifying extreme rainfall events can be defined in different ways, for example, using precipitation thresholds (IPCC, 2012).

During heavy rainfall events, surface water runoff exceeds the amount of water that infiltrates into the ground, thereby contributing to flooding, erosion, water logging, and a more rapid siltation of waterways. This phenomenon is worsened in highly urbanized areas where impermeable paving further reduces infiltration capacity (Aziz et al. 2018).

Potential adaptation measures include sustainable urban drainage systems, nature-based solutions that capture rain while delaying stormwater, and permeabilization of pavements. Depending on the region and climatic conditions, precipitation and stormwater-related risks and vulnerabilities vary, as the example of the three MGI cities below shows. Figure 12 depicts some past extreme weather events due to rainfall and stormwater.

FIGURE 12: INFOBOX

EL NIÑO AND EL NIÑO COSTERO

THE EL NIÑO PHENOMENON IS AN EVENT WHICH REFERS TO A WARM OCEAN CURRENT IN THE TROPICAL PACIFIC THAT NORMALLY HAPPENS DURING THE SUMMER MONTHS IN THE SOUTHERN HEMISPHERE.

The atypical increase or decrease in the temperature of the equatorial waters of the central and eastern Pacific Ocean results in periods of intense rainfall and drought.

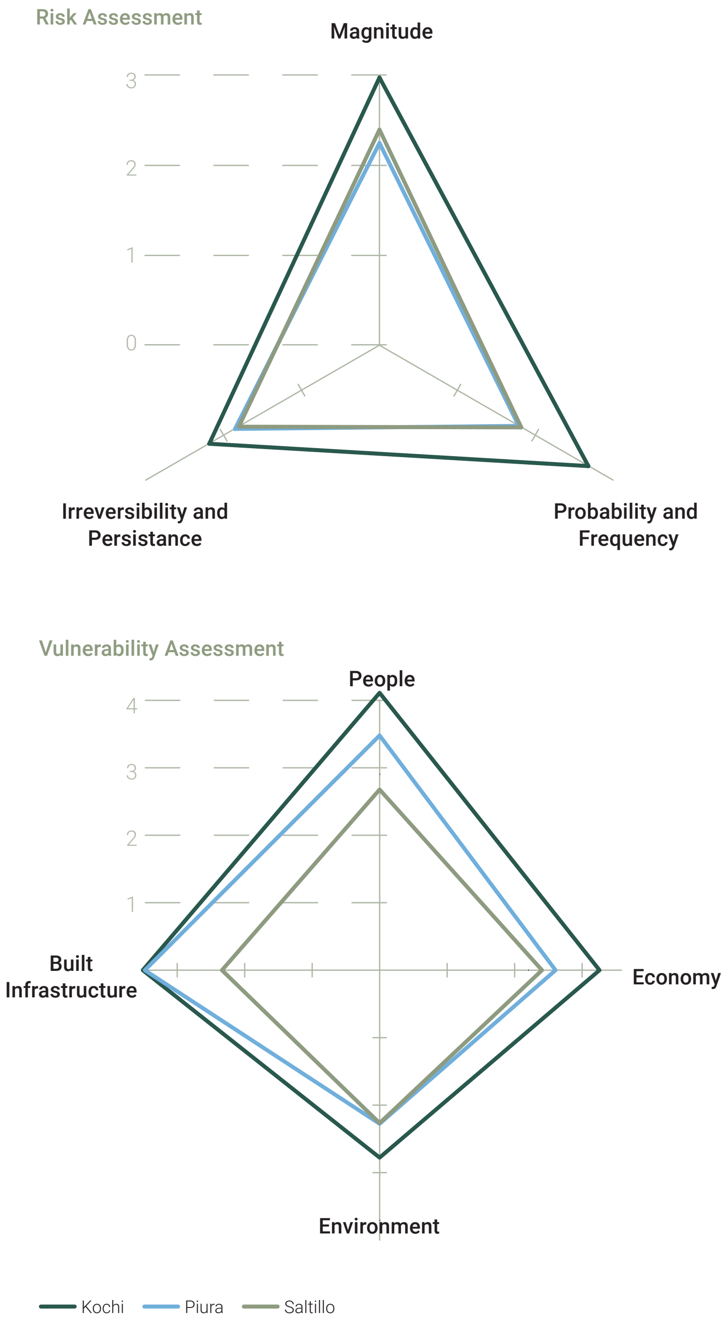
The main impact of the phenomenon El Niño (FEN) on coastal cities is the great floods that affect people, the economy, the environment, and built infrastructure. Likewise, heavy storms caused by the FEN and the El Niño Costero, which is a warming event focused on the coasts of Perú and Ecuador. It ocurred in 1925 and again between 2016 and 2017 causing floods that damaged infrastructure, as well as energy, water and sanitation, and transportation systems.
According to the United Nations (2016) it affects around 60 million people around the globe. It is most intense in the tropical regions of Africa, Asia-Pacific, and Latin America, regions which are particularly vulnerable to natural hazards.

FIGURE 13: EXPECTED AND CURRENT IMPACTS OF HEAVY RAINFALL AND STORMWATER

KOCHI	PIURA	SALTILLO
3140 mm Average annual rainfall (Indian Meteorological Department)	**302 mm** Average annual rainfall (climate-data.org)	**484 mm** Average annual rainfall (IMPLAN 2021)
EXTREME RAINFALL EVENTS and a reduction in the frequency of light rainfall are future projections of Indian summer monsoon rainfall (Mohr et al. 2020)	**EXTREME PRECIPITATION** values are expeded to increase between 5 – 20 % in the River Piura basin by 2040 ("Climate Change Risk Index in Piura" (CAF); Development Bank of Latin America, 2020)	**HEAVY STORMS AND CYCLONES** intensity is expected to increase due to climate change (INECC 2019a)
1.4 MILLION PEOPLE had to be housed in relief camps during the floods of 2018 in Kerala (GlobalMedic, 2023)	**9.2 MILLION PEOPLE** were affected by intense rainfall and floods in 2014 in Peru (SGRD 2014)	**80 THOUSAND PEOPLE** people were affected by the floodings of 2010 in Cohauila, the state to which Saltillo belongs (Zocalo, 2010)

FIGURE 14: FLOODS IN PIURA CAUSED BY EL NIÑO IN 2017

FIGURE 15: RISK AND VULNERABILITY ASSESSMENT OF RAINFALL AND STORMWATER



Context-specific risks

Extreme rainfall events and changes in precipitation patterns are among the biggest risks in all of the assessed cities. Kochi's climate is especially characterized by heavy rainfall during the monsoon season when waterlogging and flood events have been stated as occurring with almost every rainfall (Kottek and Rubel 2010). In Piura, most of the risks are linked to the El Niño phenomenon (see Infobox 1), which is the main reason for heavy rainfall, stormwater, and river overflow. Located in a less humid area, Saltillo has the lowest risk of increased rainfall. Nevertheless, the intensity and magnitude of individual cyclones and heavy storms is expected to increase due to climate change (INECC 2019a). Heavy rainfall and stormwater risks have increased due to recent urbanization patterns, the sealing of natural streams, the construction of new dwellings and building complexes on unauthorized sites (such as close to blind basins), and the intensified blocking of local creeks with solid waste. None of the cities had institutionalized a formal practice of stormwater harvesting and reuse while struggling to provide complete coverage of the drainage network.

Context-specific vulnerability

The high levels of social and infrastructural vulnerability in Piura and Kochi lead to higher risks. These risks are exacerbated by their close proximity to coastlines. The destruction of infrastructure could mean a regression in terms of public health, wellbeing, social justice, as well as food-water-energy supply. Especially low-income areas and informal settlements are amongst the most vulnerable. Often, this is related to the construction of inadequate housing infrastructure without efficient storm drainage systems. Stormwater-related disasters have already led to losses of livelihoods (Vishnu et al. 2019) and increase the risk of supply shortages and disease outbreaks in all three cities. In economic terms, vulnerability has mostly been linked to the potential disruptions of economic activities. Public services (electricity supply, water and sanitation systems, garbage collection, food) as well as transport facilities (commuting and logistics) are amongst the most named sectors. The risk imposed by polluted stormwater entering natural environments has been stated as the main effect on biological diversity. Heavy rains wash away multiple types of debris, causing pollutants to be distributed in the waterways, affecting aquatic flora and fauna.

4.3 WATER SCARCITY & DROUGHTS

"Drought" is a natural hazard caused by large-scale climatic variability while "water scarcity" can stem from the long-term unsustainable use of water resources, which water managers can influence (van Loon and van Lanen 2013). The latter can thus also refer to a shortage of good quality or drinking water due to pollution. Many cities already face challenges in terms of water management and availability, especially when located in arid regions and relying on groundwater sources which are not able to replenish as quickly as the water is extracted. Cities depending on rivers which are fed by glacial runoff might also be at risk of water scarcity.
Climate change can alter the hydrological systems affecting the availability of valuable water sources used by farms, villages, and cities.

FIGURE 16: IMPACTS OF WATER SCARCITY AND DROUGHT

Crop damage in Saltillo and neighbouring municipalities due to low rainfall levels and drought season (Source: El Tiempo die Monclova 2012).

In Kochi, several commercial establishments like restaurants and other firms depend on tanker lorries for drinking water.

FIGURE 17: INFOBOX

LA NIÑA

In Piura in 2022, drought has led to the deaths of more than 3,000 heads of cattle and has also affected crops.

THE RISK OF DROUGHT IS PARTICULARLY HIGH IN PIURA DURING THE METEOROLOGICAL EVENT LA NIÑA, WHICH IS CHARACTERIZED BY A REDUCTION IN SEA TEMPERATURE, BELOW THE ANNUAL AVERAGE (CAF – DEVELOPMENT BANK OF LATIN AMERICA, 2020).

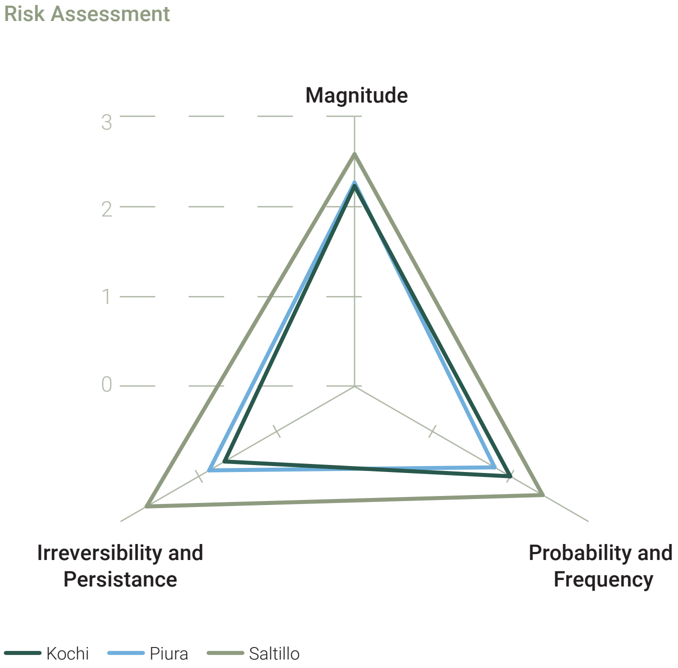
La Niña events reduce rainfall and therefore produce water scarcity and droughts. They represent serious risks for economic activities, such as fishing and agriculture. Even though this risk is not well acknowledged, a CORPAC study evaluated the city's meteorological records over a 60-year period, revealing that the city faces severe drought 40% of the time (Palacios-Santa Cruz 2010).

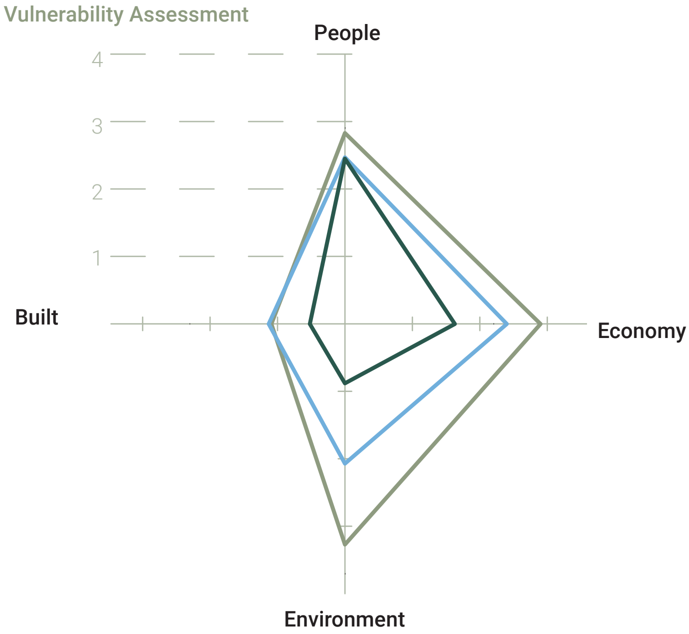
Despite this finding, there are no measures or initiatives to mitigate the impact of droughts when they occur, because the perception of their existence by the community and decision makers is low. Furthermore, the droughts mainly affect agriculture and livestock, which largely occur outside the urban boundary.

FIGURE 18: EXPECTED IMPACTS OF WATER SCARCITY AND DROUGHT

PIURA	SALTILLO
18.8 DAYS Annual average of the projected number of consecutive dry days in Peru (under scenario SSP2-4.5, World Bank, 2021)	**42.5 DAYS** Annual average of the projected number of consecutive dry days in some regions in Mexico (under scenario SSP2-4.5, World Bank, 2021)

FIGURE 19: RISK AND VULNERABILITY ASSESSMENT OF WATER SCARCITY AND DROUGHTS





Context-specific risks

Saltillo, located in the desert, has the highest risk of water scarcity of the three MGI cities. In the next 15 years, it is predicted that rainfall will decrease between 10 and 20% (Mexican Government 2015, p. 4). The irreversibility of this risk is perceived as relatively high considering that all the water in Saltillo comes from the subsoil and, in the event of total depletion of the aquifers, recovery would be very difficult. Although Piura and Kochi have a lower risk of drought and the magnitude and probability of such events are relatively lower, as the amount of rainfall is expected to increase, the probability of occurence is present and persists. Here, water scarcity and access to high quality drinking water was perceived as a major risk in comparison to the occurrence of drought. In Piura, the risk is further influenced by the La Niña phenomena.

Context-specific vulnerability

With climate change, more intense and frequent droughts, as well as irregular and decreasing rainfall patterns are amongst the main causes of the risk of water scarcity. Improving wastewater treatment and recovery, introducing rainwater harvesting, adapting crops and green infrastructure species, as well as raising awareness of sustainable water usage have been amongst the measures which cities could use to improve resilience.

4.4 CHANGE IN BIOLOGICAL SYSTEMS

Climate change has an immediate impact on the local biological system in terms of the condition, population dynamics, habitat availability, migratory patterns, and overall composition of native flora and fauna species.

Given that nature is the basis of human life and activity, these implications can have a direct and major impact on cities and people.

Potential risk areas could thereby include an increasing risk of zoonotic diseases due to better breeding conditions for biological vectors such as mosquitos and rodents, agriculture and crop growth, marine life and fisheries, nature protection and heritage, as well as biodiversity in general.

FIGURE 20: CHANGE IN BIOLOGICAL SYSTEMS

Mosquito Aedesaegypti, vector for the transmission of the Chikungunya and Zika viruses. Weather extremes can lead to explosive population growth or difficult population control.

The Peruvian carob tree (Prosopis pallida or algarrobo in Spanish) is the flagship species in the North of Peru. About 40 % of the carob tree population is affected by persistent plagues due to temperature increases. Additionally, new viruses and fungi are affecting species (Dario El Regional de Piura, 2020).

FIGURE 21: EXPECTED AND CURRENT IMPACTS OF CHANGE IN BIOLOGICAL SYSTEMS

IN INDIA

Potential **negative impacts on aquatic and marine life,** such as fish and shellfish populations, are amongst the biggest concerns, as they are the primary source of income for Kochi's fishing industry.

IN PERU

After the Niño Costero in 2017, vector populations experienced an explosive growth: the cases in Piura accounted for **64 % of the total national cases of dengue fever**.

(Díaz-Vélez et al., 2020)

IN MEXICO

In Mexico, researchers found that **each 1°C** increase in minimum temperature increased the **number of dengue cases** by 4.4 % – 5.8 %.

(Horacio Riojas et al. 2006)

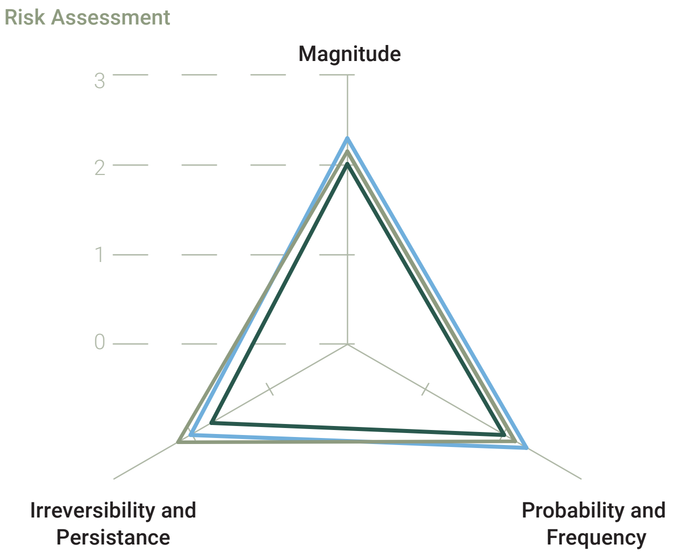
Context-specific risks

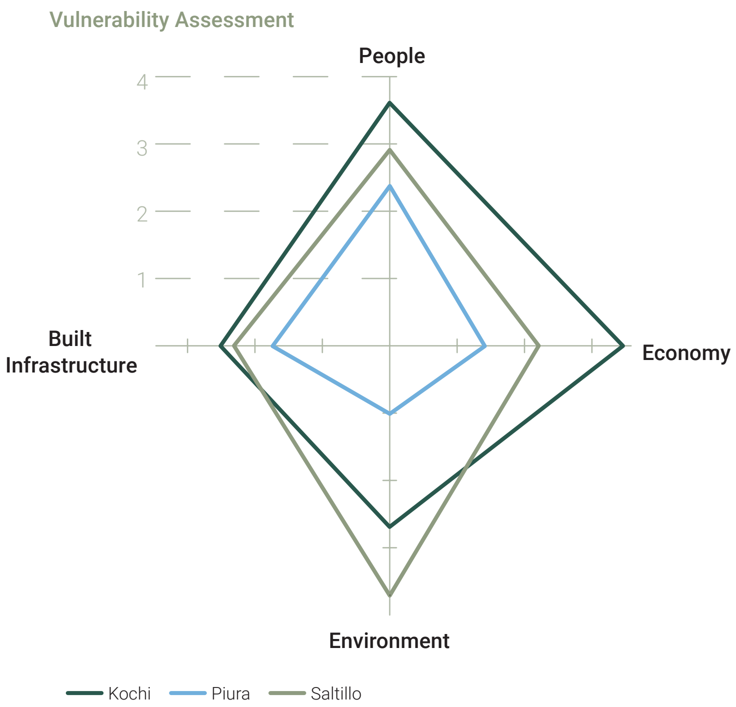
The risk of changing biological systems has been generally the least present and lowest rated risk by the local experts. Many stated that there are big gaps in knowledge and research on the actual risk and vulnerabilities and that causal relationships and actual impacts have not yet been well-understood. However, especially the probability and persistence of this risk have been acknowledged and better information would help to increase adaptive capacity and improve management practices to account for the changes to come.

Context-specific vulnerability

In the MGI cities, the main concerns were threats to public health, as a deviation in temperature levels could lead to an increase in the spread of diseases. Apart from the vulnerability of human health, local ecosystems are amongst the most vulnerable due to this change. For instance, climate change can increase competition between native species and invasive species, so invasive species may displace native species, causing them to disappear. In Piura and Kochi, economic sectors, such as forestry, agriculture, and fishing, are seen as vulnerable to plagues and variations in temperature and precipitation patterns, which can ultimately affect the income of the people who depend on these activities, like fishermen and farmers.

FIGURE 22: RISK AND VULNERABILITY ASSESSMENT OF CHANGE IN BIOLOGICAL SYSTEM

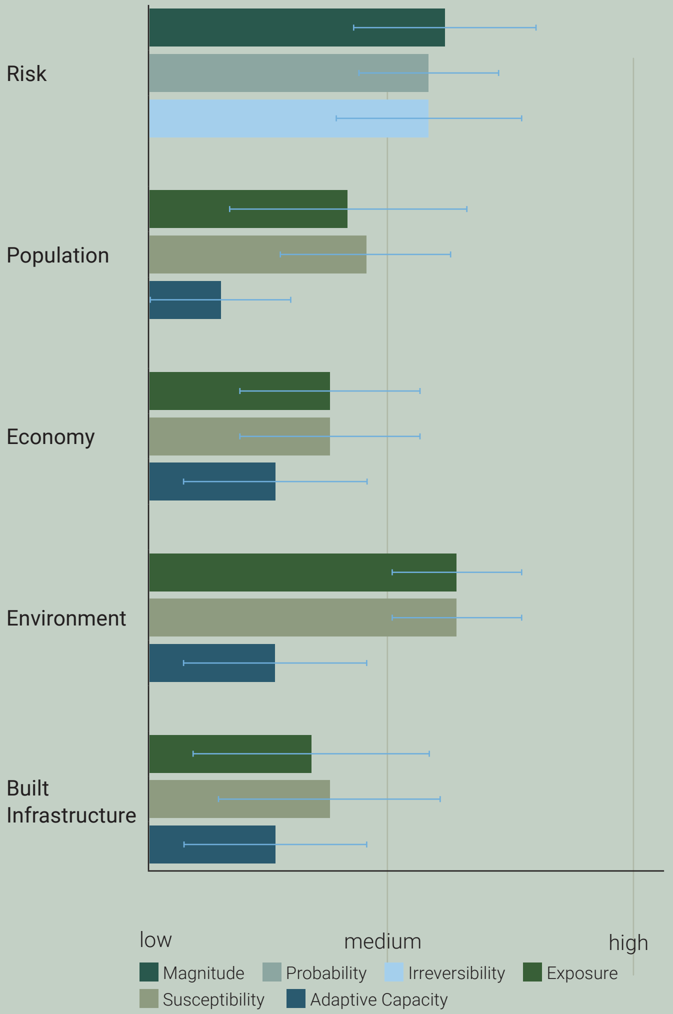




4.5 FOREST FIRES

FIGURE 23: RISK AND VULNERABILITY ASSESSMENT OF FOREST FIRES IN SALTILLO

Fire at Zapalinamé mountain and expert evaluation of the "forest fires" risk cluster for the city of Saltillo, including general risk factors and the vulnerability of the social, economic, environmental, and built systems in the city. Survey results with 12 participants from different local institutions and City Lab on-site experts. The standard deviation is shown as blue bars.



Forest fires at Zapalinamé mountain range

Large areas of mixed savanna-woodlands in the dry tropical zones of Africa, South America, Australia, and large areas of tropical humid forests burn every year (WRI, 2000). These fires are part of the natural seasonal cycle of growth, decay, and combustion and are ignited by lightning strikes.

However, humans have long played a significant role in modifying fire regimes (Goldammer and Price, 1998). Human-caused changes to the climate, land management, and demographics are causing fires, prompting a combination of dry lightning, droughts, lower humidity, stronger winds, and warmer temperatures that can prolong natural fire seasons (UNEP 2022b).

Of the three MGI cities, only Saltillo identified forest fires as significant risk to the city. The risk of forest fires in Saltillo was perceived as high by experts due to a combination between its magnitude, probability, and irreversibility. Experts highlighted the irreversible damage that fires cause in mountains near Saltillo, especially in the Zapalinamé mountain range, located to the southeast of the state.

It was noted that forest fires cause tremendous damage to the environment as they pose high risks to biological diversity and cause erosion as well as loss of vegetation and fauna. Air quality problems due to smoke and pollutants have been identified as a secondary issue.

To limit the irreversible impacts and the frequency of forest fires, prevention programs have been developed at the national and state levels including measures like interinstitutional real-time coordination, as well as communication and the dissemination of prevention actions for anthropogenic fires.

4.6 SNOWFALL & FROST

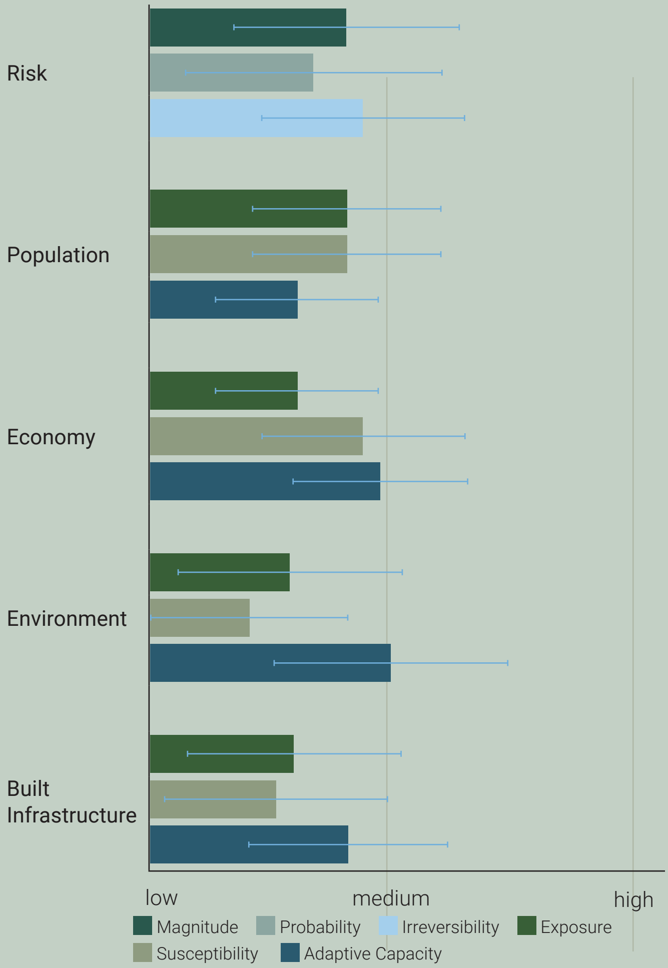
Ice and snow are important components of the Earth's climate system and are particularly sensitive to global warming. Changes in the volumes and extent of ice and snow have both global and local impacts on the climate, ecosystems, and human well-being. Snow and the various forms of ice play different roles within the climate system (UN 2022).

Of the three MGI cities, only Saltillo identified snowfall and frost as a significant risk to the city. In particular, the southern area of the municipality is classified as a critical risk area with an average frost season of more than 50 days per year (ITESM 2015, p. 147).

The experts' rating of the magnitude and probability of snowfall and frost in Saltillo was medium. Damages to crops have serious impacts on the economy, and impacts to infrastructure include the closure of sections of important highways, as well as an interruption of supply systems. The most vulnerable groups are those which do not have access to proper shelter during snowfall and frost events.

FIGURE 24: RISK AND VULNERABILITY ASSESSMENT OF SNOWFALL AND FROST IN SALTILLO

Expert evaluation of the "snowfall and frost" risk cluster for the city of Saltillo, including general risk factors and the vulnerability of the social, economic, environmental, and built systems in the city. Survey results with 12 participants from different local institutions and City Lab on-site experts. The standard deviation is shown as blue bars.

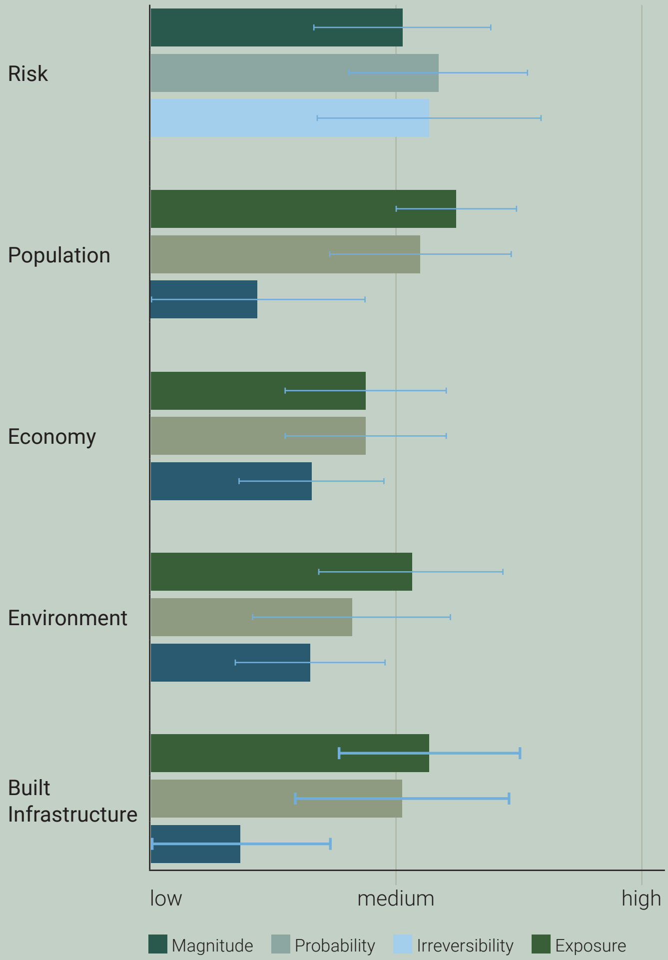


While some desert plants might have a high cold tolerance, extreme cold can destroy other food crops.

4.7 SEA LEVEL RISE & COASTAL EROSION

FIGURE 25: RISK AND VULNERABILITY ASSESSMENT OF SEA LEVEL RISE AND COASTAL EROSION IN KOCHI

Expert evaluation of the "sea level rise and coastal erosion" risk cluster for the city of Kochi, including general risk factors and the vulnerability of the social, economic, environmental, and built systems in the city. Survey results with 10 participants from different local institutions and City Lab on-site experts. The standard deviation is shown as blue bars.



The livelihoods of fishermen at Fort Kochi are exposed to sea level rise

Sea-level rise has accelerated in recent decades due to increasing ice loss in the world's polar regions. The latest data from the World Meteorological Organization shows that global mean sea-level reached a new record high in 2021, rising to an average of 4.5 millimeters per year over the period of 2013 to 2021.

Together with intensifying tropical cyclones, sea-level rise has exacerbated extreme events such as deadly storm surges and coastal hazards such as flooding, erosion, and landslides, which are now projected to occur at least once a year in many locations. Historically, such events occurred once per century (UN 2022). Of the three MGI cities, only Kochi is directly located next to the sea.

The city identified a high risk of severe long-term impacts due to sea level rise. Due to the continuing melting of glaciers and polar ice, the probability and persistence of this threat is seen as very high and almost inevitable. According to the literature, the submergence of land, increased flood events, saltwater intrusion, and a disruption of human activities are named as major impacts by experts.

Fast urbanization, land reclamation, and intense dredging activities, which create a loss of natural water retaining structures, could amplify these impacts. Expected impacts include an increased risk of flooding and coastal erosion, which would predominantly affect areas of touristic interest, industrial areas, and densely populated central areas.

According to the District Collector of the Disaster Management Authority, around 10 % of the houses are at risk. Furthermore, increased saltwater intrusion in both surface and groundwater sources threatens the natural freshwater reservoirs.

5 ADAPTING TO CLIMATE RISKS - CHALLENGE & BEST PRACTICE

The TAMD framework was used to assess so-called soft adaptation measures (at the governance level) and evaluate adaptation success (IIED 2014). Six indicators were used to summarize climate change adaptation measures taken by the three cities. Related challenges and best practices that were identified are presented in this section.

5.1 CLIMATE CHANGE INTEGRATION INTO PLANNING

This indicator captures the extent to which considerations of climate change (risks, opportunities) are integrated into formal planning processes in national, sectoral or other institutional contexts. The incorporation of climate change into planning and investments by countries, donors, multilateral development banks (MDBs), and other development entities is a key outcome in Theories of Change (ToC) related to adaptation (IIED 2013). The figure below shows examples of measures that have or have not yet been undertaken at a municipal level by the three MGI cities, followed by perceived challenges and enablers.

Best practice example: Best practice example: Saltillo's Plan de Acción Climática para Saltillo (PACMUN) is an official document approved by the municipality which targets CO2 mitigation aligned with Mexico's nationally determined contributions (NDCs) and includes specific strategies for adaptation and mitigation to climate change (IMPLAN 2022).

The cities' progress in the implementation of soft climate change adaptation and governance measures

INDICATORS OF THE TAMD FRAMEWORK	KOCHI	SALTILLO	PIURA
Climate change strategy	No	Partially	Partially
Legal requirement for integrating climate change adaption	No	Partially	Yes
Funding of specific adaption measures	No	Partially	Partially
Routine screening for climate risks	Partially	Partially	No
System integrating risk screening, assessment and reduction	No	No	No

Yes Partially No

MAIN CHALLENGES	ENABLERS
Developing city-specific strategies to integrate climate change measures **requires staff** and **resources**.	Having a national or regional strategy for climate change can help to **induce local planning and implementation efforts**.
Routinely screening for climate risks, safeguarding systems that integrate climate risk screening, as well as risk reduction measures, are often **time-** and **resource-intensive**.	Regular adaptation and evaluation of measures can help to **prioritize resources and efforts**.
Even if measures do exist, the incorporation of resilience plans into official urban planning and decision making is necessary to **ensure their uptake**.	The use of frameworks and methodologies that **address uncertainty**, such as scenario planning exercises, can be helpful in the planning.
Achieving a coordinated approach to address climate change instead of individual atomized efforts is a major challenge.	**Directly including local plans** for disaster risk reduction and prevention.

5.2 INSTITUTIONAL COORDINATION FOR INTEGRATION

This indicator captures the extent to which climate risk management (CRM) is coordinated across relevant institutions such as ministries, government agencies, or other bodies with a responsibility to integrate CRM into their activities.

Being a cross-sectoral issue, efforts to tackle climate change, whether through mitigation or adaptation activities, will need to be coordinated across sectors if they are to be effective at regional and national levels (IIED 2013). The figure below shows examples of measures that have or have not yet been undertaken by the three MGI cities, followed by perceived challenges and enablers:

FIGURE 27: INSTITUTIONAL COORDIANTION FOR INTEGRATION PROGRESS, CHALLENGES, AND ENABLERS

The cities' progress in the implementation of soft climate change adaptation and governance measures

INDICATORS OF THE TAMD FRAMEWORK	KOCHI	SALTILLO	PIURA
A body coordinates climate change plans	No	Yes	Yes
The coordinating body has cross-sectorial authority	No	Yes	Yes
Defined cross-sectorial institutional mechanism for coordination	No	Yes	Yes
Regular contact between coordinating body and ministries	No	Partially	No

☑ Yes ☑ Partially ☐ No

MAIN CHALLENGES
Lack of coordination between different levels of government on the development and implementation of policy instruments.
It is a challenge to **provide relevant and permanent training** for all areas of a municipality.
Measures should be implemented **not only ex post but also ex ante** a disaster.

ENABLERS
Introduction of a national technical and normative **authority in charge of monitoring and assessing the implementation** of climate change management programs at all three levels of government.
Enhancement of cooperation agreements with international organizations can **support facilitation and integration**.

5.3 BUDGETING & FINANCE

This indicator denotes the extent to which actions, measures and processes that address climate change are accounted for, budgeted for, and provided with the necessary financial support.

For effective action on climate change (whether in the form of adaptation or mitigation), there needs to be financial support in place for mainstreaming processes and for the implementation of adaptation/mitigation measures (IIED 2013).

The figure below shows examples of measures that have or have not yet been undertaken by the three MGI cities, followed by perceived challenges and enablers:

FIGURE 28: BUDGETING AND FINANCE PROGRESS, CHALLENGES, AND ENABLERS

The cities' progress in the implementation of soft climate change adaptation and governance measures

INDICATORS OF THE TAMD FRAMEWORK	KOCHI	SALTILLO	PIURA
Funding available for piloting measures	Partially	No	Partially
Funding to mainstream climate change	No	No	Partially
Funding available for climate change measures	No	No	No

☑ Yes ☑ Partially ☐ No

MAIN CHALLENGES
No mechanisms or capacities exist at the local level to assess the costs associated with climate change adaptation measures.
A **lack of budgeting and finance** designated for climate change adaptation is often linked to political priorities and will.
It is a challenge to tap into **international funds or international initiatives**, mainly due to complicated application procedures and lacking capacities.

ENABLERS
Collaborating with academia and international research centers can help to **assess the costs and benefits** of certain actions or predict the costs associated with climate-related risks.
A strong budget performance helps to **make a case for individual structures and funds** related to climate mitigation and adaptation.

5.4 CLIMATE INFORMATION

This indicator assesses the extent to which adaptation and adaptation relevant development interventions are informed about climate change (nature, magnitude, rapidity, local manifestations, associated risks), and to which extent these interventions help to generate new information about climate change.

For effective action on climate change, government personnel, staff in key institutions, key stakeholders and the public at large need to be aware of climate change and the associated risks, as well as the responses to initiatives intended to address climate change through adaptation and/or mitigation/low-carbon development (IIED 2013). The figure below presents examples of measures that have or have not yet been undertaken by the three MGI cities, followed by perceived challenges and enablers.

Best practice example: The public executing agency "National Service of Meteorology and Hydrology of Peru" (SENAMHI) generates and provides meteorological, hydrological, and climatic information and backgrounds to society in a timely and reliable manner. This facilitates capacity building, planning processes, and the development of new services around climate adaptation in the country (Servicio Nacional de Meteorología e Hidrología del Perú, 2020).

FIGURE 29: USE OF CLIMATE INFORMATION PROGRESS, CHALLENGES, AND ENABLERS

The cities' progress in the implementation of soft climate change adaptation and governance measures

INDICATORS OF THE TAMD FRAMEWORK	KOCHI	SALTILLO	PIURA
Availability of observational data	Partially	Partially	Yes
Accessibility of climate information	No	Partially	Partially
Accessibility of climate inf. generated by international orgs.	Partially	Yes	Yes
Capacity to interpret and use climate information	No	Partially	Partially
Complementing information with indigenous knowledge	No	Partially	Partially

Yes Partially No

MAIN CHALLENGES	ENABLERS
Developing regular climate-related risk assessments and monitoring schemes **requires regular investment**.	There is often **free information available** on upcoming weather events to inform the population.
Generating disaggregated data at the local level and not only at the state level.	Recordings of hydrological and meteorological data and climate related risks are also **available from international sources**.
Bridging data gaps and interpreting data related to, for example, water quality and pollution sources and local level emissions.	Using information **generated by partnerships** with universities or international research projects.
It costs time and money to **research and integrate local experience** dealing with environmental issues and bottom-up adaptation measures.	**Established disaster emergency response protocols** is a way to organize important information on climate risk response.

5.5 PARTICIPATION

This indicator assesses the extent to which climate change planning involves different sectors of the community, including adversely affected groups, i.e., whether there is widespread participation and "buy-in" throughout the design and implementation of climate adaptation initiatives and whether the latter are informed or driven by the community.

Climate change initiatives are most likely to be accepted by the public and those within the relevant institutions and to deliver sustained benefits, if there is widespread participation and "buy-in" throughout the design and implementation processes. In particular, when initiatives are intended to deliver community benefits (IIED 2013). The figure below shows examples of measures that have or have not yet been undertaken

Best practice example: Efforts to integrate and work with citizen participation, e.g., the urban gardening project in Piura, which is a citizens' initiative, has been supported by the city through a citizens' engagement festival to increase sensibilization and participation around the topic of urban gardening and climate change within the city. This is an opportunity for appropriating and reclaiming public open spaces, reducing pollution in the city, reducing the effect of high temperatures and generating spaces for social interaction that improve biodiversity.

FIGURE 30: PARTICIPATION PROGRESS, CHALLENGES, AND ENABLERS

The cities' progress in the implementation of soft climate change adaptation and governance measures

INDICATORS OF THE TAMD FRAMEWORK	KOCHI	SALTILLO	PIURA
Representation of all levels of governance	No	Partially	No
Representation of adversely impacted groups	Partially	No	No
Sustainable participation of all groups	No	Partially	No

☑ Yes ☑ Partially ☐ No

MAIN CHALLENGES	ENABLERS
Moving away from only top-down decision making and considering the community level input in planning and implementation often requires a **cultural change**.	**Participation platforms** like decision making committees, development of participation apps, and the active participation of environmental activist groups.
Despite the existence of citizen participation mechanisms such as the participatory budget process, prior consultation, public hearings, etc., there is **dissatisfaction** with the way public policies are decided and formal participation is very low.	
It may require resources including time to **involve all groups in society**, particularly those that, due to their vulnerability, might face extra difficulties to engage and participate. Engaging the most vulnerable groups is important as they are the most likely to experience the worst impacts of climate change.	**Training** to conduct well-designed participatory workshops.

5.6 AWARENESS AMONG STAKEHOLDERS

This indicator is designed to evaluate the awareness of climate change issues, risks and potential response options, and actions to promote such awareness in different contexts.
Awareness is most likely to be enhanced, and useful information is most likely to be produced, when key institutions are given mandates to raise awareness and generate and distribute information while engaging with stakeholders and the public at large (IIED 2013).
The figure below shows examples of measures that have or have not yet been undertaken by the three MGI cities, followed by perceived challenges and enablers:

Best practice example: In Kochi, the Centre for Heritage, Environment and Development (C-HED) (research wing of the city's local government) plays a key role in raising awareness about climate change risks. C-HED communicates and works in coordination with public and private sectors in climate adaptation and mitigation related projects and gives public visibility to coordination efforts with national and international development organizations. Local governments of cities should further support organizations like this or provide resources for their creation. Through the organization of workshops, the inauguration of demonstration projects or the provision of manuals on how to increase urban climate resilience, C-HED aims to raise awareness among the population and urban decision-makers about the risks of climate change in order to promote urban development.

FIGURE 31: AWARENESS AMONG STAKEHOLDERS PROGRESS, CHALLENGES, AND ENABLERS

The cities' progress in the implementation of soft climate change adaptation and governance measures

INDICATORS OF THE TAMD FRAMEWORK	KOCHI	SALTILLO	PIURA
Stakeholders are aware of climate change	Partially	Partially	Yes
Stakeholders are aware of response options to climate change	No	Partially	Partially
Relevant information reaches key stakeholders	Partially	Partially	No
Institutional mandate to disseminate information about climate change	Partially	Partially	Partially
Adequate funding available for awareness raising	No	No	Yes

☑ Yes ☐ Partially ☐ No

MAIN CHALLENGES	ENABLERS
A challenge can be to **reach the whole population and inform them** about how they can actively improve local resilience towards climate change impacts in their daily lives.	**Having a well-educated population** regarding climate risks and the impacts of climate change helps to improve adaptive capacity and willingness to change or take personal precautions.
Allocating funds for awareness-raising campaigns requires **prioritizing these activities in the political agenda**.	

6 OVERARCHING SUMMARY AND CONCLUSIONS

Cities across the world are already experiencing and struggling with the impacts of climate change. In the three MGI cities, seven major risk clusters could be identified – namely, 1) temperature rise and urban heat islands, 2) heavy rainfall and stormwater, 3) water scarcity and droughts, 4) changes in the biological system, 5) forest fires, 6) snowfall and frost, and 7) sea level rise and coastal erosion. The related risks are thereby manifold and vary from city to city in their magnitude, probability, and frequency, as well as irreversibility and persistence. Alongside geographical particularities, location, and climate zone, also the social, political, cultural, and economic context is relevant for determining the risk of and resilience to specific climate risks.

In terms of vulnerability, the indicators of exposure, susceptibility, and adaptive capacity are amongst the criteria that are recommended for evaluation by the IPCC which are summarized in a vulnerability index. Within the MGI, an assessment focus was set on four different sectors: people, economy, environment, and built infrastructure. Of these, people were perceived as the most vulnerable to climate change impacts, including increased negative effects on public health and well-being, the supply of critical goods and resources, housing and livelihoods, as well as social justice issues. In addition, the dependency on income and vulnerable economic sectors are major concerns. Agriculture, fisheries, and tourism were amongst the most often named industries at risk due to climate change. Furthermore, logistics, energy security, and resource provisions are subject to disruptions and harm. Other sectors have been found to be particularly vulnerable to a specific risk cluster, such as built infrastructure to heavy rainfall and flooding, or the local environment to changes in biological systems.

Different adaptation measures have been discussed to increase resilience and limit damage. Amongst the commonly applied or suggested "hard adaptation measures" are the increased use of nature-based solutions and urban greening, the impermeabilization of surfaces and sustainable urban drainage systems, as well as rainwater harvesting and use. In addition, climate change impacts will need to be tackled through improved governance systems and so-called "soft adaptation measures". These may include a targeted uptake of climate change adaptation in formal planning processes and municipal strategies, cross-sectoral and multilevel coordination and organization, the creation of special budgets and financing vehicles for climate response, the generation and availability of up-to-date information and relevant data, participative structures which reach and involve citizens and vulnerable groups, as well as increasing awareness among local stakeholders to improve personal preparedness and adaptive capacity.

The MGI risk and resilience assessment presented in this report has been successfully applied to three cities with very different settings and preconditions – namely, Kochi in India, Saltillo in Mexico, and Piura in Peru. It helped in identifying key risks and related vulnerabilities, as well as mapping first adaptation measures and potential fields of action. In the case of Saltillo, the results of this assessment have been directly incorporated in the Municipal Climate Action Plan as a baseline for future planning and project development processes.

Furthermore, all three cities have used the new insights to further inform and incorporate climate adaptation aspects in their individual project roadmaps and pilot projects. These insights are also part of the City Lab approach in the MGI project and represent specific collaborative investments of resources and energy in the implementation of climate adaptation projects. During the work, it became evident that involving the right experts (both locally and internationally) is crucial to limiting subjectivity, ensuring validity, and helping to include various perspectives and aspects. For future implementation and planning processes, it is recommended that vulnerable groups and indigenous knowledge are utilized further, which requires the design of adequate participation formats.

International projects and initiatives provide an opportunity for exchanges on challenges and best practices around climate resilience and to better understand and evaluate the extent of specific impacts. They may also help to bundle expertise, form new alliances, and create synergies with local partners who can contribute their expertise and capacities. The MGI project demonstrates that it is possible to implement projects in middle- and low-income countries that harmonize the objectives of both the Paris Agreement and the Agenda 2030 which lie at the intersection of climate adaptation, mitigation, and the improvement of the quality of life. This initiative also exemplifies that it is possible to bring together different development objectives. Ultimately, however, it is important to put the gained knowledge into practice and develop local solutions and strategies to be prepared for the global challenges to come.

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Most of the content related to the climate risks in the three cities of Piura, Saltillo and Kochi draws on the three climate risk and resilience assessments and the summary reports published in the framework of the MGI project.

For further reading and more specific outcomes of the project see the three summary reports:

Fernández, T.; Schroeder, S.; Stöffler, S.; Eufracio Lucio; D.; Ordóñez, J. A. et al. (2021): Summary Report of the full technical City Profile Piura within the Morgenstadt Global Initiative.

Mohr, M.; Schwegler, M.; Maciulyte, E.; Stryi-Hipp, G.; Winkler, M.; Giglmeier, S. et al. (2020): Executive Summary 2020 - City Lab Kochi India.

Ordóñez, J. A.; Díaz, C.; García, X.; Santillán, E.; Beckett, M.; Fernández, T. et al. (2021): Summary Report of the full technical City Profile Saltillo within the Morgenstadt Global Initiative.

And the three risk and resilience assessments:

Mok, S.; Schwegler, M.; Jayawant, A.; Brittas, A. (2021a): City Lab Kochi: Climate Risk and Resilience Assessment developed within the frame of the MGI Morgenstadt.

Mok, S.; Vivas, A. M.; Díaz, C.; Jayawant, A. (2021b): City Lab Saltillo: Climate Risk and Resilience Assessment developed within the frame of the MGI Morgenstadt Global Smart Cities Initiative.

Vaccari Paz, B.; Hernández, G.; Mok, S.; Schroeder, S.; Fernandez, T. (2022): City Lab Piura: Climate Risk and Resilience Assessment developed within the frame of the MGI Morgenstadt Global Smart Cities Initiative.

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